WoodMusICK

FPS COST Action FP1302

Preservation of Wooden Musical Instruments
Ethics, Practice and Assessment

Proceedings

directed by Pascale Vandervellen

4th Annual Conference
COST FP1302 WoodMusICK

Musical Instruments Museum, Brussels
October 5-7, 2017

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

COST is supported by the EU Framework Programme Horizon 2020

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Useful Information

Conference venue

Musical Instruments Museum
Montagne de la Cour 2, 1000 Brussels
Tel. +32 2 545 01 30
www.mim.be

The Conference will be held in the concert hall (8th floor).

How to get there:
Tramway: 92, 93, 95
Metro: Central Station
Bus: Lines 38, 71, 27, 95
Train: Central Station

Lunch and refreshments	Refreshments will be available on the 9th floor (accessible directly from the concert hall) during breaks in the scheduled programme. You can have lunch at the mim restaurant located on the 10th floor (please make your reservation in the morning)
Musical drink and dinner	A musical drink, followed by a dinner, will be organised on Thursday 5th from 6:00 pm.
Hostesses	Several hostesses shall oversee registration, lunch and dinner reservations. They will provide any necessary help.
Emergencies	In the event of an emergency, please notify a member of the staff. In case of a fire, an alarm will sound and all delegates and staff members will be asked to leave the building through designated emergency exits. Please follow the instructions given.
Instructions for presenters	Due to the busy conference schedule, it is important that participants respect their speaking time. Speakers should ensure that their equipment needs are met before the start of the session. If you have not sent your presentation ahead of the conference, please report to the chairman at the conference table at the beginning of the coffee break before your session.
Restrooms	Restrooms are located on the 9th, 7th, 5th, 3rd and 1st floors.

The Musical Instruments Museum, Brussels

Founded in 1877, the Musical Instruments Museum, fourth department of the Royal Museums of Art and History, is one of the richest museums of musical instruments in the world. It is also one of the most successful Brussels museums. Since June 2000, date of its opening in the former Old England department store, it has welcomed almost two million visitors. On close to 3,000 square metres, its exhibition halls present some 1,200 instruments divided into five categories: Belgian and European folk instruments, extra-European instruments, Western art music, keyboard instruments, and mechanical, electric and electronic instruments.

WoodMusICK – 4th Annual Conference 2017

Preservation of Wooden Musical Instruments Ethics, Practice and Assessment

Musical Instruments Museum (Brussels), 5-7 October 2017

The conservation of wooden musical instruments involves the preservation of tangible and intangible values. Often conservators are facing various dilemmas in balancing between preserving the current state of an instrument (conservation), returning to its previous or original state (restoration) and/or making instruments functional again (repair), establishing criteria for the use of the instruments (playability).

In order to have a correct understanding of the complex reality represented by each instrument, the decision-making process requires a close collaboration between different figures (i.e. conservators, curators, musicologists, historians, makers, musicians, conservation and materials scientists) for a proper management of various factors such as the condition of the instrument, its uniqueness, owners' desire, conservation materials, limitations of methods, cost and time. The process is therefore not easy and sometimes not possible as criteria are not weighted and standardised.

The main topics selected for the Conference are the following:

Ethical considerations and decision making processes

- ✓ theoretical approaches
- ✓ case studies of treatments that did or did not manage to preserve wooden musical instruments values

Innovative methods and materials

- ✓ examination and investigation (methods and/or techniques)
- ✓ preventive conservation
- ✓ remedial conservation (disinfection, cleaning, consolidation, adhesion, aesthetic reintegration, etc.)
- ✓ conventional and innovative materials, methods and techniques

Assessing the impact

- ✓ analytical techniques
- ✓ monitoring techniques
- ✓ assessment protocols

Conference Agenda

Thursday 5th October 2017

09:30	Registration
09:50	Welcome address : Sandie Le Conte & Pascale Vandervellen
	Session 1 - Ethical Considerations and Decision Making Processes Chair: Christina Linsenmeyer
10:00	Keynote * Never a Simple Decision – Case Studies and Ethical Considerations Concerning Playable Instruments *Darryl Martin*
10:30	Standards for Cultural Heritage and Their Implications in the Conservation and Preservation of Wooden Musical Instruments *Marie-Anne Loeper-Attia*
11:00	Coffee Break
11:30	Conservation of Musical Instruments - Decisions *Vera de Bruyn-Ouboter*
12:00	Preservation of the Wooden Musical Instruments of the Traditional Egyptian Storytellers' Heritage *Hany Hanna, Neeven Atef*
12:30	Poster pop up talks
	Technology and Cultural History of Altered Lute Instruments *Sebastian Kirsch*
	Preserving Sound – Musical Instruments and Their Ephemeral Feature: Possibilities to Deal with It *Tom Lerch*
	Treatment of the Appleton Organ at the Metropolitan Museum of Art *Jennifer Schnitker, Manu Frederickx*
	Reconciling Past and Present: the Rijksmuseum 1640 Ioannes Ruckers Muselaar Project *Giovanni Paolo Di Stefano, Tamar Hestrin-Grader et al.*
13:00	Lunch
	Session II - Methods and Materials - Chair: Marco Perez
14:00	'De fare uno manicho novo saria inposibile […]'. Evolutionary Aspects of Violin Restoration Techniques *Emanuele Marconi*
14:30	Searching and Squirrelling: Sourcing Materials for Early Pianos *Christopher Clarke*
15:00	Conservation Issues on Historical Pedal Harps: Preserving Tangible and Intangible Properties *Panagiotis Poulopoulos, Marisa Pamplona et al.*
15:30	Coffee Break
16:00	Changes in Vibrational Properties and Color of Wood due to Heating at Different Relative Humidities *Nanami Zeniya, Miyuki Matsuo et al.*

16:30	Structural Assessment of Wooden Musical Instruments by Simulation: Models, Validation, Applicability *Daniel Konopka, Benjamin Schmidt et al.*
17:00	Adapting Conservation Techniques for the Remedial Conservation of Musical Instruments *Jonathan Santa Maria Bouquet*
17:30	Poster pop up talks
	Criteria for Selecting Reed (*Phragmites Australis*) of Japanese Traditional Oboe (Hichiriki) and Recent Attempt for the Plantation of Reed in a Managed Field *Eiichi Obataya, Ryo Nakanishi*
	Vibrational Properties of Compressed Wood and Possibility of Using Compressed Wood as a Material for Repairing Cracks in Wooden Musical Instruments *Shiori Sato, Eiichi Obataya et al.*
	CNC Milling Wood Patches in String Instruments Restoration *Alberto Cassutti, Francesco Piasentini*
	Non-invasive Wood Identification on Historical Musical Instruments *Giovanni Signorini*
	3D-Reflected-Light Microscopy as a Tool for Wood Identification in Historical Instruments *Volker Haag, Gerald Koch et al.*
18:00	Musical drink
19:00	Dinner

Friday 6th October 2017

	Session III - Case studies - Chair Anastasia Pournou
09:00	Restoration of a Fortepiano by Nannette Streicher, Vienna 1813 *Ina Hoheisel*
09:30	Restoration of the Ioannes Ruckers' Mother-and-Child Virginal Dated 1610, (Musical Instruments Museum, Brussels) *Livine Huart, Agnès Esquirol et al.*
10:00	Restoring the Piano-Viole: an Adventure in Sound *Pierre Gevaert, Michel Terlinck, Elisabeth Salverda* *Musical Demonstration by David Lively*
10:30	Poster pop up talks
	Ukrainian Hutsul's Wooden Musical Instruments and Their Preservations *Ivan Sopushynskyy, Vasyl Zayachuk et al.*
	Restoration of Keyboard Instruments: Two Case Studies from the Varaždin City Museum, Croatia *Vilena Vrbanić*
	Conservation of a Portable Wooden Pump Organ *Ch. Sperantza, A. Pournou*
	Organs, Music, Architecture: the Restoration of Julián de la Orden's Organs in the Cuenca Cathedral *Pilar Tomás*

	A Zither Resonance-Table With an Integrated Tuning-Button *Heidi von Rüden*
	The Collection of Musical Instruments of the Museo Nazionale della Scienza e Tecnologia "Leonardo da Vinci" in Milano: an Interesting Study-Case of Conservation and Restoration *Donatella Melini*
11:00	Coffee Break
	Session IV - Imaging Session - Chair: David Mannes
11:30	Web Based Visualization Software for Big Data X-CT Volumes with Optimized Datahandling and Workflow *Markus Eberhorn, Tobias Koppers et al.*
12:00	Assessing Musical Instruments Conditions Before and After Restoration Using Industrial X-Ray Ct (iCT) *Francesco Piasentini, Marco Moscatti*
12:30	The Varnish Barrier Effect on the Sorption Properties of Wood Based on Neutron Imaging Measurements *Sarah L. Lämmlein, Francis W.M.R. Schwarze et al.*
13:00	Poster pop up talks
	Post-Processing of Musical Instrument 3D-Computed Tomography Data for Conservational Applications *Niko Plath, Sebastian Kirsch*
	Monitoring Changes in Wood Properties Using Very Near Field Sound Pressure Scanning *Filip Pantelić, Daniel Ridley-Ellis et al.*
13:15	Lunch
	Workshop - Chair: Vera de Bruyn-Ouboter
14:15	Introduction
14:30	1st group
15:30	Coffee Break
15:45	2nd group
16:45	Results Presentation
17:15	Conclusion

Saturday 7th October 2017

	Session V - Assessing the Impact – Chair: Darryl Martin
09:00	An Innovative Monitoring Plan: the Case of Museo del Violino (Cremona, Italy) *G.V. Fichera, M. Albano et al.*
09:30	Correlation of Mechanical Behaviour with Advanced Chemical Analysis of Varnished Wood *M.Odlyha, A.Lluveras-Tenorio et al.*
10:00	Poster pop up talks
	A Comparative Study on Adhesives Used in Wooden Musical Instruments Conservation *Antonia Platanianaki, Eleni Tsetsekou, Anastasia Pournou*

	Structure Modification of Polymeric Components of Wood Cell Wall Due to Aging Processes *Martina Sassoli, Marco Fioravanti et al.* Conservation and Restoration of Two Harpsichords at San Colombano, Bologna (Italy): Acoustic Analysis *Lamberto Tronchin* Martin's Acoustic Guitar circa 1880: Assessing the Impact of the Former Restorations on the Historical and Acoustic Values *Lise Allindré, Rémi Benecchi, Stéphane Vaiedelich*
10:30	Coffee Break
11:00	Management Committee Meeting
13:00	Lunch
14:00	Restitution of the Management Committee and Closing

Conference Abstracts

Never a Simple Decision – Case Studies and Ethical Considerations Concerning Playable Instruments

Darryl Martin[1]

[1] University of Edinburgh, Scotland (UK) / Musikmuseet, Copenhagen (DK)

Abstract

The paper looks at the justification and processes involved in the decision to return an instrument to, or retain an instrument in, playable condition from the perspective of a collection in which the objects were intended to be playable. The paper gives a series of case studies and presents the decisions made from a curatorial perspective.

1. Introduction

The decision to return an instrument to playable condition is almost always a trade-off between losing information about the object itself (even if only adding an extra layer of history to that object) and gaining the chance to hear the instrument perform in its original function. Although there are instances in which the ethical decision is comparatively straightforward, in the majority of circumstances the criteria are not nearly so clear-cut, particularly in a context where there are various stakeholders to whom the outcome must be justified.

From a museum perspective there is rarely any issue when making decisions to do with any form of preventative or immediate reactive conservation. In many cases the need decision comes from a need to arrest an immediate or a pre-existing condition. This might include treatment against moth or woodworm infestation, both of which can affect other objects within the collection if not dealt with immediately.

Other treatments might not have an effect on other objects, but can be immediately taken to avoid the risk of further damage to the object, for example regluing loose pieces of veneer which might become knocked and lost if knocked, or de-tensioning instruments to avoid risk of bridges becoming unglued.

The decision to return an instrument to playing condition generally involves an acceptance that the treatment will be – to some extent – invasive. Often this will be to the point that the object might need to be disassembled in order to provide a solid framework to withhold the tension of the strings or to be visually acceptable to the collection visitor.

On an instrument in which the decision has been made to return to playing condition the major objective is to play and hear the instrument above all else. In this case the decisions are less to do with structural or decorative features, but with issues of tone and touch.

2. Overview

The Russell Collection of Early Keyboard Instruments formed the nucleus of keyboard instruments belonging to the University of Edinburgh. Since then the initial gift of 19 instruments, plus several that were already in the possession of the University, has been expanded to approximately 100 keyboard instruments through purchase, donation, and loan, considerably expanded most recently in 2005 with the gift of the Rodger Mirrey Collection, amounting to 22 instruments.

The University has also (in 2004) combined its instrument collections into a single management structure (rather than two as previous) with the same set of rules and the same collection management philosophy. This means that, although the approach to playable instruments was devised with the keyboard instruments specifically in mind, the overreaching policy documents must apply to other instruments as well, and in particular stringed (bowed or plucked) which share many of the same issues.

One of the conditions in the initial gift of the Raymond Russell Collection was that it was to be used as a playing and teaching collection, and this philosophy has continued with more recent acquisitions, a number which never would have been offered to the University without playing as one of the primary motivations.

At the same time, not all of the instruments in the collection are in playing condition, including a number of those from the initial Russell gift. It has always been an unsaid assumption that not everything can, or should, be returned to playing condition, and not everything that is playable will invariably be able to remain in that state.

3. Case Studies

In most circumstances the decision to return an instrument to playing condition or leave in a non-playing state is, on a philosophical level, comparatively straightforward. For example, the University of Edinburgh has a double-manual harpsichord by Ioannes Ruckers (1638) which retains its original unaligned keyboards and action. Although one other Ruckers has been returned to that state, the value of the 1638 aa a document has meant that returning it to playing condition has never been considered in any meaningful sense. This is despite the instrument being in a structurally sound condition and easily able to withhold the tension of the strings.

On the other hand, the 1608 Andreas Ruckers has a history of alterations from both the historical and modern periods. This includes two 20th century changes that have resulted in an entirely new action (with a non-historical compass). In this instrument there would be little loss to make an entirely new action based on historical models. There is some conservation work required on the soundboard to fill in missing pieces of wood and repair cracks, and these would not be thought to greatly affect the tone of the playing instrument. However, there are implications when trying to make the argument to funders for such an approach, particularly given the comparatively high cost of making a new action from scratch.

For any relatively large collection there will a number of instruments that are already in, or have been in, playable condition and that need work to return them to a good state for performance. This can be for a variety of reasons such as not remaining in optimal condition due to climate, been stored in poor conditions, simple neglect by not being regularly played, joints giving-way as a result of tension over an extended period, and so on. It can sometimes be a situation that the instrument is not able to be made playable although the reasons are unclear. An example of this is a harpsichord with a Hans Moermans inscription, though probably the work of Hieronymus Mahieu, c 1740. This instrument arrived in Edinburgh with a replacement (modern) set of jacks and every appearance of having been playable in modern times. However, in attempting to return the instrument back to playable condition upon arrival it was found that the register gap kept closing and, once that was firmed up, the soundboard would rise so that it touched the 4’ strings. In both cases this could be attributed to the case not being strong enough to hold the tension of the strings – although it remains unclear how it could have played at any time with the replacement jacks that were made for it. In any case, following experiments over a period of years it was decided to no longer attempt to return the instrument to playing condition. If we decided to continue the next step would have been to remove the baseboard and see if the framing inside was in some way damaged, or could be strengthened. In either scenario it was decided that the intervention and time required to undertake this course of action was not justifiable simply to have that particular instrument returned to playable condition.

Another instrument which was considered for restoration was a harpsichord by Francis Coston, made in London around 1725. This instrument also appeared to have sound joints and it was felt that there was no physical reason it could not be returned to playable condition. However, this instrument was modified in 1761, and doing so involved several compromises to its design. Although the reasoning behind these changes is understood, and there is no increased risk of damage or organological loss, it is appreciated that restoring it to it last historical state would not represent the importance of the instrument. It would also leave it as a compromised example with much the same playing features as other instruments in the collection which are already playable.

Two instruments in the collection which are, and have always been, in playable condition are the 1668 Stephen Keene virginal, and an anonymous clavichord, believed to date from c1620. For many years (certainly since the early 1970s) the Keene has been strung in brass wire and tuned to A415. As part of my PhD research[1] it was shown that the instrument should be in iron wire at a higher pitch (approximately A473). It was decided that the instrument was not representative of the historical period in brass string, and so was restrung in iron wire and tuned to high pitch. On the other hand, a case has been made for the clavichord as a Flemish example and an argument made that it should be strung in iron at quint pitch.[2] This instrument has not, as yet, been restrung from its present brass wire, to allow for the option that there might be dissenting views presented.

An example of a non-keyboard instrument is a French baroque guitar of c 1760. This instrument has been strung for display purposes and was viewed as in a structural condition to allow it to be played. It was set with appropriate strings for a concert and recording, then had the tension lowered. After several months it was discovered that the bridge had come off the instrument. It was cleaned and reglued, only for the same thing to happen again. After this second time it has been assumed there is a residue which is stopping its proper adherence, and although the bridge has subsequently been reglued for display purposes, the strings are at extremely low tension to avoid the bridge coming off again. More recently two other guitars were considered to be used for a research project. Both appeared sound, but as tension was applied in each case it was felt there was too much risk of the bridge coming unglued and the work did not proceed.

4. Philosophic Implications

For all instruments, both playable and unplayable, there is the question of what can be learned from them. It would be a difficult argument to make that preservation is, in itself, the major objective of a museum. This would possibly logically mean the instrument should not ever be touched, let alone researched in any way. If we accept the view that such a philosophy is extreme then it becomes a question of where is there a line of what might be acceptable. This will, of course, depend on the collection, but within a collection that is, *de facto*, playing collection there is a duty of responsibility.

It must be questioned whether, even ignoring issues of whether the instrument sounds as it did when knew (or similar enough to claim such justification), does a playable historical instrument represent a knowingly false impression of the historical, and can playable use be acceptable. Is it acceptable, for instance, to tune an instrument to a lower pitch, or using lighter strings in an attempt to lower the tension on the original so it may be playable? Is it acceptable to use the wrong plectrum material even if moist might agree the difference is minimal from two meters away? How much work should be done to an action to stop the keyboard from having loose keys – the minimum to make it play (which might give a totally different feel, particularly relating to a sense of player security), or making the action as good as the best modern instrument (which may be much more exacting than the original when new). Should replacement cloths be chosen based on their ability to reduce action noise despite perhaps responding differently in feel to historical cloths?

5. Conclusion

There are few instruments in which the decision to return to playing condition is not problematic, and such decisions (even within collections that are viewed as having playable examples) might differ from collection to collection. It might be said that it is much easier to make the decision not to restore or repair to playing condition, even on instruments which had been playable in comparatively recent times.

Even in examples where it has been decided to return an instrument in playing condition there is the possibility that it might not be possible without more intervention than originally intended. There must remain, in a museum situation, the possibility that such work be stopped at any stage it is felt that progressing is no longer the most appropriate decision. Clearly this can have implications for projects which either have external funding or are being restored out-of-house.

Each instance must be considered and judges on its own merits and according to the particular Collection Management Policy, and it must be kept in mind that even in examples where there is very limited risk of organological loss, there may also be no corresponding gain by the proposed intervention.

Acknowledgement

The author would like to thank colleagues at the University of Edinburgh musical instrument collection who are regularly involved in discussions concerning the playing of instruments within the collection, and to external experts – makers, conservators, restorers and players whose opinions have also been expressed in discussions on particular examples.

References

[1] Darryl Martin, *The English Virginal*, PhD thesis, University of Edinburgh, 2003

[2] Darryl Martin, "A South-Netherlandish Quint-Pitch Clavichord", *Galpin Society Journal XLIX*, 2016

Standards for Cultural Heritage and their implications in the Conservation and Preservation of Wooden Musical Instruments

Marie-Anne Loeper-Attia,

Philharmonie de Paris – Cité de la musique, France

The draft of the first European Recommendation for the Conservation-Restoration of Cultural Heritage proposed by E.C.C.O. (European Confederation of Conservator-Restorer's), written with the support of ICCROM and participation of ENCoRE (European Network of Conservation-Restoration Education) signifies a further step towards guaranteeing preservation of cultural heritage and greater recognition of the actors in this field. The Recommendation takes into consideration the need to define and regulate the field itself as a whole. It complements other efforts pursued by E.C.C.O. by participating in the European Committee for Standardisation's Technical Committee for the Conservation of Cultural Property (CEN/TC346). France is engaged since 2004 in the CEN with european countries in a process of creation of specific standards devoted to the conservation of cultural heritage.

The organisation of the CEN

The CEN has 33 members in Europ. The general organisation of the working groups can be summarized as below.

CEN/TC 346	General methodologies - Terminology
WG 1	Conservation of cultural heritage
WG 2	Characterisation / analysis of materials
WG 3	Porous inorganic materials
WG 4	Protection of collections
WG 7	Climate
WG 8	Energy efficiency of historic buildings
WG 9	Waterlogged wood
WG 10	Historic timber structures
WG 11	Conservation process
WG 12	Showcases
WG 13	Architectural surfaces

Table 1: *general organisation of the CEN/TC 346*

Why a CEN? For which benefits?

The market relevant to the conservation of cultural heritage is considerable and it involves a great number of small and medium enterprises, such as conservation-restoration companies, installation companies (e.g. lighting installation, conditioning and heating systems, air quality control), packaging and transportation companies, those companies that produce technological instruments, measurement devices and control and analysis equipment, test laboratories, producers and manufacturers of various materials (e.g. paints, stones, plastics, glass, paper, mortars, cement, wood composites,) archaeological excavation companies, institutions, and all those who have responsibility for heritage buildings and objects.

The conservation of cultural heritage is also very important in many places as a major source of income through visitors, both from the locality and tourists from further afield. Visits to the Museum can be prolonged or enhanced by concerts presented on the instruments in the collection or on fac-similés. The amount of foreign/local visitors is frequently seen as an argument to promote the protection and of heritage resources and favour its preservation. Distributors are usually small private companies with 10-15 employees (few have more than 100 employees), and standardisation on the conservation of cultural heritage, giving specific requirements for products and methodologies, will enhance the protection of the cultural heritage.

The need to identify environmental parameters and assess material-environment interactions are also extremely important considerations to be taken into account for displays in museums, galleries, buildings, monuments, libraries and archives, as well as in temporary exhibit galleries, in stores and in transporting moveable heritage objects.
Safety is another element to be taken seriously, because incorrect estimation of the durability of a product can lead to the decay of some of the components, which in turn may lead to a fragile and possibly dangerous structure.

A specific European standardisation activity in the field of conservation of cultural heritage is essential to acquire a common unified scientific approach to the problems relevant to the preservation/conservation of the cultural heritage itself. Moreover, this common approach and the use of standardised methodologies and procedures would promote the exchange of information, would avoid the risk of duplication and foster synergy between the European experts and specialists involved in the preservation activity.

It should be underlined that the subjects of conservation works and care are unique by nature and definition and rarely susceptible to be standardised for themselves. This is why conservation work will benefit from standardised approaches respecting materiality, significance and values, bringing together all professionals involved in shared and visible methodologies and practices. These standards could be considered as the potential links between the materials and artefacts inherited from past (and their creators or transformers, the ideas and histories they convey) and the present public benefit, the pleasure, understanding and education of visitors and new generations.

Standardisation in the field of conservation of cultural property will:

- facilitate the exchanges between interested parties in Europe, respecting cultural identities, through the use of a common vocabulary;
- improve the efficiency and pertinence of the diagnosis with a subsequent better management of funding for the conservation/restoration works and therefore increasing the number of conservation projects and spin-off economic benefits/opportunities for new investment, and consequent job creation;
- give precise and appropriate indication on the kind of diagnosis studies to be performed, promoting in this way conservation works on an increasing number of artefacts;
- help to develop and improve products, materials, equipment and technologies to be specifically used for the conservation of cultural property;
- increase longevity and reduce maintenance costs of conservation works, therefore reducing costs in the long-term because conservation operations will be needed less frequently over time;
- improve safety and life of objects and collections, especially in case of temporary exhibitions;
- facilitate professional mobility and international trade and increase employment opportunities especially for young conservators, restorers, technicians etc...
- facilitate and identify needs and opportunities for Continuous Professional Development for all professionals and stakeholders;
- improve and increase the knowledge on materiality of cultural heritage and its consideration by all the stakeholders.

The development of standardized, procedures, test and analysis methods will provide the cultural institutions, businesses and laboratories with correct and comparable ‘tools’ for carrying out their work, whilst at the same time improving their proficiency/competencies.

Standardisation in the field of conservation of cultural heritage can also support the determination of specific technical requirements that may influence the production and improvement of equipment, products and devices.

For example:

a) methodology, protocols, guidelines to allow implementation of better practices or define equipment for preservation and conservation;

b) Scientific equipment for laboratory and in situ chemical, geological, physical, mechanical and biological tests, measurements and analysis. In particular, this type of equipment is useful for non-destructive analyses, and to produce standard reference materials whose compositions match those of cultural material (i.e. ancient alloys compositions) as well as providing reference data of compounds found in degraded materials for analysis purposes;

c) Products used in the different phases of the conservation work/treatment, such as cleaning agents, biocides, sealing materials, mortars for restoration, surface protective materials, water-repellent materials, environmental friendly varnishes and adhesives, packing materials, lighting equipment, etc;

d) Equipments and technologies used during conservation-restoration work (e.g. nebulizers/vaporisers, micro and macro-air abrasive machines, laser equipment) that are safe to use, respect the aims of conservation, preserve objects, significance and materials, and have a low environmental impact.

What's the implication on the conservation and restoration of musical instruments?

Today, several standards has been published, many concerns our subject today.

EN 15757:2010	Conservation of Cultural Property - Specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic materials
EN 15758:2010	Conservation of Cultural Property - Procedures and instruments for measuring temperatures of the air and the surfaces of objects
EN 15759-1:2011	Conservation of cultural property - Indoor climate - Part 1: Guidelines for heating churches, chapels and other places of worship
EN 15801:2009	Conservation of cultural property - Test methods – Determination of water absorption by capillarity
EN 15802:2009	Conservation of cultural property - Test methods – Determination of static contact angle
EN 15803:2009	Conservation of cultural property - Test methods – Determination of water vapour permeability
EN 15886:2010	Conservation of cultural property - Test methods – Colour measurement of surfaces
EN 15898:2011	Conservation of cultural property — Main general terms and definitions
EN 15946:2011	Conservation of cultural property - Packing principles for transport
EN 15999-1:2014	Conservation of cultural heritage - Guidelines for design of showcases for exhibition and preservation of objects - Part 1: General requirements
EN 16085:2012	Conservation of Cultural property - Methodology for sampling from materials of cultural property - General rules
EN 16095:2012	Conservation of cultural property - Condition recording for movable cultural heritage
EN 16141:2012	Conservation of cultural heritage - Guidelines for management of environmental conditions - Open storage facilities: definitions and characteristics of collection centres dedicated to the preservation and management of cultural heritage
CEN/TS 16163:2014	Conservation of Cultural Heritage - Guidelines and procedures for choosing appropriate lighting for indoor exhibitions
EN 16242:2012	Conservation of cultural heritage - Procedures and instruments for measuring humidity in the air and moisture exchanges between air and cultural property

EN 16302:2013	Conservation of cultural heritage - Test methods – Measurement of water absorption by pipe method
EN 16322:2013	Conservation of Cultural Heritage - Test methods - Determination of drying properties
EN 16790:2016	Conservation of cultural heritage - Integrated pest management (IPM) for protection of cultural heritage

Table 2: *some of the standards published concerning musical's instruments*

There is usually more than one approach to how anything to do with conservation is achieved, and every point and action written into these standards has been arrived at and agreed by consensus. Standars can be restricting and hardly accessible but it gives correct and comparable 'tools' for carrying out our work. With the variety of our community: conservators, curators, musicologists, historians, makers, musicians, conservation and materials scientists, those definitions are the basis of a transversal and community work.

Conservation of Musical Instruments - Decisions

Vera de Bruyn-Ouboter

Ringve Music Museum, Norway

The discussions around conservation, restoration and repair of musical instruments in museum collections has been ongoing for several decades. The playing and maintenance of an instrument can lead to loss and damage of important historic material. A decision has to be made: Should the instrument be played and maintained or should it be preserved unchanged?

Value and meaning of the musical instrument

For insurance purposes, the musical instrument must be assigned a monetary value, based on a combination of various values.

These values are determined by the instrument´s meaning (significance): provenance, date of production, owners, artistic and aesthetic factors, connection to social and spiritual life, the value for research purposes, the instrument's value as tool for auditive, sensomotoric and functional experiences, the state of historicity, its authenticity and the condition. To establish the meaning, these aspects must be defined for the individual instrument.

Preservation shall sustain the meaning

The aim of preservation and conservation is to retain all values - the meaning of the object. It shall neither be changed through physical damage and aging nor through treatments and intervention. In case of treatments and intervention, there are choices to be made between several conservation options. To avoid treatments that might change the object's meaning, the conservator must reflect on the decisions.

Decision-making in conservation

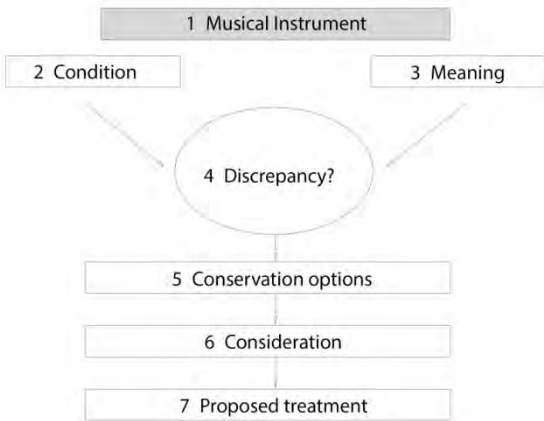

Figure 1: Decision Making Model, Foundation for the Conservation of Modern Art, 1999 (adapted and modified)

Since there are often several specialists with different backgrounds involved in projects related to the use of musical instruments, it is always a challenge to include all the important factors. In collaboration between conservator, organolog, music historian, museums educator, musician, instrument maker and technician, the decision-making model supports identifying the right treatment for each individual case. This model has been used for different object groups before and is presented here, adjusted for the conservation of musical instruments.

The model helps to keep in mind important aspects by answering a selection of questions in seven steps:

Step 1 Data registration of the Musical Instrument

Gather and register data available to describe the musical instrument.

History	Dating, Production, collector, owner.
Technology	Measure and analyse the materials, form. Describe the structure according to the function and the method of production.

Step 2 Condition

Make a condition report regarding all materials' chemical and physical stability. Examine the function and the ability of the instrument to produce sound. This must be done without risking damage to physical material.

Materials	Examine and report the condition (degradation, deformation, cracks, missing parts). Use visual and other suitable methods.
Playability	Examine the playability as well as the fullness and quality of the sound. Determine the risk of expected change in condition or damage in the short- and long- term.
Earlier repairs/restoration and traces of use	Describe changes to parts and materials which were made after production. Use old reports to support your work.

Step 3 Meaning

Determining the meaning of the musical instrument is the foundation for responsible decision-making.
Use Step 1 as starting point.

History	Does the instrument carry information about a special period of time, place, incident, person, process or development? How unique is it?
Social or spiritual factors	Was the instrument used in the context of religious, spiritual, political or other social groups? Does it stand in the context of traditions, practices or ideas?
Historicity	Is there an important history connected to repairs or traces of use made to the instrument?

Art and aesthetics	Does the instrument show high quality art and craftwork? Is it an example for a special period of time, design or “school” of production?
Playability	How important is the playability of the instrument? How unique is the sound? Is it important as an educational tool, auditive experience for the listener or as sensomotorical tool for the musician? Weigh the importance.
Scientific research	Is the instrument important to Social Sciences and / or Natural Sciences, Acoustics, Engineering?
Relevance today	Has its meaning and / or relevance changed in the museum’s context today?

Step 4 Discrepancy?

When there is a discrepancy between the condition and the meaning, there is a demand for conservation. Determine if there is a discrepancy.

Use step 2 and 3 for reference by answering the next question:

Has the meaning of the instrument changed as a result of damage or alteration?

If the meaning has changed, conservation should be considered.

History	Does the altered condition hide important factors of the history (special period of time/ place, incident person/process or development)?
Historicity	Does the condition hide important traces of use or important repairs?
Art and aesthetics	Does the condition affect the instrument as art and craftwork?
Playability	Does an altered playability affect the meaning in an unacceptable way? Are there options to address the demand to play by using a copy or a recording of a similar playable instrument?
Authenticity	Are there damages or alterations, which affect the authenticity of the instrument?

Step 5 Conservation options

After having stated the meaning of the instrument (Step 3) and established if the meaning has changed (Step 4), the need for conservation may be determined. The aim is to achieve a condition which matches the meaning of the instrument.

Formulate now the aim of conservation. Consider then the conservation options (active or passive) with the help of research on appropriate methods and materials. Find the source of the poor condition and make suggestions to avoid future problems.

Aim of conservation	Formulate the appropriate/ desired result of conservation for both materials and playability.
Options of conservation	Make an inventory of conservation methods and materials. Describe conservation options. In case of a playable making, the long-term stress for the instrument and maintenance must be included.
Research on conservation methods and materials	Add practice research needed for the development of conservation options.
Source of poor condition	Identify the reason for the poor condition. Make suggestions to eliminate the problem.

Step 6 Weighing of the conservation options

This step helps to consider the most appropriate conservation method formulated in Step 5.

The following questions are asked:

In what sense will the meaning change as a result of the proposed conservation option?

Are there risks and limitations?

Meaning	Does the meaning change after the suggested conservation option according to History, Aesthetics, Playability, Authenticity
Conservation ethics	Is the instruments integrity always guaranteed? Is the suggested conservation option reversible?
Risks in case of playing and maintenance	What are the risks for loss and change of material? Make a plan for how they can be controlled and reduced.
Limitations	What is possible according to budget, time and technical options?

Step 7 Proposed treatment

A definition of the chosen conservation treatment is placed here.

Conservation proposal	Make sure that the proposed treatment is suitable and covers all important factors. Double check the proposal from the most objective point of view possible. Think about the society / audience as a whole, who shall have the pleasure of experiencing the instrument's significance in the future.

Conclusion

The conservation and repair of musical instruments is usually interdisciplinary, and as such, the 'decision-making model' is an effective tool to ensure good decision-making. For the purposes of conservation, this model enables work carried out on an instrument to be documented and understood by future generations.

The application of the model and its list of questions should be viewed as a mental process and basis for discussions. In the actual work situation the discussion group will go through a mutual learning process and reach conclusions through compromises.

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Preservation of the Wooden Musical Instruments of the Traditional Egyptian Storytellers' Heritage

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2. Former Assistant Coordinator, ICOM-CC-Wood, Furniture and Lacquer, Egypt.

Abstract

The danger of losing the instruments of the Traditional Egyptian Storytellers' Heritage is latent. It is rapidly disappearing under the impact of several reasons. Therefore a project been launched, during its first phase, survey, assessment and documenting of these assets in some Egyptian and some museums/institutions in some other countries have been done.

1. Introduction

The traditional Egyptian storytellers' heritage is very important. It is one of the unique expressions of Egyptian's rich performing arts tradition and folk culture.
The instruments of the traditional Egyptian storytellers have an irreplaceable value to our understanding of past and present cultures.
The danger of losing such heritage and its instruments is latent. It is rapidly disappearing under the impact of several reasons. Therefore, A project led by Dr. Hany Hanna been launched in cooperation between: The UNESCO office in Cairo, ICOM-CC-Wood, Furniture and Lacquer and The International Storytelling Center, Jonesborough, Tennessee, USA, during its first phase, survey, reviewing, inventory, assessment and documenting of this instruments have been conducted in some Egyptian museums/institutions and some museums/institutions in some other countries.

2. The Musical Instruments of the Traditional Egyptian Storytellers' Heritage

There are three forms of the Egyptian storytellers' heritage: cinematic, theatrical and musical.
In its musical form, there are different types of storytelling performed by vocalists and poets accompanied by various musical instruments made mostly of wood and some other materials such as reed, skin, metals and ceramics.
These include several sorts of instruments such as:

2.1. String instruments

I. *Rababa* or the Arabic fiddle: It is one of the earliest known bowed instruments. In Egypt there are several sorts of *Rababa* include:
   - *Rabāba al-šā'Ir* "The poet's fiddle". It has one string. (figure 1).
   - *Rebab el moganni* "The singer's fiddle". It is similar to *Rabāba al-šā'Ir* but has two strings.
   - *Kamancheh*, (*Kamanja Aguz*,or *Goza*). It often has two strings. (figure 2).

II. *Simsimiyya*: *Simsimiyya* (figure 3) and other lyre instruments such as *Lyra* (*Kinnar*) (figure 4), and *Tanpora* (*Tanbura*) (figure 5) are plucked instruments.

2.2. Percussions Instrument:

I. *Riqq*: It is a frame drum, in which the frame usually made of wood (figure 6).
II. *Darbukkah*: It is a goblet shaped hand drum (Single-Headed) (figure 7).

2.3. Wind Instrument

I. *Mizmar*: It is a double reeds, which is a woodwind (basically made of wood) (figure 8).
II. *Nay*: It is an end-blown flute which is a simple woodwind instrument (figure 9).

3. The Project (Phase I) Proceedings

The work of phase I of the project includes survey, reviewing, inventory, assessment and documenting of the assets of this heritage as the following:

3.1. Proceedings in Some Egyptian Museums/Institutions

1. Surveying, reviewing and assessment of the existing collections in some Egyptian museums, to assess ri eht quality, quantity and state of conservation.
   19 Egyptian museums/institutions in 5 Egyptian cities have been surveyed.
   388 related musical instruments have been found in the existing collections in 10 surveyed museums/institutions (table 1). No objects have been found in 9 museums/institutions.
2. Assessing the conservation problems of the mentioned instruments in the Egyptian museums and proposing the required conservation process within a general detailed comprehensive conservation plan. That includes:
   I. Evaluating the existing conservation facilities of the museums and propose their upgrading. Unfortunately, most of surveyed museums/institutions do not provide the necessary good environment for preserving the objects (figure 10-figure 11).
   II. Conducting a full assessment of the state of conservation of the collections.
   The assessed instruments within this project showed several signs of damage, resulting from the effects of the different factors of decay. (figure 12 – figure 16).
   III. Determining the conservation needs, proposing the required conservation processes for the instruments and upgrading the collections within the conservation plan.
3. Documenting and gathering existing visual and textual documentation of the mentioned instruments for digitization and storage. The documentation has been done within detailed reports and a database.

3.2. Proceedings in Some Museums/Institutions in some other countries

Surveying and reviewing the existing collections in some museums/institutions in some countries such as Germany, Italy, UK, Sweden, Greece, USA, Japan and India.
27 museums/institutions have been surveyed; we found 126 related musical instruments in 9 museums/institutions (table 2). NO objects have been found in 18 museums/institutions.

4. The Project (Phase I) Outcomes

1. Writing full detailed comprehensive reports on the results of phase I [1].
2. A general detailed comprehensive conservation plan for the instruments as well as upgrading of the host museums/institutions has been created. [2].
3. Publishing a 34 pages coloured short brochure [3].
4. Under the name 'Egyptian storytellers' heritage'; a database for the found instruments (objects) with basic information has been specifically designed.
5. Defining future development for further phases of the project such as:
   I. Setting separated conservation projects for every individual museum.

II. Publishing a printed detailed catalogue and make it available digitally too.
III. Setting technical partnership between museums in Egypt and other countries regarding this subject.

Figure and tables


Figure 1: *Rabāba al-šā'Ir.*


Figure 2: *Kamancheh.*


Figure 3: *Simsimiyya.*


Figure 4: *Lyra .*


Figure 5: *Tanpora.*


Figure 6: *Riqq.*


Figure 7: *Darbukkah.*

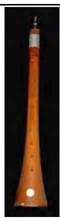
Figure 8: *Mizmar.*


Figure 9 *Nay.*

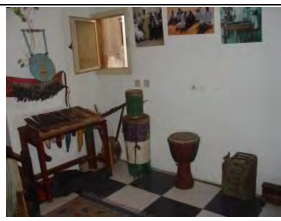
Figure 10: Displaying in *El-Mastaba* Center.


Figure 11: A part of a show case, Museum of Folk Arts.






Figures 12 - 16: Some examples of damage to the objects.

Museums/Institutions	**Location**	**Numbers of instruments**	**String instruments**	**Percussions instruments**	**Wind instruments**
Museum of Folk Arts	Cairo	131	13	35	83
Museum of Musical Instruments	Cairo	79	10	23	46
Egyptian Agricultural Museums Complex:	Giza	78	16	13	49
-The Scientific Collection Museum.		28	1	6	21
-The Arabic Parlor Museum.		49	14	7	28
-The Legacy Properties Museum.		1	1	-	-
Ethnographic Museum	Cairo	54	7	22	25
El-Mastaba Center	Cairo	10	10	-	-
Egyptian Museum	Cairo	26	2	1	23
Museum of Islamic Art	Cairo	3	1	2	-
National Center for Theater, Music and Popular Arts	Cairo	7	-	3	4
Total:		**388**	**59**	**99**	**230**

Table 1. Numbers of instruments have been found in 10 Egyptian museums/institutions.

Museums/Institutions	Numbers of instruments	String inst.	Percussions inst.	Wind inst.
1. Museums/institutions in USA:	25	03	03	19
Museum of Fine Arts, Boston, MA.	14	03	01	10
Dayton C. Miller Flute Collection, Library of Congress, Music Division, Washington, DC.	07	-	-	07
Grinnell College Music Instrument Collection, Grinnell, Iowa.	03	-	01	02
National Music Museum, Vermillion, South Dakota.	01	-	01	-
2. Museums/institutions in Europe:	79	17	28	34
Edinburgh University Collection of Historic Musical Instruments, Reid Concert Hall. Museum of Instruments, Edinburgh, UK.	12	02	04	06
Horniman Museum, London, UK.	46	09	16	21
Germanisches National museum, Nürnberg, Germany.	12	03	02	07
Museo Nazionale degli Strumenti Musicali, Rome, Italy.	09	03	06	-
3. Museums/institutions in Asia:	22	01	01	20
Tokyo National University of Fine Arts and Music Collection, Tokyo, Japan.	22	01	01	20
Total:	**126**	**21**	**32**	**73**

Table 2. Numbers of instruments have been found in 9 museums/institutions in some other countries.

Notes

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I would like also to thank all those who encouraged, supported and helped us.

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The brochure is available at:
http://www.icom-cc.org/54/document/egyptian-storytellers-heritage-brochure/?action=Site_Downloads_Downloadfile&id=612

Technology and Cultural History of Altered Lute Instruments

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Abstract

Old lute instruments were always highly appreciated items. Due to many alterations almost no instrument is preserved in the original shape. During a short time scientific mission (STSM) nine lutes in the Musée de la musique in Paris were examined in order to analyse the history of repair of every instrument. The results will be part of the PhD thesis concerning the technology and cultural history of altered lute instruments.

1. Introduction: Musical instruments - conservation and transformation

The analysis of historical objects as authentic proof of the past concerns not only their originality but also the history of the object, the alterations caused by age, damages and repairs. One group of objects which shows the dichotomy of original and alterations in a particular way is the group of musical instruments. Old instruments were always highly appreciated items, mythical stories are telling of the extraordinary sound quality. De facto all preserved historical musical instruments are changed by repairs and alterations. In this way they unite different shapes and become "diachronic" objects.

Lutes are possibly the most altered instruments through the ages. In the history of this class of instruments from 16th to 19th century many musical developments have taken place and left their marks on the instruments. Almost no historical lute is preserved, which was not altered in terms of pitch range and thus also in shape. Many repairs and alterations are documented in the instruments due to repair labels.

2. A short history of lute repairs

Early sources like Thomas Mace's *Musick's Monument* describe many details about the repair of a lute. Especially the instruments made by the Bologense lute makers Laux Maler and Hans Frei dating from 16th ct. were highly appreciated in the Baroque era. In order to make a renaissance lute suitable for Baroque music, either the neck was cut and renewed or in case of a 10-course lute, only the only a descant rider was attached. Also the bridge had to be changed. Often also the braces on the inside of the belly had to be rearranged. In some cases not even the bowl was untouched by these interventions: "We have lutes that they call cut'lutes – that is, when of a great lute they will make a little one, which is done in cutting off something of the breadth and length of every rib, and then joining them together upon a little mold." [1] Until the 1720s most of the baroque solo music for lute was for an 11-course instrument. The compositions of the famous lutenist Silvius Leopold Weiss demanded 13 courses which were realized in an instrument which often is called the German Baroque lute and has an extended range in the bass. For implementing this in the existing old lutes, again the pegbox and the bridge had to be changed. Either the whole pegbox was renewed for example into a theorbo-style pegbox with two sections or a bass rider was added onto an existing pegbox. In the 18th century already, many old lutes were changed into a Mandora or later in a guitar disposition. With the beginning of the revival of early music in the 19th century, many instruments were restored to an earlier shape.

3. STSM in the Musée de la musique (Paris)

The research on the topic was enriched by a short time scientific mission (STSM) funded by WoodMusICK which allowed to study nine lutes during a two week stay in the Musée de la musique, Paris. A useful start for the research was the catalogue by Joël Dugot [2] who already tried to sum up the repair history of every instrument.

3.1 Lute by Laux Maler, Inv. Nr. E.2005.3.1

Label: Laux Maler

Many different repairs and alterations occur in this instrument. Before the reconstruction by Sinier & de Ridder in 2003/4 the instrument was in the shape of a baroque guitar. There are 11 different types of reinforcements in the bowl. This amount of different papers and parchments gives an idea about how often the instrument had to be opened. On the belly there are four different generations of bars, but at least two are apparently original. The neck was renewed during the last restoration.

3.2 Lute by Jacomo Stadler, Inventory number E.26

Label: Jacouo Stadler Tudesco / in Napoli l'anno 1613

This instrument used to be a big chitarrone. According to the visible repair marks, not many changes were made apart of cutting the upper, long pegbox and keeping the small one. There is just one additional layer of reinforcements in the belly, so it can be assumed that the alteration to a guitar is the only major intervention. As the X-ray image shows, even the position of the braces is still original. A new bridge was made. An interesting fact is, that the old small pegbox was kept, but the former unsymmetrical cut-out was widened to make it more symmetrical.

Fig.1: Laux Maler: reinforcements in the bowl

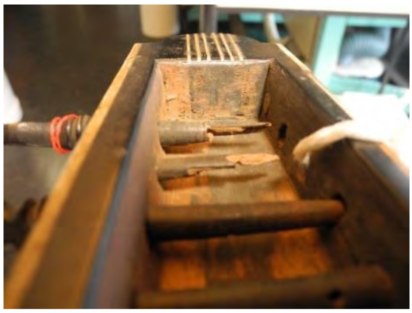

Fig. 2: Stadler: widened pegbox

3.3 Lute by Magno Stegher, Inv.Nr. E.980.2.332

Label: Magno Stegher in Venetia

Repair label: Reparé par Arnold Dolmetsch / Londres Sept. 1893.

An old lute with a new belly, which was made by Dolmetsch. The neck was also replaced. Some interesting features show craft techniques of 19th century instrument building. The bridge is supported with three nails, which can be seen in other repairs made at that time. The first rib on the treble side of the bowl is completely renewed. The old rose is inserted in the new top plate. The reinforcements in the bowl show that there was at least one more repair before the historicizing restoration by Dolmetsch.

3.4 Lute by Gerog Aman, Inv. Nr. E.2346

Label: Georg Aman, Lauten- und / Geigenmacher,in Augspurg. //1739

The date of production 1739 is very late for a big theorbo or chitarrone like this. In the inside there is just one reinforcement. It is possible that the intervention that brought the instrument in the current shape was the only big repair. Now the shape is like a guitar with 6 single strings. The pegbox used to have a bass and a treble rider and at all it was possible to carry 24 pegs. The neck is, however, too small for so many strings. It seems that the old pegbox was reused like in the case of E.26, in order to create a historicizing type of guitar-lute.

3.5 Lute by Gregori Wenger, Inv. Nr. E.0243

Label: Gregori Ferdinand Wenger / Lauten- und Geigen-Macher. / Fectit Augustæ. 1741

This instrument is an interesting combination of two old instruments. The bowl is made by Wenger, the neck is from a big mandola or guitar. However, there are several reinforcements in the bowl, which means, that at least this part of the instrument was repaired at least three times. At the connection of top plate and neck there is a piece of tortoiseshell which has a piece of conifer wood underneath, which means it could possibly be the rest of the pick guard of the other instrument.

3.6 Lute by Hans Fichtoldt, Inv.Nr. E.99822

Label: hans fichtoldt / in fiessen /1627
Repair label: Rept. Phe Draude (?), Cologne

Originally this was a 10-course lute. It was later changed to become a 13-course baroque lute. The pegbox comes from a different instrument. It is too wide and was used before with a treble rider. The veneer at the pegbox comes from a different instrument, probably from a theorbo. In order to keep the precious neck, it was widened by adding a piece of ebony.

Fig. 3: Fichtoldt, traces of former bridge tips

Fig. 4: Anonym, the neck joint was cut smaller

3.7 Anonym, Inv. E.1184

A 10- or 11-course lute was altered to a 6-course mandora. An interesting fact is that the pegbox is made of one piece – a technique which is rare, but known for example from Sebastian Schelle's instruments. Almost no other signs of repairs are visible. A big additional nail goes through upper block and the below part of the neck, but comes out close to the neck.

3.8 Lute by Wendelio Venere, Inv. Nr. D.AD.48483

Label: Wendelinus Tieffenbrucker dictus /Venere Patauÿ faciebat
Repair label 1: Matthias Fux/Röm. Kays. May./ HoffLautenmacher in Wienn. 1689
Repair label 2: Joseph Klein, Violin-/ Instrumentenmacher / in Würzburg. 1868. / reparirt

The bowl is built in the Bolognese style like it was in fashion in the 17. ct. to suit a 10-course renaissance lute. Fux changed the disposition to an 11-course lute and therefore made a new neck. Later it was changed by an unknown repairman to a 13-courde-lute. This proves the additional bass rider. In another repair the bridge was fastened with a string through the chanterelle-bore and another bore hole in the bass side of the bridge. Klein's repairs are easily to recognize by a characteristically colored red glue.

3.9 Lute by Jacob Hes, Inv.Nr. D.AD.40381

Label: Iacob Hes in Venetia / 1586

Repair label: Voncentius Lucarini // restauravit Faventiae an. 1802

The repair of 1802 seems to be one of two major interventions. Lucarini made out of a 6- or 7-course lute a type of mandolin with 6 courses and a bridge, which was not glued on the top. Traces of old frets are witnesses of this state which had a string length of approximately 580 mm. A second layer of ribs underneath the neck hides a former damage. A second intervention was made to change it into a guitar disposition with 5 courses. The amount of pegs is 14, but 4 pegs are renewed, which is a good hint that the instrument was really used in the 5-course state.

4. Conclusion

The nine lutes studied during the STSM represent a wide range of repairs and alterations. Almost every possible disposition of lute instruments is represented by one of the current or possible former shapes. This shows how manifold the history of conservation can be, if transformed objects are understood not as less valuable due to their lower amount of original substance, but as more valuable items due to their feature as diachronic objects which unite a high amount of information on the history of lute making, repair and performance practice.

Acknowledgments

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Preserving Sound – Musical Instruments and Their Ephemeral Feature: Possibilities to Deal with It

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Abstract

Sound is an integral part of musical instruments and is of essential importance concerning the readability of these objects. Preserving this aesthetical aspect is a special challenge. Some possibilities are described in the following: from keeping the originals 'alive' to high quality recordings.

1. Introduction

Sound is an integral part of our inherited musical instruments. These are functional objects, which belong to our cultural heritage not only because of their artistic design. They are complex constructions and their acoustical properties are an absolute essential part of their aesthetics. Restricted capability of sounding necessarily leads to a restricted readability and so reduces the cultural, social and scientific value of our objects. What are our means for conserving this aspect of musical instruments and how do we conserve sound?

The look at some musical instruments - keyboard and woodwind instruments of different types - and their historic and actual use in museums and collections, instrument copies and their associated concepts as well as recordings of different ages will create a representative cross section of our efforts to preserve sound since the founding of the great musical instrument collections.

2. Methods

In attempt to find a solution, to enable also following generations to experience the ephemeral sound of music and musical instruments we have developed some methods during the last century:

- preserving the instruments as tools in playable condition
- manufacturing reliable and true copies of the tools
- sound recording and distributing (hopefully including conserving the recordings)

3. Examples

Following there are a few examples of projects we realised during the last decades.

3.1. Playing Musical Instruments

Traditionally the first way to preserve sound is to obtain the playability of musical instruments. Conservators try to find a balance between conservation and using suitable objects. Even as this might not be the *ultima ratio* in any case – as the condition of our objects, the wear and tear in use or the acoustic quality make playing historic instruments highly questionable – it may deliver satisfying results in some cases: For example the *Mighty Wurlitzer* Theatre Organ of the Musikinstrumenten-Museum PK, Berlin, which is regularly played during guided tours, concerts and cinema events.

There is a lively scene of theatre organ enthusiasts and many of the still existing originals are still in playable condition. For this purpose nearly every wearing part is in production in good quality today. And from a technical and aesthetical view these parts are very close to the originals. Even better, these organs were made for heavy use and therefore they show reasonable wear and tear.

Figure 1. The Mighty Wurlitzer, Kat.-Nr.: 5369.
©Musikinstrumenten-Museum PK, Berlin / Photo: Jürgen Liepe

3.2. Copies and Originals

There are many conservational and technical reasons for originals not to be held in playable condition. An alternative solution is the production and use of copies of some musical instruments of special interest, just as well as the use of copies of functional parts.

To the collection of the Musikinstrumenten-Museum PK, Berlin, belongs a famous harpsichord, which assumedly has belonged to Johann Sebastian Bach: The Bach-Cembalo, Kat.-Nr. 316, made by the Harraß-workshop, Großbreitenbach (Thüringen), around 1700. After having suffered from WWII and of many years of use, it was in no playing condition anymore. A restoration to a playable state would have demanded heavy intrusion into the original substance. Also there are several traces in the construction of the harpsichord, which document very early and fundamental alterations by the maker: two different stages of development caused through musical requirements and use. In the 1990s as a consequence it was decided to conserve the original harpsichord in its impaired state and build two copies: each one representing one state of construction. Both of these copies are made to be played and enable the musicians as well as the audience to experience the sound of the Bach-Cembalo as it must have been during the times of its use.

Figure 3: Bach-Cembalo, Kat.-Nr.: 316 and Copy, Kat.-Nr.: 5614

3.3. Sound Recordings

Figure 4:: CD-Cover and Recorder Kat.-Nr.: 659 & 660. ©Musikinstrumenten-Museum PK, Berlin.

In 1890 the parish of St. Wenzel, Naumburg , sold 37 historic wind instruments to the "Sammlung alter Musikinstrumente bei der Königlichen akademischen Hochschule für Musik", which is now the Musikinstrumenten-Museum PK, Berlin. Among them were 13 recorders, three of them still exist and two are still in a limited playable condition. These recorders, signed "HD" (Kat.-Nr.:659 & 660), have some special features, which draw interest in their acoustical qualities: they appear to be built as a pair of recorders. One labium is placed on the back side and both instruments have different bore profiles. It seems that one recorder was designed as the leading and the other as the accompanying instrument. Therefore it was decided to produce a high quality recording with musicians, who had ample experience with historic instruments and a solid reputation for performing contemporary music. The recorders were examined and over a period of several weeks meticulously prepared to avoid any damage as far as possible. These recordings were combined with a concert to make the best use of this singular event. In 1999 a selection of recordings were published together with similar records of other Naumburg instruments and now the second edition of this CD is on sale since 2014.

*3.4. **Conserving the Recordings***

Of course there are not only audio recordings made to be sold on CD. In fact, documenting sound with various media is pretty old. So we have to handle and preserve various formats. The conservation of data media is relatively young and has grown to an own specialised field in the science of conservation.

Even during the production of the above-mentioned CD *Die Blasinstrumente aus der St. Wenzelskirche in Naumburg,* which took place during a period of about ten years, multiple media formats got used. Over the decades, starting in 1930, the following media were in use and are to be stored in our institute:

- recorded disc
  - shellac
  - vinyl
- magnetic tapes (analogous)
  - from ¼'' to 2''
- magnetic tapes (digital):
  - U-matic
  - Betamax
  - DAT
- optical discs
  - CD
  - DVD
- HD

Not only need these different media to be stored and preserved. But we also require the reproducing devices which have to be kept in working condition. Due to the fact that audio recording got dominated by powerful data processing during the last decades, we additionally have to care for the appropriate IT Hardware and the associated software.

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Treatment of the Appleton Organ at the Metropolitan Museum of Art

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Abstract

The Appleton organ at the Metropolitan Museum of Art is a rare example of early American organ building. After 35 years on the museum's sunlit balcony, the mahogany casework had faded and the 1980s restoration beeswax finish had partially opacified. Testing revealed that removal of this finish was feasible with ethanol poultices, which improved the wood's appearance. Using photographic and physical evidence of the original color, the organ was recoated with thinly applied acrylic paints pigmented with transparent iron oxides. Top coats of Paraloid™ B-72 doped with zinc oxide were used to reduce incident ultraviolet radiation on the wooden substrate.

1. Background

The Metropolitan Museum's pipe organ, made by Thomas Appleton, stands 16 feet tall and has 836 pipes, making it by organ standards modest in size and musical scope [1]. The best indication of its manufacture date is an inscription found on the interior, which reads "Maid in 1830". Thomas Appleton was a Boston-based cabinetmaker who turned to a career in organ building and developed considerable renown for his fine craftsmanship, use of high quality materials, and the musical qualities of his instruments [2]. There are few surviving Appleton organs. There are fewer still that have not been significantly altered in order to remain viable as musical compositions grew in their sonic and technical demands. Remarkably, the Met's instrument survives in a nearly unaltered state. It is thought to have started its life installed in Hartford, Connecticut's South Church [3]. By the mid -19th century, the changing tide of musical tastes dictates use of larger more powerful organs [4] and the Appleton was replaced not twenty-five years later in 1854 [5]. It surfaces again in the 1880s, at which time builder Emmons Howard undertook a campaign of work and expanded the pedal compass to 27 notes from its original 18 [6]. Luckily this is Howard's most significant alteration, which makes the Met's instrument a tremendous source of information about early American organ building and musical practice. Emmons Howard then installed the organ in a small church near Wilkes-Barre, Pennsylvania where it was used until the middle of the 20th century [7]. The organ fell into disuse before being serendipitously rediscovered in 1980, when it was brought to the attention of then Met curator Laurence Libin.

2. Condition and Treatment in 1980

After acquisition the organ was brought to New York-based restorer Lawrence Trupiano for restoration. The 1980s restoration is recorded as being "relatively straightforward" [8]. Arguably the most intrusive part of the 1980s restoration occurred to the casework. To remove the 20th century paint added during its life in Sacred Heart Church, the mahogany was hand scraped down to bare wood, thus removing the vast majority of the original finish. It was then refinished with a layer of shellac and hand rubbed beeswax [9]. Other interventions included straightening and patching of lead pipes, releathering the reservoir and bellows, and recreation of missing mouldings based on other extant Appleton organs.

3. Condition and Treatment in 2016

The organ is utilized as one of a select number of playing instruments in the collection of the Met. It was played as much as weekly in its earlier years and now is played a few times a year for audiences that range from departmental donors to museum visitors. Over time, the

Appleton organ had developed condition issues impacting both playing components as well as the casework. To treat the mechanism of the Appleton organ, the Metropolitan Museum of Art again contracted Larry Trupiano, the restorer who installed the organ in the 1980s and who has since been tuning and maintaining the instrument. Copious dust produced by the galleries' 1970s era carpeting had accumulated in the pipes. This created problems with sound production, especially in reed pipes. Further, the wooden wedges used to hold the reeds in place were also extremely aged and fragile. To combat these issues, Trupiano cleaned the pipes and contracted a reed pipe expert to address the damaged reeds as well as tune them. The wooden wedges were replaced and the originals retained by the museum. The leather gaskets on the pallets inside the windchest, possibly original, had deteriorated which caused air leaks and unwanted noise when the organ was played. In situ treatment was not feasible, so they were carefully documented before removal, delicately removed, and afterwards preserved by the museum. Finally, the restoration flap valves inside the bellows and air reservoir had warped and buckled, causing air leaks that made it virtually impossible to maintain constant air pressure or use all of the organ's pipe registers. While initially the organ was only partially disassembled, ultimately it required full disassembly to allow Trupiano the necessary access to replace the valves and for the authors to address the condition issues of its case.

The mahogany casework had faded from the typical dark, rich color to a pale blonde. In uppermost areas it was even grey-tinged. Parts of the case that were protected from incident light by removable elements revealed the extent of cumulative light damage. This fading clearly presented a significant change to the aesthetic of the instrument and was a concern to both conservators and curators. Initial mechanical and solvent testing revealed that the grey color and dull appearance of portions of the wood was mainly due to the degradation of the beeswax finish applied during the 1982 restoration campaign. Removal was thus desirable and achieved via ethanol-moistened poultices to the wooden surface. Traces of original finish in areas too low to have been accessed by the scraper during restoration were sampled and analyzed using Attenuated Total Reflectance Fourier Transform Infrared spectroscopy (ATR-FTIR). It was found that under the 20th century paint there originally was an oil-diterpenoid resin mixture indicating an oil resin varnish. This information not only revealed the builder's materials and methods, but also gave an indication of how the original surface finish would have looked.

Any conservation treatment of the case obviously would need to address the source of the damage: the amount of light coming into the gallery. Window filters applied in 2010 removed little visible light and UV filtering performance was only guaranteed for five years [10]. In situ light readings taken with an Elsec 764 Environmental Monitor in January 2016 show visible light levels up to 29.000 lux in a direct sunbeam with UV levels of 27 microwatts/lumen (µW/lm). An eight-month study of light exposure in the gallery was conducted measuring light intensity every fifteen minutes with a HOBO U12-012 data logger. Based on these measurements the total light exposure was estimated to be around 3,635,000 lux hours/year. This correlates to a constant, day and night exposure at 415 lux or almost three times the generally accepted maximum level of illumination for wooden objects of 150 lux [11]. While applying neutral density filters or scrims to the windows would be an effective means of protection, it requires lead time for coordination of resources. This led to investigation into a coating that would restore the color of the case and protect it from further light damage.

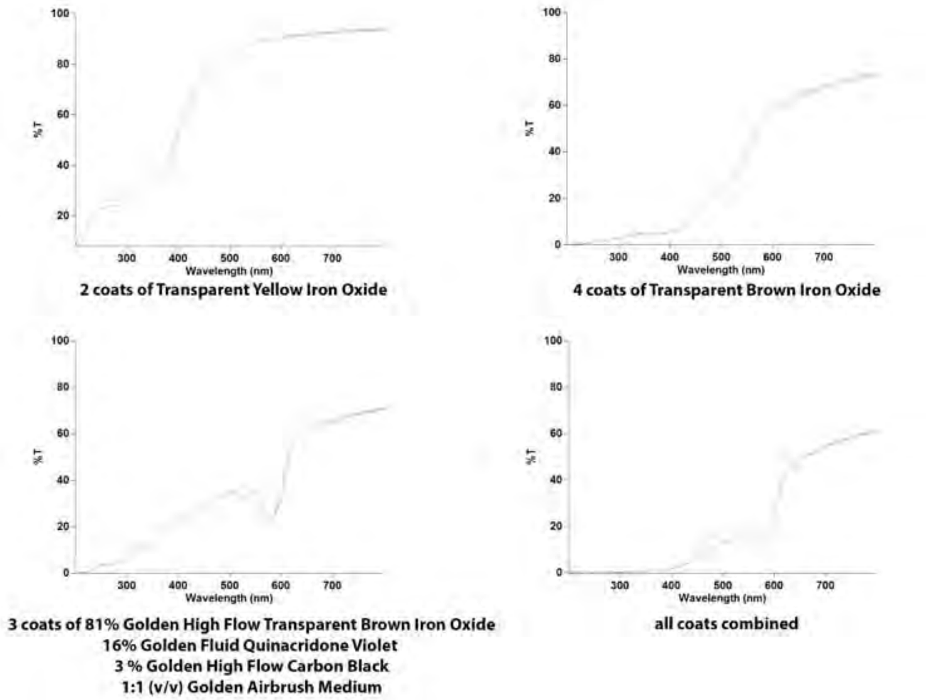

Figure 1: UV-Vis spectroscopy of the various color coatings containing transparent iron oxides applied to quartz slides using a Varian Cary® 50 UV-Vis Spectrophotometer equipped with a Xenon flash lamp and a diode array detector. Spectral range: 190-1100 nm, approximately 1.5 nm fixed spectral bandwidth.

Synthetically produced transparent iron oxides are known to have excellent lightfastness properties and are additionally reported to be strong absorbers of UV radiation [12]. High Flow Acrylics from Golden Artist Colors, Inc. were used to recreate the mahogany color. Colorants included transparent yellow, red, and brown, as well as carbon black and quinacridone violet. They were applied in thin coats, achieved by brushing paint on and then mostly wiping it off with KimWipe™ tissues. UV-Vis spectroscopy of the transparent iron oxide High Flow Acrylics showed that they indeed act as excellent UV absorbers, filtering out virtually all UV radiation.

The challenging light situation, however, prompted exploration into the use of a UV-inhibiting top coat to limit exposure of the more light sensitive quinacridone violet. The use of zinc oxide and titanium dioxide nanoparticles as UV absorbers in transparent coatings has been explored by various studies and found to be effective in the photostabilization of wood [13][14] Experiments were carried out with the use of Paraloid™ B-72 doped with zinc oxide nanoparticles. Zinc oxide was preferred to titanium dioxide for the wavelengths it filters and its greater optical transparency at a given concentration. Paraloid™ B-72 was chosen because of its excellent stability and reversibility. [15] It was found that 9 to 10 coats of 10% Paraloid™ B-72 with 4% w/w zinc oxide in xylenes applied with a spray gun effectively reduced UV radiation by about 50%.

Figure 2: Part of the mahogany case before (left) and after (right) treatment.

After removal of the restoration coatings with ethanol poultices, treatment proceeded with the following coatings:

- 2 coats of 10% Paraloid™ B-72 in toluene as a barrier layer.
- 2 coats of Golden High Flow Transparent Yellow Iron Oxide
- 4 coats of Golden High Flow Transparent Brown Iron Oxide
- 3 coats of a violet-brown mixture. (This contained 81% Transparent Brown Iron Oxide, 16% Quinacridone Violet and 3 % Golden High Flow Carbon Black and was diluted 1:1 by volume with Golden Airbrush Medium for desired consistency)- 10 coats of 10 % Paraloid™ B-72 in xylenes with 4% by weight of 40nm zinc oxide

After treatment the organ was reassembled in its original location on the balcony above the Equestrian court. During the interim during treatment of the organ, the carpet was removed, the underlying hardwood floors were refinished, and a new platform was made for the instrument display.

Further Testing

While our treatment aimed at achieving the best possible protection for both wood and organic colorant (quinacridone violet), ongoing study will be critical to understanding how our coatings will age. To this end, exposure test panels with the various colorants and zinc oxide doped Paraloid™ B-72 will be created to reside discretely in situ on top of the organ.

Acknowledgement

We would like to extend our appreciation to colleagues within the Department of Objects Conservation and Department of Musical Instruments and to Lawrence Trupiano for his part of the treatment of the Appleton pipe organ and for sharing research, archival photographs, and his extensive knowledge of American organs.

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Reconciling Past and Present: the Rijksmuseum 1640 Ioannes Ruckers Muselaar Project

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Abstract

The paper here described focuses on the conservation treatment and reconstruction of a muselaar virginal, built in 1640 by the famous Ioannes Ruckers of Antwerp, which is preserved at the Rijksmuseum in Amsterdam. The on-going Ruckers Muselaar Project aims to develop a new approach to the eternal problem of balancing the three goals of understanding the instrument's original state, of determining how to preserve it better, and of finding a way to give its original function as a musical instrument new life without compromising its preservation.

Figure 1: Muselaar, Ioannes Ruckers, Antwerp 1640, inv. BK-KOG-595

1. Introduction

The BK-KOG-595 muselaar virginal is one of the two surviving instruments from the year 1640 that were built in Ioannes Ruckers's workshop in Antwerp. It belongs to the Koninklijk

Oudheidkundig Genootschap (The Royal Antiquarian Society) which, in 1885, gave it on long term loan to the Rijksmuseum.

Like most instruments of its age, it was deliberately adapted multiple times in the first century or so of its existence, accommodating changes in musical and visual tastes. The original compass of the keyboard was extended in the bass. The short octave was converted into a chromatic bass octave by adding four keys and widening the left-hand side of the keywell. The bridges were rebuilt, the tuning pins were moved and the scale of the strings was slightly altered (Fig. 2). The exterior of the case, originally imitating green porphyry marble, was repainted to simulate a wood veneer with inlaid wooden banding. A third layer of translucent (now) dark varnish was probably added in the 19th century (Fig. 3).

Figure 2: The arrows indicate some elements which were altered in the past

Figure 3: A detail of the front side of the case. The arrow shows an area where the green porphyry marble imitation is visible.

Eventually, the virginal fell out of use, and further alterations, probably less deliberate, occurred (e.g. papers darkened, soundboard painting seriously worn). It is no longer in playing condition, nor can it be returned to playing without compromising its preservation, both as a record of historical instrument building practice, and as an object of cultural heritage.

Detailed technical analysis of the instrument, backed by thorough archival research, will lead to a deeper understanding of the object itself, and any conservation issues that may arise. A scrupulously accurate replica-reconstruction, making use of identical materials and working techniques wherever possible, will reveal further information about the instrument's construction and design. This fully functional musical instrument will then be a source of information and a means of research into the audible qualities of the instrument.

2. Methodology

The project, methodologically, can be considered to fall into three parts. First, the direct study of the instrument's materiality, supported by the study of parallel extant instruments where necessary (discussed in more detail in Section 3 below).

Second, the archival and historical research into the instrument's context and background. This will be used to trace the development of the decorative style and origins of the decorative elements, as well as establishing a clearer understanding of the physical and intellectual context of the instrument, and filling some of the gaps in current knowledge about the supply chain used by the builders.

Third, the making of the replica-reconstruction instrument. Copying extant instruments is a practice that dates back to the late 19th century at least, but recent developments in analytical methods will allow this method to be pushed to a greater degree of scientific and artistic rigour than was possible earlier.

3. Technical Analysis

The examinations aim to clarify questions of concept (design, scaling, etc.), of method (process, tools, order of work, etc.), and of materials. Multiple techniques will be needed in order to understand the composition and structure of the many materials used on the instrument: woods (case, keys, soundboard, stand, etc.), metals (hinges, pins, strings, rose), leather (jack guides, key arcades), parchment (key arcades), glues, textiles (dampers, jackrail, keyrack), bone (key covers), pigments and media (decoration), paper (decoration) and so on.

	Concept	Process	Wood	Metal	Leather	Parchment	Glues	Textiles	Bone	Pigments	Media	Paper
CT scan	X	X	X									
X-ray Fluorescence				X						X		
Macro X-ray Fluorescence						X						
X-ray Energy Spectrometry				X								
Micro-Raman Spectroscopy									X	X	X	
Dendrochronology			X									
Imaging in visible light	X	X			X					X	X	X
Imaging in UV light	X	X					X			X	X	X
Infrared Reflectography		X								X		
HIROX Microscopy		X								X	X	X
Scanning-Electron Microscopy EDX								X		X		X
Gas Chromatography- Mass Spectrometry							X			X	X	
Stratigraphic Analysis		X								X	X	
Optical Coherence Tomography		X									X	

Figure 4: Provisional list of technical examination methods and their areas of application

Due to the instrument's status as an object of cultural heritage, its physical preservation will be given priority. Non-invasive analytical techniques will be emphasised. Where direct non-destructive techniques cannot yield the information needed, preference will be given to the use of models, mock-ups, and experimental reconstructions. When neither of these approaches apply, direct sampling will be employed, when it is possible to do so without compromising the integrity of the object (e.g. stratigraphic sampling of exterior paint layers at the edge of existing damage to the surface decoration). Where the materials are too damaged or contaminated (or simply absent) to be analysed directly, mock-ups and reconstructions will be created and artificially aged (where possible) to determine their plausibility.

Figure 4 (below) shows a provisional list of analytic techniques to be employed in the material study of the instrument. Further methods will be added as their usefulness and feasibility is determined. This work will build on the preliminary analyses that have already been performed on the instrument by Miriam Orlando [1], as well as more broadly Ruckers-related research conducted by Grant O'Brien [2], the MacTaggarts [3], Sheridan Germann [4], the Musical Instrument Museum of Brussels [5], and the Musée de la Musique in Paris [6].

Figure 5: The pictures made with the Hirox microscope show the original green porphyry marble imitation layer followed by a whitish layer over which a brown pigmented layer, later covered with a dark varnish, was applied.

4. Aims

The Rijksmuseum's 1640IR project aims to give the original instrument new life, without compromising its preservation. The approach – that of building a replica – is not new; however, the project will take this approach to hitherto unattempted levels depths of analytical and reconstructional precision.

First, a detailed technical analysis into every aspect of construction, material, and technique, will allow the instrument to *teach.* Second, the construction of a replica-reconstruction of its original state, as faithfully and accurately built and decorated as possible, will allow the instrument to *sing* and step from its case by proxy, once again interacting with the public.

This newly built instrument will occupy a space *in-between:* both a working musical instrument and a museum object specimen, both a replica and an individual in its own right, both a manifestation of rigorous scientific research and a product of contemporary craftsmanship and art.

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‘De fare uno manicho novo saria inposibile […]’. Evolutionary Aspects of Violin Restoration Techniques

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[1] National Music Museum, Vermillion SD, USA

Abstract

The goal of this paper is to examine some evolutionary aspects of violin restoration techniques. The paper will be focusing to increased care to details and the visual aspects of the restoration, showing how, after the middle of the 19th century, attention to aesthetics parameters became central in restoration activities.

1. Introduction

The practice of restoration of musical instruments has been characterized, in the past centuries, by an approach aimed mainly to preserve the functional characteristics of the object, often to the detriment of its coherence and its historical unity. This approach is probably due to the traditional representation of the musical instrument: an object or - better - a tool producing sound, in opposition to the heritage object which has a special status in our society. According to the traditional representation, the quality of its "conservation" is closely associated with the survival of its functionality. A well-preserved instrument seems to be an instrument working to its full potential.

Particularly from the 19th century, one may affirm that commercial-purpose restoration was at the origin of each intervention on musical instruments and influenced the evolution of restoration techniques, from a simple functional intervention to the progressive development of interventions techniques in which aesthetics is the core.

2. Methods

The term *restoration* has been used to denote multiple parallel activities -sometimes complementary- as *repair* or *maintenance*. Until the last century all these practices have been interlocked, and up to the 19th century we find no evidence of a lexical discussion: *restored* and *repaired* were used as synonyms.

The study of the history of restoration benefits of written sources as a direct consequence of the *Siècle des lumières*. It’s just in the 19th century that we observe the emergence of an important production of treatises and works that deal, in one way or another, with the restoration practice.

3. Before the 19th century: a few examples

Before the 19th century written information is extremely sporadic and not connected each other: mostly found in musicians’ memories, correspondences, or musical treatises, they consist in short descriptions or mentions of interventions. The following are some of the most known sources.

One of the oldest testimonies of repair practices is found in the correspondence (1496 - 1515) between Isabella d’Este (Marquise at the Court of Mantua) and Lorenzo Gusnasco (luthier, merchant, and intellectual).

Isabella ordered instruments from Lorenzo and asked him to repair others. In his answers, Lorenzo describes in details the interventions he made:

> “[...] I opened it, removed the neck and thinned it as necessary, and remade the pegbox, and eliminated the buzzing from the frets, and I think that you will like the

voice even more than before. I also restrung it because it didn't have any good string. "[1]

He pointed out the dangerousness of certain interventions (which today would be defined as invasive), specifying that he will do his best:

> "[...] I received the ebony lute along with your letter in which you asked to thin the lute neck: I will do it with extreme diligence […]. Making a new neck it would be impossible because one would have to open the lute and it will be dangerous as it could be damaged, but I will do anything I can with diligence to satisfy Her Ladyship." [2]

In 1676, Thomas Mace (composer, music theorist but also singer and violist) described with accuracy how to repair the cracks of a lute soundboard:

> "Then laying the Belly flat upon smooth place, Press the Joynt close and even with your Fingers, and then lay all along upon the Crack a little slip of Paper, about a quarter of an Inch broad, or less, wet with Glew very thinly, and with your hot Iron fasten on the Paper, which will immediately cause that Crack to be as Firm as any part of the Belly. "[3]

A century later, in 1779, Giovan Battista Guadagnini wrote to count Ignazio Alessandro Cozio [4]:

> "[…] to re-angle the neck, make a new patch and everything is necessary […]. […] to put a new dovetail joint on the old Stradivari violin's neck […]. "[5]

Similarly, the *Encyclopédie méthodique*, published in 1785, gives us a very detailed description of the so-called intervention named *mise à ravalement*:

> " […] Il faut, pour cet effet, les couper du coté des dessus & du coté des basses ; ensuite élargir & même alonger tout les corps du clavecin. Enfin ajouter du sapin vieux, sonore, & le plus égal qu'on puisse retrouver à la table d'harmonie, pour lui donner sa novelle largeur & longueur.
>
> Le grand sommier se fait tout à neuf dans ce fortes de clavecins, qui, tout bien considéré, de leur premier être que la table, & environ deux pieds & demi de leurs vieilles éclisses du coté droit.
>
> Les parties accessoires, comme claviers, sautereaux, registres, se sont à présent avec beaucoup plus de justesse & de précision, que les maitres flamands ne les ont faites dans le siècle passé. "[6]

4. The 19th century: towards a new aesthetic

In the 19th century Paris was the leading center for bowed instruments. Between 1806 and 1913, many publications on violin-making, containing long descriptions of restoration interventions, are published and re-edited. They show a change in the mentality of the actors practicing the interventions but also in the intervention techniques.

Cracks gluing techniques were often described and show a constant evolution during the century.

From a very simple approach described by Sibire in 1806

> "If we had just to glue some cracks, a bit of glue would be enough; the operation would be a game." [7]

we assist to an evolution trough the treatise of Maugin in 1834

> "We slide some hot glue in the cracks and, tighten with the left hand the part of the table or the back on which is the crack, to place the two edges of the crack on the

> right position; […] we place on the crack, inside of the instrument, a strip of thick paper […].” [8]

In 1903 Tolbecque’s publication suggests building wooden clamps to glue the edges of the fracture. The use of wooden clamps is the starting point for the future development of all kinds of clamps commonly used today:

> “For lateral clamping of these fractures, we will make small, lightweight poplar clamps [...]. Their shape will be modified according to the need and adjusted as best as possible so that they hold well in their place.” [9]

The evolution of gluing techniques is directly related to the final aesthetical result: we clearly observe after the middle of the century an increasing attention to *invisible* interventions, never found before, as Fétis (“[…] does not leave any trace of the regluing operation […]) [10] and Simoutre (“[…] to make disappear all traces of the fracture […] showed no traces of the operation […]) [11] report in 1856 and 1886.

5. The 20th century and the present day:

Technical evolution continued during the 20th century, following the path traced in the previous century: greater attention to details, “invisibility”, and impeccable execution.

In 1988 Han Weisshaar and Margaret Shipman published *Violin restoration: A Manual for Violin-makers* [12], considered as the “bible” in the field, and mainly consisting in a compendium of the more popular commercial intervention techniques of the previous thirty years.

The evolution of clamps is the most relevant technical innovation of the end of the 20th century: a few companies specialized in engineering clamps suitable for all kind of interventions and different areas of the violin, improving their efficiency and allowing greater precision in cracks gluing. The availability of CT-scan that became popular at the very beginning of 2000’s, allowed experimenting with 3D rendering and 3D printing. 3D printed molds, supports or clamps could save time and avoid manual building of custom-made tools.

In recent years, CNC routing machines, in connection with 3D scans, demonstrated to be extremely efficient, precise, and the most revolutionary tool in the hand of a restorer. The possibility to replicate in few hours details that will request weeks of traditional labor, allows preserving a greater amount of the original parts of the instrument that would be otherwise lost or destroyed.

6. Conclusion

The diachronic examination of violin-related written and material sources clearly show an evolution of mentality and intervention techniques towards more effective and less visible interventions. This trend becomes especially noticeable after the second half of the 19th century through the observation of the instruments that still bear restoration’s traces of that period and it’s supported by many written sources, mainly published in Paris.

The 20th and 21st century mark a fluid continuous evolution in making interventions less visible with an increasing attention to the varnish retouch. Technology such as 3D-scan provides extremely detailed information on the state of conservation and allows reproducing parts with a precision degree that allows much more conservative and respectful interventions.

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Searching and Squirrelling: Sourcing Materials for Early Pianos

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Abstract

Early pianos incorporate a great variety of materials, both organic and inorganic, whose nature profoundly influences their musical characteristics. In a changing world, many of these materials are no longer easily accessible; this paper describes the problems inherent to the quest for the materials needed for the facsimile of a *piano-forte en forme de clavecin* (Érard frères, Paris 1802[1]) which we built in 2009-2011 for the Musée de la Musique, Paris.

1. Introduction

The musical, mechanical and decorative characteristics of all musical instruments are defined by their constituent materials; few instruments incorporate a greater variety of materials than the piano, in both structural, mechanical and acoustical aspects, as well as musical and decorative ones[2]. In eighteenth-century Europe, keyboard instruments were made by craftsmen using predominantly local materials, operating in small workshops located in princely capitals or in smaller towns. However, at the end of the century and during the next, the great centres of London, Paris and Vienna saw large manufactories spring up in cities that were already graced with a host of specialised trades, supplied with materials brought from the world over. The abolition of guilds allowed interaction between these trades, and materials of all kinds could be exploited without restriction. The new pianoforte was very much the child of this context. Caught up in the Industrial Revolution, it saw rapid development in a symbiosis of technical, musical and social impulses; its early adoption as a status symbol was bound to changing decorative tastes and displays of technological progress.

Keyboard instruments had early seen division of labour and the rationalisation of design of their parts. This system survived with only marginal use of machinery until the mid-nineteenth century, when the cost reductions introduced by large-scale industrial woodworking, mechanised component making and the employment of consistent and reliable new materials opened up new mass-markets for cheap pianos. A highly-skilled, elitist craft became a highly-rationalised, pragmatic and commercial one.

The nature of any piano as a musical vehicle, its materials and the methods of its manufacture, are all specific to the time at which it was built; a truthful restoration or reconstruction thus relies on finding appropriate materials and working methods.

2. Methods

In 2008, we were commissioned by the Musée de la Musique in Paris to build a facsimile of an Érard *piano-forte en forme de clavecin* of 1802, as part of an on-going research programme into French music in the Classical period. Relatively few of these pianos were built, and only one completely unaltered playing instrument[3] has come down to us.

The Musée undertook to provide us with the fruits of their scientific research in four fields related to the project: studies in modal analysis of the soundboard (carried out by Sandy Leconte): analysis of the varnishes used in the instrument (as part of the Musée's VERNIX project): genetic analysis of the leathers used for the hammers: analysis of historical music wire. Dr. Leconte published her findings in 2010[4] and again in 2012[5]. We still await the results of the varnish, leather and wire analyses.

We benefitted from the practical research into phosphor-iron music-wire by Stephen Birkett of the University of Waterloo[6]; he provided us with the wire needed for the instrument.

The identification of all the other materials, including varnishes and leathers, was done visually and empirically, with special reference to two untouched Érard pianos, the 1808 grand already mentioned and a square of 1802[7]. The sources included a range of sometimes unique conventional ones (general and specialist wood merchants, veneer-cutters, bookbinders' suppliers, tanners, metal warehouses, varnish and colour merchants, musical instrument suppliers...) but also less conventional ones (a hat-felt maker, cloth remainder shops, second-hand shops, car boot sales, ironmongers' clearance sales) and a certain amount of recycling of wood &c. from damaged old furniture, steel from old springs and worn files. The ivory for the keys was put at the Musée's disposal by the French Customs, who had seized it from a dishonest diplomat...

3. The Materials

The transformation of piano-building in the 18th. to mid-20th. centuries from modest city-centre craft enterprises to large purpose-built suburban manufactories with powered machinery[8] also brought changes in materials. Until about 1840 exotic materials were incorporated into pianos, often recyclable waste from nearby trades. Examples in the Érard: beaver-fur felt for hammer-butt bushings (trimmings from luxury hat-making) and the gut threads binding the damper-lifting mechanism (scrap violin strings). Other commonly-found materials include selvedge cut from the edges of woollen cloth, trimmings of rabbit-fur felt, baleen from corset- and umbrella-makers, recycled waste paper and parchment.

With industrialisation and standardisation, the serendipitous use of recycled or readapted materials disappeared in favour of normative ones especially produced for the trade, such as felt, steel wire and cast iron. These new materials involved considerable experimentation and technological advance: the piano's nature was transformed by their use. Rediscovering each step musically implies recreating each step of technology; in many ways the early industrial piano is more inaccessible to accurate reconstruction today than its artisanal forebears.

To the difficulties of material transformation are added the difficulties of availability. Many natural materials, both animal and vegetable, have in the past been grossly over-exploited, especially by the luxury trades, in which piano-making took pride of place. Ivory, tortoiseshell, whale products, many exotic woods: all now lie under the Washington Convention protecting endangered species, and more will surely be added. Although there are residual historical stocks, many of these are now outlawed by legislation and made unavailable even for restoration or for scientific projects. Recycling from old objects is often the only recourse.

Other natural materials, although not endangered, suffer from past over-exploitation: for example, pencil cedar, *juniperus virginiana*, is no longer available in the straight-grained lengths required for hammer-shanks. Increasing industrialisation of forest management and the disappearance of country trades has meant that non-commercial species of tree and shrub are no longer valued. Lime, maple, service, wild pear, hornbeam, box, holly, alder, to name only a few used in piano-making, are becoming unavailable as timber.

Many trades, such as tanning using traditional methods, parchment-making, weaving or paper-making, have declined drastically in the past fifty years and much expertise has been irretrievably lost; more hangs in the balance as it is conserved by only a handful of artisans. When one of these trades disappears, a whole cascade of others dependent on it is put at risk. Actions such as those of UNESCO and the French Maître d'Art and Patrimoine Vivant schemes, while they are indispensible, are not sufficient to preserve this heritage; in these difficult times, funding is inadequate and frequently ill-applied.

Finally, human pressure and climate change threaten most of the world's natural habitats, and materials now in abundance are likely to become scarce.

4. Prospects: conclusion

Many materials required for the restoration or replication of early pianos are today scarce or unobtainable because of over-exploitation of natural resources and/or the disappearance of the skills and means to transform them. Others form the subject of research destined to recreate them. In this precarious situation, largely unsupported by public bodies or funding, continued high-level exploration of the early piano is dependent on individual sourcing and squirrelling of materials, new and recycled. Co-operation between the different protagonists in the form of sharing suppliers' addresses, pooling resources both material and financial (group purchases for example), is essential for our own professional survival and that of the suppliers on whom we depend. Group action to maintain an element of legislative reason concerning the products of threatened species is another essential direction[10].

In an ideal world, a conservatory of rare materials and techniques would not only acquire and hold stocks, made legally available for conservation and research, but it would actively and materially promote the survival and the study of rare techniques and encourage their rediscovery. In an ideal world...

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Conservation Issues on Historical Pedal Harps: Preserving Tangible and Intangible Properties

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Abstract

This paper presents the results of interdisciplinary research aiming to document, classify and preserve the features of historical pedal harps, while discussing issues of conservation and restoration. The focus of this study is an early double-action harp by Erard in the Deutsches Museum. Because little is known about the manufacture and use of this harp, the instrument is initially investigated with several analytical techniques in order to identify its original construction materials and to detect any additions or modifications. Additionally, due to its fragility this historically important instrument is not in playing condition, and thus non-invasive tests are employed to obtain information about its vibratory behaviour. The data collected from the examination of this harp are compared to data from four similar Erard harps in private and public collections with the intention to expand the knowledge on the design of these instruments. Moreover, since one of these harps has been restored to playing condition with the addition of a new soundboard, the comparison between the five harps also allows to observe the impact of the different conservation and restoration approaches on the vibratory behaviour as well as on the authenticity of the instruments.

1. Introduction: The Shift from Material to Immaterial

Until recently the conservation of historical musical instruments in museums focused mainly on the documentation and preservation of their construction materials. However, in the last years the attention of researchers and conservators has shifted towards the immaterial characteristics, which are considered equally significant for the comprehensive study of such artefacts [2]. Because of the double role of musical instruments as cultural objects and functioning devices designed to produce sounds, it has become increasingly important to preserve not only their substance, but also the information they contain [3]. An example that demonstrates the above-mentioned issues in the conservation of musical instruments concerns historical pedal harps from the late eighteenth and early nineteenth centuries. These instruments, which are built and decorated with various materials, including wood, metal, ivory, bone, textile, paper, etc., typically include numerous delicate functioning components controlled by pedals [4]. With the passing of time and due to the physical and chemical degradation of their materials, many of these harps have become fragile and unplayable [10]. Apart from any aesthetical, mechanical or statical issues, this fact also creates issues of interpretation and contextualisation of these instruments.

2. Case Study: Object-based Research on Erard Harps

This situation can be observed on an early double-action harp by Erard N° 2631 (London, 1818) in the Deutsches Museum (Inv. No.: 16147). This harp will be displayed in the new permanent exhibition of musical instruments and therefore a thorough examination of its tangible and intangible properties is crucial for its preservation and future display. Because little is known about the manufacture and use of this harp, the instrument is initially investigated with various analytical techniques (e.g. SEM-EDX, FT-IR, GC-MS, fibre analysis, endoscopy, radiography) in order to identify its original construction and decoration materials, and also to detect later additions or modifications [7]. This material analysis enhances the results of earlier scientific research [8], assisting the harp's forthcoming conservation. For instance, radiography reveals hidden details of the harp's internal structure (**figure 1**), while allowing useful comparisons to extant Erard patents [9].

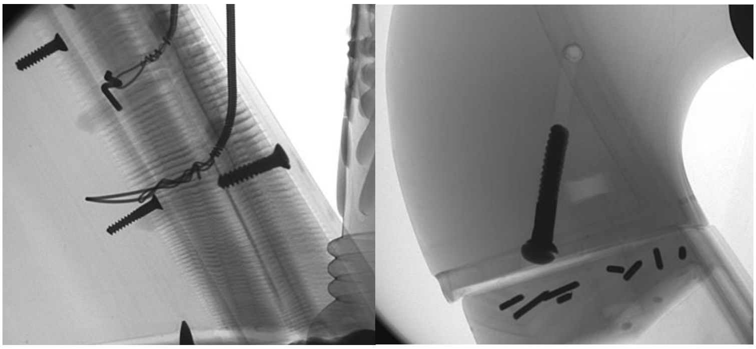

Figure 1: X-ray photographs revealing the use of screws for the attachment of the soundboard to the soundbox (left) and inside the shoulder (right) of the harp N°2631.

However, due to its fragility this historically important instrument is currently not in playing condition. Therefore, in order to examine the vibroacoustic behaviour of the harp N° 2631 the methodology proposed in a recent study of historical harps [6] is applied. Using a simple setup with a piezoelectric sensor and impact hammer (**figure 2**), mechanical mobilities are measured for the soundboard and for two symmetrical positions at the soundbox, and mean values of mobility are calculated. This method of excitation is commonly utilised on modern instruments, but on historical instruments it has certain limitations. For example, the pointed metal tip of the used impact hammer can leave visible dents on the soundboard wood and therefore low-strength adhesive tape should be used to protect the soundboard, resulting unavoidably in a smaller observable frequency range due to a softer contact surface. Furthermore, fixing the acceleration sensor on the harp with synthetic wax can cause abrasion, stains or loss of paint and thus preliminary tests should be performed on unobtrusive areas of the instrument to examine if there is any surface damage. Also to avoid any risk of mechanical damage from tension, the strings of the harp N° 2631 are not tuned to playing pitch.

Figure 2: The setup for the vibroacoustic examination on the harp N°2631 (left) and detail of the sensor and hammer used for the mobility measurements on the soundboard of a similar Erard harp N°4534 (right). Note that the harp strings are damped with felt and that low-strength adhesive tape is used to prevent any dents from the sharp hammer tip.

The results for harp N° 2631 are compared to results obtained from a similar Erard harp in private collection. This harp was restored in the late 1980s; during this work, the original soundboard was removed and a new soundboard was installed. The data from these two harps are then compared to data from three other Erard harps in the Musée de la musique [6]. **Table 1** presents the main reference details of the five Erard harps.

Table 1: Main reference details of the five Erard harps.

Serial No.	Place	Date	Collection	Inv. No.	Strings tensioned
2631	London	1818	Deutsches Museum, Munich	16147	No
3006	London	1820	Musée de la musique, Paris	E.991.14.1	No
3070	London	1821	Musée de la musique, Paris	E.0997	No
3830	London	1826	Musée de la musique, Paris	E.2003.5.8	Yes
4534	London	1832	Private collection, Germany	NA	Yes

The organological documentation and comparison of the harp N° 2631 to the other four harps shows that Erard double-action harps manufactured in London during the early nineteenth century demonstrate a relatively uniform and stable design regarding their overall dimensions, geometry, scaling, weight, etc., as well as a similar vibratory behaviour (**figure 3**), reflecting the standardisation of their production. In addition, the low mobility value for the soundboard of the harp N° 4534 can be attributed to its new soundboard, which is considerably thicker and heavier than that of N° 2631, an instrument that retains its original soundboard.

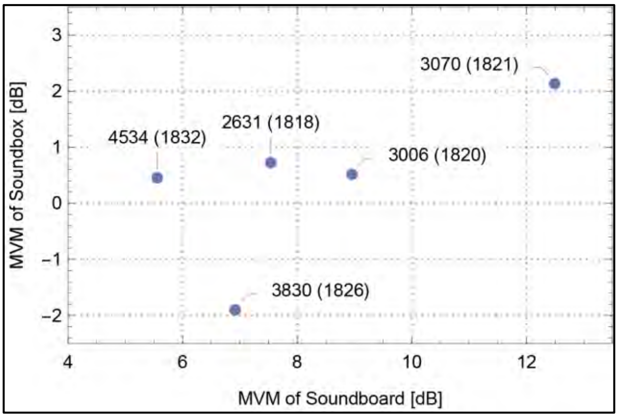

Figure 3: The mean values of mobility for the soundboard and soundbox of the five Erard harps listed in Table 2.

3. Conclusions

Object-based research on surviving Erard harps is essential for the better understanding of these instruments, complementing existing archival research on the Erard firm [1]. However, when dealing with historical instruments there is often a conflict of approaches, since by obtaining information on intangible values (e.g. sound) there is always a risk of losing tangible values (e.g. materials) [5]. For example, the return to playing condition with extensive restoration measures (e.g. new soundboard) can distort the original features of a harp. Furthermore, the vibroacoustic study of the harps proves that there are conservation issues even for methods that are usually described in the literature as 'non-invasive' or 'reversible' and thus a risk management plan is necessary to prevent damage.

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Changes in Vibrational Properties and Color of Wood Due to Heating at Different Relative Humidities

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Abstract

The vibrational properties of hydrothermally treated spruce wood depend strongly on the relative humidity during heating. Particularly, the mechanical loss tangent of the wood increases remarkably when it is heated at high humidity, because the depolymerized hemicelluloses act as a plasticizer in the wood cell wall. The temporary effects of hydrothermal treatment are also explained by the physical ageing of the wood polymers.

1. Introduction

It is well-known that long-term ageing affects various physical properties of wood. The enhanced acoustic quality and dimensional stability of aged wood is important for wooden musical instruments. Hydrothermal treatment is expected to be an efficient method to reproduce the effects of long-term ageing, because chemical reactions during ageing in ambient conditions are promoted by elevating the temperature. If we can precisely reproduce the effects of ageing, high quality, "artificially aged" wood can be produced with low production times. The artificially aged wood may be useful for making musical instruments, and for the restoration of old wooden instruments, because its appearance (e.g. darkened color) is very close to that of naturally aged wood. For precise reproduction of aged wood by hydrothermal treatment, the relative humidity during heating (HRH) should be considered, because humidity greatly affects the physical properties of hydrothermally treated wood. In fact, Endo et al. reported that the vibrational properties of wood change significantly by heating at high HRH, while they remain almost unchanged by heating at low or intermediate HRH [1]. In addition, recent investigations have suggested that the effects of ageing are partly reversed by moistening or rewetting the wood, particularly when the wood is heated at low or intermediate humidity. This paper describes the effects of HRH on the vibrational properties and color of wood heated at different temperatures. The effects of water soluble decomposition residues were also examined. In addition, the reversible and irreversible effects of hydrothermal treatments were reviewed to highlight the importance of humidity in the process.

2. Methods

Sitka spruce lumber selected for soundboards of harps was used. The lumber was cut into strips with dimensions of 120 mm (longitudinal) by 15 mm (radial) by 1.6 mm (tangential). The specimens were moistened under humid conditions and then dried to eliminate the effect of seasoning. The specific dynamic Young's modulus (E'/ρ) and mechanical loss tangent ($\tan\delta$) of the specimens were measured at 25°C and 60% RH. The specimens were hydrothermally treated in an autoclave or an oven at 95, 120 and 140°C and 0-100% HRH. After the vibration test, the specimens were leached in water to remove the water-soluble decomposition residues (extractives). The specimens were then conditioned at 25°C and 60% RH and their vibrational properties were measured again. The color of the wood specimens was evaluated by using the CIELAB color parameters. The extractives were analyzed by ion chromatography.

3. Results

Vibrational properties of hydrothermally treated wood

In general, higher E'/ρ and lower tanδ values are preferable for wood used in soundboards of musical instruments. Figure 1 shows the relative E'/ρ and tanδ of hydrothermally treated wood as a function of loss in weight (WL). When the wood was heated at low or intermediate HRH, the vibrational properties remain almost unchanged. In contrast, by heating at high HRH, the E'/ρ decreases remarkably and the tanδ increases steeply. That is, the acoustic quality of wood is degraded by heating in humid conditions. Such adverse effects of high humidity are explained by the plasticizing effect caused by low molecular weight sugars. When wood is heated at high HRH, the hemicelluloses are depolymerized into low molecular weight sugars, which then act as plasticizers in the wood cell wall to change the vibrational properties of wood. In fact, the E'/ρ increases and the tanδ decreases with an increase in WL after the removal of sugars. Table 1 shows that the major low molecular weight sugars in the extractives are mannose and xylose, which are the major constituents of hemicelluloses.

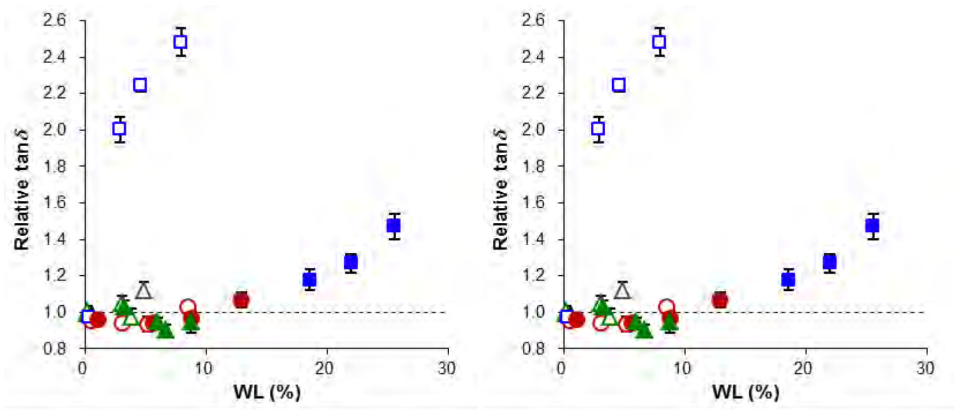

Figure 1: Relative E'/ρ and tanδ values of hydrothermally treated wood plotted against the WL.

Dashed lines, unmodified; ○●, heated at 140°C and 0% HRH; △▲, heated at 120°C and 60-75% HRH; and □■, heated at 120°C and 100% HRH. ○△□, hydrothermally treated; ●▲■, hydrothermally treated and extracted in water; *error bars*, standard deviations.

Table 1: The yields of low molecular weight sugars in the water-soluble extractives remaining in the hydrothermally treated wood.

HRH (%)	Heating duration (days)	WL (%)	Total yields of extractives (%)	Yields (%)				
				Arabinose	Galactose	Glucose	Xylose	Mannose
Control	0	0	0.4	0.1	0.1	0.0	0.0	0.1
60	10	3.9	4.7	0.0	0.5	0.5	0.4	1.4
100	2	3.2	12	0.4	1.5	1.5	1.3	4.6

Color of the hydrothermally treated wood

The color is another important factor affecting the quality of wooden products. The antique color of aged wood is sometime preferred for making string instruments such as violins. Figure 2 shows the changes in color of the wood as a function of WL due to hydrothermal treatment. With hydrothermal treatment, the L^* (brightness) value decreases monotonically with increasing WL, and the a^* (redness) and b^* (yellowness) values increase at the beginning of the treatment and then decrease. This suggests that the change in color of the wood depends on the WL due to hydrothermal treatment, irrespective of HRH.

In Figure 3, the relative values of tanδ of the hydrothermally treated wood are plotted against their brightness. When wood is heated at low or intermediate HRH, the color becomes darker while the tanδ value remains almost unchanged. In contrast, when wood is heated at high HRH, the color becomes darker, and the tanδ increases drastically. These results suggest that we can modify the color of wood while keeping its vibrational properties, when the wood is heated at low or intermediate HRH.

The hydrothermal treatment in the present study is considered to accelerate ageing, and the changes in vibrational properties and color exhibited in Figures 1 and 2 are also likely induced by long-term ageing at ambient temperatures. It should be emphasized that the same color does not indicate the same vibrational properties, in the case of aged wood. Even when two lumber specimens show the same "antique" color, their vibrational properties may be completely different depending on the relative humidity that the specimens have experienced.

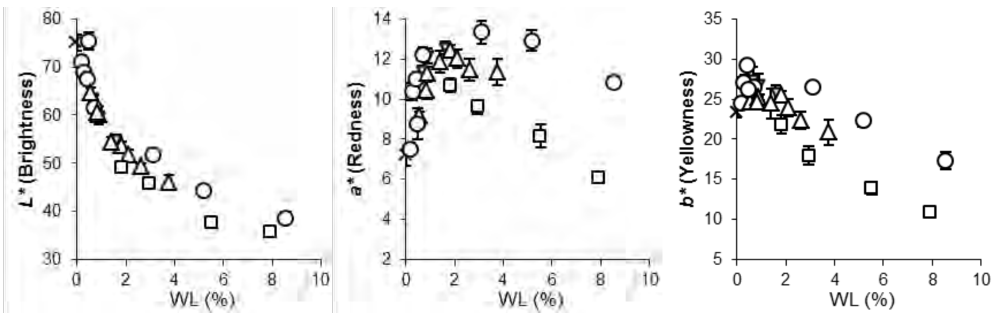

Figure 2: Color parameters of hydrothermally treated wood as a function of WL due to the heating.
×, Unmodified; ○, heated at 120°C, 140°C and 0% HRH; ▽, heated at 120°C and 33% HRH; △, heated at 120°C and 60-75% HRH; □, heated at 120°C and 100% HRH; and *error bars*, standard deviations.

Recoverable effects of ageing and hydrothermal treatment

Many studies indicate that the effects of hydrothermal treatment or ageing are irreversible. However, recent studies show that those effects are partly recoverable in humid conditions at ambient temperature [1]. Such a recovery should be considered when maintenance of the improved performance of aged or hydrothermally modified wooden musical instruments is needed. Figure 4 shows the changes in vibrational properties plotted as a function of heating duration. When wood is heated at moderate humidity, the E'/ρ increases and the tanδ decreases with increased heating duration. These changes have important implications for acoustic quality of wooden soundboards. However, after the wood is moistened in humid conditions at room temperature, the E'/ρ decreases and the tanδ increases. This suggests that the effect of hydrothermal treatment is partly reversible when the wood is exposed to highly humid conditions. Similar recovery is also observed in naturally aged red pine wood [2]. Therefore, it is advisable to keep aged or hydrothermally treated wooden instruments in dry conditions to maintain their performance.

The temporary effects of hydrothermal treatment are closely linked to the physical ageing of amorphous wood polymers [1,2]. The wood cell wall is a composite in which crystalline cellulose fibers are embedded in amorphous matrix substances. The crystalline cellulose is rigid and hydrophobic, whereas the amorphous polymers are swollen with moisture in green state and ready to shrink by drying. When wood is dried from its green state, the amorphous polymers are distorted because their shrinkage are restricted by the crystalline cellulose. Since the amorphous polymers are glassy and immobile in dry conditions, the drying stress cannot be relaxed immediately. However, it may be relaxed by hydrothermal treatment because the temperature used is higher than the glass transition point, mobilizing the polymers. Even at room temperature, the polymers may gradually relax during long-term ageing. The wood polymers can recover their initial arrangements once they are re-swollen and plasticized by increased moisture at high HRH. Therefore, the effect of hydrothermal treatment and long-term ageing can be partly reversed.

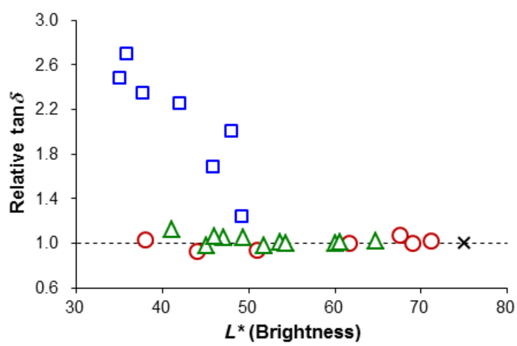

Figure 3: Relative tanδ values of hydrothermally treated wood as a function of the L*(brightness).

Dashed line and ×, unmodified; ○, heated at 120°C, 140°C and 0% HRH; △, heated at 120°C and 60-75% HRH; and □, heated at 120°C and 100% HRH.

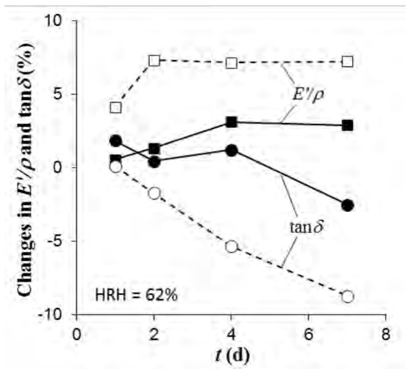

Figure 4: Changes in E'/ρ and tanδ values of the wood due to hydrothermal treatment at 120°C and 62% HRH as a function of heating duration (t) [1].

□■, Changes in E'/ρ; ○●, changes in tanδ; *dashed lines*, hydrothermally treated; and *solid lines*, hydrothermally treated and moistened.

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Structural Assessment of Wooden Musical Instruments by Simulation: Models, Validation, Applicability

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Abstract

A long-term experiment on the load bearing structure of a replicate of a clavichord from 1807 at cyclic humidity changes is carried out. The photogrammetrically measured, three-dimensional deformations serve as validation base for the developed objective, general and non-destructive, numerical assessment tool for cultural wooden heritage.

1. Introduction

Museums with collections of historical music instruments have the conflict between conservation of the original substance and maintenance of original use. Especially playable stringed keyboard instruments are complex wooden structures under heavy mechanical loading. Hygrical loadings as alternating climate conditions induce additional mechanical loadings and influence the physical properties enforcing damages to the structure like large deformations and cracks. This recent research field is focused on two kinds of structures with respect to the external loads: purely hygrically loaded structures, like furniture and panel paintings [1] on the one hand, and more complex stringed wooden music instruments, like pianofortes [2], violins or guitars, on the other hand. The latter, additionally loaded by mechanical forces, are strongly susceptible to plasticisations and creeping deformations, enhanced by moisture dependent mechano-sorptive effects. The goal is the development of an objective simulation tool for museums and conservators in order to support conservation strategies and to be able to evaluate these wooden structures.

2. Validation Experiment

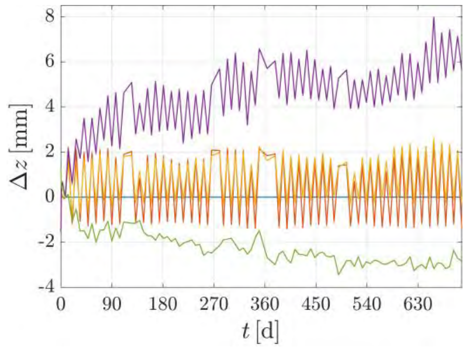
Within a long-term experiment, two identical replicas have been stored in constant and cyclic climate, respectively and measured photogrammetrically. Due to validation purpose, the instruments are unvarnished and the amplitude is very large. The climate cycles last one week to enable large moisture uptake and diffusion deep into the cross-section within a practical duration with respect to the number of climate cycles and the measurement maintenance.

The instrument is mechanically loaded by the tensioned strings initially in room climate (ca. 55% RH). After a first period of four days with 80% RH, all periods last one week, each.

Within this abstract, it is focused on the evaluation of the four top corners of the clavichord case at cyclic climate load (see Figure 1). The main deformation is identified as torsion of the case, due to the inclined load angle of the strings. The deformation measurement is carried out photogrammetrically at the end of each climate cycle. Therefore, a mesh of marker and target points along the edges with a distance of about 10mm is applied. Both instruments are photographed (ca. 60 photos per measurement) on the test rig and are processed with the software AICON 3D Studio. It uses bundle adjustment to calibrate the camera in each measurement [3].

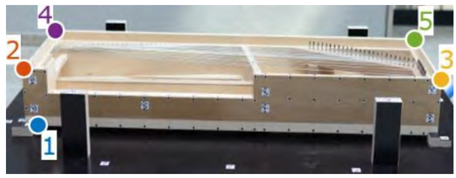
Figure 2, shows the alternating climate data of the ambient air in storing conditions. Although the storing room is in well-defined climate, an annual oscillation is detected, with the mean values of 78% and 30% RH for large and low humidity, respectively.

(a)



(c)

Figure 1: (a) Clavichord MS-85, built by Sauer, Dresden, 1807, (b) Replicate on the measurement rig and (c) corresponding deformations of the replicate's corners as coloured in the photo.



(b)

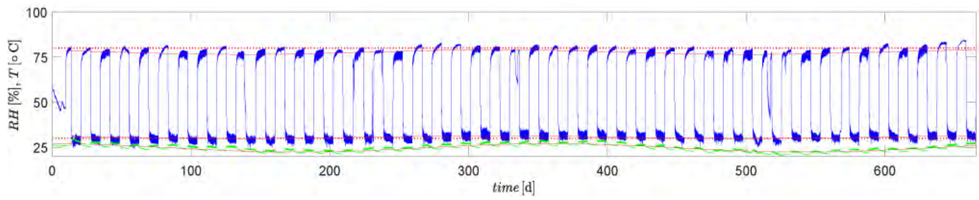


Figure 2: Storing climate of the clavichord replicate, with RH (blue), T (green) and fitted sin-functions (red, solid).

In the following, the climate loading cycles are discussed. In contrast to the reference replicate, the clavichord in cyclic climate shows dominant creep behaviour. Especially, at backside corner points 4 and 5 (graphs at top and bottom in Figure 1c), large irreversible deformations increase. Moreover, the wet and dry states can easily be identified, due to hygro-expansion. For both instruments, the slight annual climate oscillations are visible in the deformation plots as well.

The measured overall deformations of the structure are the assumption of the wooden materials' elasto-plastic, hygro-expansional, viscous creep deformations and the compliance of the structural components joints. Simple estimations and extrapolations by these data set are not recommended.

3. Numerical Validation

Basing on the numerical analysis by the finite element method (FEM), a comprehensive hygro-mechanical material model for the mechanical short-term behaviour is applied for the transient, i.e. time-dependent simulation of the first three climate cycles of the clavichord. The results will be compared and serve as validation of the comprehensive model. Furthermore, the numerical simulation enables to analyse the internal mechanical and hygrical state of the instrument and, thus, the origin of measured deformations.

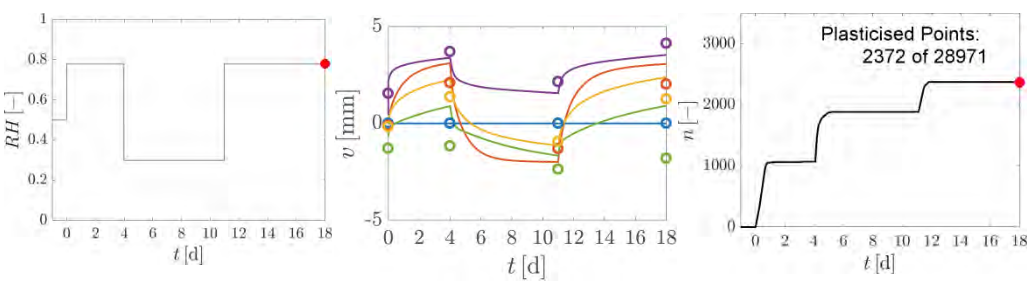
The material model is recently introduced in [4] and is applied within a hygro-mechanical FE-analysis of a panel painting of Lucas Cranach the Elder in [1]. Several material models have been developed and implemented for elastic and failure behaviour with respect to the moisture dependency. Compressively loaded wood, especially perpendicular to the grain, leads to ductile failure with plastic deformations beyond the elastic range, modelled by a multi-surface plasticity model. The moisture transport plays an important role in the analysis of transient processes, i.e. climate changes. The transfer at the surface is captured by a boundary-layer model, while the inner transport is characterised by a multi-Fick'ian diffusion approach. A simpler and commonly used single-phase diffusion model is found to be not accurate enough. The two phases of bound water in the cell walls and the water vapour in the lumens are coupled via a sorption isotherm, without considering of hysteresis.

The clavichord's wooden load bearing structure is very complex. The structural parts include different species with different hygro-mechanical characteristics and fibre orientations, like spruce (sidewalls and bottom, dry density ρ0=0.38kg/m³), beech (wrestplank, ρ0=0.65kg/m³) and oak (hitchpin rail, ρ0=0.65kg/m³). Further material characteristics are published in [4,5].

Due to the unknown exact material directions, a Cartesian coordinate system is applied for the anisotropic material directions. The fibre direction (local longitudinal material direction) is assumed to be in length directions of the structural parts and the tangential material direction is simply assumed to be in vertical direction for all parts.

The transient simulation starts with the beginning of the alternating climate, at 27. August 2015, with the simulation time t_0=0 days. The computation is performed with the inhouse FE-program MatFEM.

The simulated vertical displacements u_z are shown in Figures 3 and 4 and fit to the experimentally determined deformations. The calculated deformations of the tensioned strings at time t=0 days fit generally very well. Only for point 5, larger deviations of ca. 1mm are visible, which also can originate from the experiment (settlement, joint friction) or the measurement error. The final states of the climate cycles can be reproduced with a satisfying accuracy as well. The consideration of sorption hysteresis within future investigations is supposed to achieve even more accurate results.



(a) (b) (c)

Figure 3: (a) Simulated surrounding climate, (b) vertical displacement of the first three climate cycles in comparison to the experimental results (circles) and number of plasticised points of the analysed clavichord replicate.

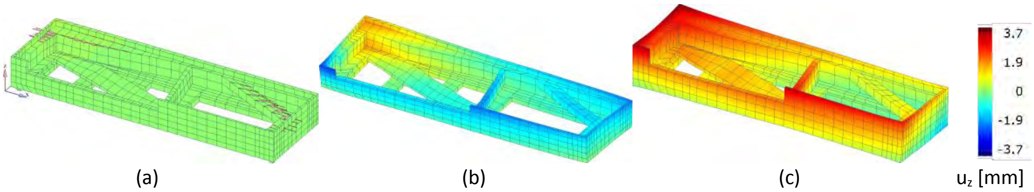


Figure 4: (a) Initially unloaded clavichord, vertical clavichord deformations u_z (scaled) after (b) 11 and (c) 18 days.

The simulation delivers more continuous results and can give an insight into the process of time-dependent stress peaks due to internal constraints, caused by the anisotropic swelling and shrinking behaviour of wood. The wooden material plasticises, when the material's compression strength, which decreases with increasing moisture, is exceeded. In Figure 3c, a strong increase in the number of the plasticised points directly after each climate change can be observed. Plasticisations are detected near the surface, especially along the edges and joints. This is in accordance with, e.g. [2,4], where it is identified as a consequence of moisture-change. On the one hand, due to the anisotropic hygro-expansion, i.e. swelling and shrinking, internal constraints occur in multi-dimensionally loaded areas. In this case, the moisture-gradient is a significant factor, i.e. the velocity of moisture change inside the wooden material. On the other hand, connected structural parts, especially in case of parts with different species or fibre orientations, prescribe external constraints. Both may lead to material or structural failure.

4. Conclusion

A long-term experiment on clavichord replica at changing climate over a time-span of about two years is carried out successfully. The three-dimensional deformations of a large point cloud are measured photogrammetrically with good precision. Within a transient, hygro-mechanical FE-analysis, the first cycles of the experiment are simulated. The results are compared to the experimental findings and showed good agreement. The analysis of ductile failure, due to compression, showed plasticisations in areas of internal or external constraints. The huge influence of moisture, even in short-term range, is approved.

Current research aims to consider bond-lines, material inhomogeneities, due to natural variation and long-term behaviour, like creep. Further experiments in the material parameter characterisation, especially in the long-term behaviour and the moisture dependency, would support the simulation quality. However, the first step to an objective, general and non-destructive assessment tool for cultural wooden heritage, accounting for the multi-physical nature of wood, is done and successfully applied to recalculating the deformations of a clavichord.

Acknowledgement

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Adapting Conservation Techniques for the Remedial Conservation of Musical Instruments

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Abstract
The core purpose of conservation is to preserve the cultural and historical objects in such a condition that present and future generations may experience and study them.
Due to this complexity, musical instruments have been historically regarded as unique within the field of objects conservation; however, there is a wide variety of objects within public collections with somewhat similar challenges concerning their functionality and preservation. Therefore, conservation treatments, methods and techniques originally intended and developed within other fields of conservation such as books, paper, furniture, clocks, and even arms and armour can prove useful for specific remedial treatments of musical instruments. Using John Koster's eloquent words, 'the ideal musical instrument conservator should know everything about everything'. [1]
In this paper, I will present techniques, materials, and treatments originally intended for other conservation disciplines and their possible application to the preservation of musical instruments with the intention of providing alternative methods for the conservation of musical instruments.

1. Introduction

Musical instruments are inherently complex mix-media objects, composed of materials with diverse properties which sometimes have been made even more complex with the addition of other materials in the course of their existence. In addition, they are often regarded as functional objects even within the context of public collections. As such, they offer particular challenges in regard to their best preservation, particularly when deciding the most adequate treatments for their remedial conservation intrinsic to their use as functional items, as well as their appearance as decorative objects on display.

"There is no optimum restoration method, but only one technique deemed most suitable for the object in question". [2] Therefore, the treatment of any object should be addressed in a case by case perspective, employing suitable materials and methods accordingly. [3]
At present time, most remedial treatments in conservation of static objects, can be divided in two groups: cleaning and consolidating. Amongst dynamic objects, a third group is added, that of interventions of maintenance and up-keep, which involve the replacement of parts deemed 'consumables', structural reinforcements, and constant adjustments to the movable parts.

2. Methods, materials, and their use in the conservation of musical instruments

The following are only a few examples of materials and techniques used across conservation specialties that can be useful when employed to the treatment of musical instruments. There are certainly many more that due to the nature and constrains of length of this format cannot be presented in this paper. In addition I am only too aware of the fact that there are also many materials and methods unbeknown to me at present time.

2.1. Cleaning: Cleaning is by definition a non-reversible interventive treatment, and should be approached accordingly. However, cleaning is also a necessary interaction in order to ensure the preservation of historical objects. The cleaning method employed should be dependent on the materials and condition of the specific surface to be treated. Some of the most common surface cleaning methods are:

2.1.1 Wet methods

Gels: Water can be, depending on the situation, either a desirable or a strictly necessary medium for the cleaning of objects. Moreover, water is the right environment for two of the most important cleaning processes to take place: chelation and emulsification or detergency. Nevertheless, water has potentially dangerous consequences, particularly when treating hygroscopic materials, like wood or ivory. Anisotropic changes can result in fractures and irreversible deformations; dust and dirt particles can be drawn through capillarity causing lakes and stains; polychrome decorations are particularly susceptible to moisture and the contact with water can result in irreversible losses.

In order to limit the amount of water in contact with the object it is possible to increase its viscosity by means of hydrophilic polymers or gelling agents, particularly when dealing with water-sensitive materials. Some of the polymers generally used for this are: cellulose ethers like Klucel and xanthan gum, and the high-viscosity polyacrylic acid derivatives like Carbopols and Pemulens.

Nowadays, gels are a fast-growing area of conservation, with particular relevance in the cleaning of works of art, predominantly paintings. The conventional cleaning treatment for painted surfaces was based on mechanical action and/or organic solvents to remove surface grime. Unfortunately, solvent penetration into the paint layers can result in swelling and leaching of organic components, therefore damaging the integrity of the object. With the use of gels it is possible to minimise the contact of the solvents with the outer layers of coatings or pollutants without disturbing the original paint.

The use of gels in the cleaning of wooden surfaces is documented and has been successfully carried out by furniture conservators. Gels applied directly to the wood or with poultices allow the removal of grime without leaching the surfaces, limiting the hydroscopic exchange and therefore preventing further damage.

Detergents: Neutral detergents are useful cleaning agents often employed in object conservation. Vulpex is a commercial non-corrosive, non-foaming, non-hazardous, germicidal, non-acidic, and insecticidal spirit soap. It is an effective emulsifier of dirt, fats, fatty oils, mineral oils, waxes and hydrocarbons. Vulpex is soluble in water and in organic solvents (e.g. white spirit, trichloroethane, etc.), which makes it a remarkably versatile 'wet' or 'dry' cleaner for a wide array of materials. It can be used in the treatment of musical instruments as an effective cleaner of finished surfaces, from varnished wood, and metals when solved in water, to unfinished wood, ivory, and leather in a spirit solution. Once the cleaning treatment is completed, it can be rinsed or simply wiped clean to neutralise the cleaned surface.

2.1.2 Dry methods

Smoke Sponges: Smoke sponges are made of vulcanized natural rubber, or synthetic latex-free materials. They were originally intended to remove soot and smoke damage from materials in which solvent or wet cleaning is not desired or possible like fabrics, wallpaper, polychrome metal and wood surfaces, etc.

Currently, sponges are widely used for dry cleaning of books and paper, predominantly for the removal of dust and dry mould. Similarly, these sponges are very effective when cleaning untreated, varnished, and polychrome wooden surfaces.

Erasers: Common erasers (made of rubber and polymers) are also employed for dry surface cleaning, particularly in paper conservation. They remove dust and debris mechanically from the surface, in addition, the polymers work chemically by sticking to unwanted pollutants and lifting them from the surface.

Erasers are very effective as dry cleaning agents for wooden and ivory objects in which wet treatments are not desirable.

Microfiber cloth: made from polyester/polyamide ultra-micro-fibres microfiber cloths are particularly effective breaking down, trapping and absorbing dirt particles without scratching the surfaces. In addition, the rubbing action of these cloths generates static energy which enhances their dust and micro particles accumulation ability.

Microfiber cloths are extremely useful in dry cleaning treatments of delicate surfaces in musical instruments to remove impurities from all sorts of materials, such as glass, stainless steel, plastics, treated and untreated wood, brass, etc.

Calcium carbonate and deionized water: The tarnish that collects on objects made of silver is silver sulphide. Tarnish forms from particles of hydrogen sulphide present in the atmosphere. An effective polish to remove tarnish can be made by mixing precipitated calcium carbonate with deionized water to form a paste. Calcium Carbonate is inert and softer than tarnish therefore it is ideal to remove the black silver sulphide from the surface without damaging the object.

An alternative method to remove tarnish is using an electrochemical reduction. This can be achieved by submerging a silver object in a warm solution of sodium carbonate whilst in contact with aluminium. I this process, the carbonate solution acts as the electrolyte, and the contact between the two metals causes the aluminium to corrode producing hydrogen gas; the gas reacts with the tarnish, reducing it back to silver metal. Once cleaned using this method, the object should be rinsed well with deionized water to remove any traces of electrolyte, and a gentle polishing with microfiber cloth is advisable.

2.2. Consolidating: The choice of a material to be employed for the consolidation of a particular object must be dependent on a thorough consideration of the properties required for the material in situ, its use, the method of application, and the method of removal.

2.2.1. Reinforcing materials

The Japanese paper or *washi* (wa-Japanese shi-paper) is widely employed in paper conservation. Some of its more remarkable characteristics that make it suitable for conservation are: it is acid free, made with natural fibres so it does not degrade, the high strength of its fibres allows the production of extremely thin sheets.

This paper is made with the bark of *kozo* (mulberry tree) or *gampi* (a bush found in the mountainous areas of Japan) employing traditional papermaking techniques and equipment. Hand-made sheets are produced one-by-one on a bamboo screen, hence the long fibres constituting the paper sheets are interlaced randomly in all directions, resulting in a multidirectional strength and flexibility.

Some of the more common uses of this material within paper conservation are: to interleaving sheets for archiving materials, hinges, repairing page tears, and mounting objects (e.g. graphics, photographs, etc.). Alternatively; machine-made paper using hand cleaned *kozo* fibres will result in a definable grain direction which is often preferred for repairing or lining brittle machine-made papers, as grain direction can be aligned.

The versatility, stability, and strength of this paper makes it ideal as reinforcement for fractures and repairs in musical instruments, thus avoiding the weight and rigidity of the commonly used wood cleats. Larger areas of unstable or compromised materials can be reinforced with a thin layer of Japanese paper. Depending on the object and the material to which the *washi* would be applied, it can be adhered using either water soluble protein based adhesives or a resinous acrylic fixating agent (paraloid B72).

Toned paper: Another application of Japanese paper commonly used in book conservation is the replacement of missing sections or tear repairs on book covers (either in leather or fabric) using previously coloured *washi*. In this technique, the paper is prepared by matching the colour of the surface to which it will be applied using natural pigments and dyes in a binding agent (e.g. gum arabic). The paper is allowed to dry and then adhered to the surface.

This technique can be very useful for cosmetic treatments of musical instruments with parts made of leather (e.g. drum heads, animal skin soundboards, etc.). Its flexibility and strength make a remarkable solution to withhold and consolidate tears even when in moderate tension.

Japanese paper allows stock weights far lighter than those of wood pulp papers; the thinner sheets (down to 1.6gsm) are nearly translucent. Wooden musical instruments can be consolidated also externally by applying light-weight toned *washi,* resulting in virtually invisible reinforcements.

2.2.2. Adhesives and coatings

Paraloid B72 (Acryloid B72): B72 is a copolymer of ethyl methacrylate and methyl acrylate, soluble in acetone, ethanol, and isopropanol, amongst other solvents. It is water-resistant, clear, flexible, stable, has a high adherence, and fast drying times. All of these characteristics make it a versatile adhesive, commonly used in conservation of ceramics, glass, and stone.
Paraloid B72 is also effective as a coating agent, commonly used as a consolidant in paintings, wall-paintings, and fragile wood. It has also been widely used as a protective layer for the labelling of museum objects.
B72 can be used in the conservation of musical instruments both as a reversible non-aquose adhesive, as a consolidant of compromised parts, or as a coating mean for metal, and wooden parts.
Microcrystalline wax: Microcrystalline waxes are produced by de-oiling petrolatum. Waxes are widely used for conservation of metals as coating means in order to protect the surfaces from moisture and oxygen hence providing a protective anti-corrosion layer, as well as preventing against the introduction of contaminating elements by handling.
Microcrystalline wax is also used in furniture conservation as an alternative to beeswax and carnauba wax which contain acids or became acidic over time.
In musical instrument conservation, this wax is very effective as a protective coating for metals (e.g. silver parts, brass instruments, etc.) to prevent oxidation, damage due to fingerprints, tarnishing, etc. Or as a coating layer for ivory or bone key-tops of keyboard instruments.
It is advised to apply a light coat of wax evenly and lightly over the surface, then lightly buffed with a smooth lint-free cloth to obtain a sheen. If the shape or size of the object requires it, a soft brush may be used to apply a similar coat
This wax is soluble on white spirits and can be easily removed if necessary using and soft cloth impregnated in the solvent.

3. Conclusion

Conservators as a whole can learn a lot from each other. The technical knowledge and expertise of the various conservation fields are transferable and are particularly relevant to musical instrument conservation because of the multi-medium nature of musical instruments. Looking to conservation techniques used in paper, metal and furniture conservation expands the possibilities of instrument conservator for providing the best treatment for the instruments within our care. As the field of conservation continues to develop with new scientific advancement and techniques, we should collaborate across disciplines to widen our understanding.

Acknowledgements

The author would like to acknowledge John Koster, Bob Van de Kerkhove, Caroline Scharfenberg, Emily Hick, Marijn Manuels, and Sarah Deters.

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Criteria for Selecting Reed *(Phragmites Australis)* of Japanese Traditional Oboe (Hichiriki) and Recent Attempt for the Plantation of Reed in a Managed Field

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Abstract

Criteria for selecting reed of Hichiriki are discussed and a recent attempt for the reed plantation is introduced.

1. Introduction

Gagaku is Japanese ancient court music. In fact, the Gagaku that is played in the imperial palace is listed in the UNESCO Intangible Cultural Heritage of Humanity. The hichiriki (shown in Figure 1) is an oboe-like double reed woodwind instrument used in Gagaku music. The vibrating plate (Rozetsu) of the hichiriki is made of Japanese reed (Phragmites australis) harvested in the Udono area of Osaka. High-quality reeds are harvested by skilled harvesters, selected by musicians, and then made into Rozetsu [1]. According to these harvesters and musicians, it is becoming increasingly difficult to harvest high quality reeds, probably due to recent urbanization around the reed fields as well as the invasion of alien species. In addition, the unique skills and knowledge of the reed harvesters are not being passed down to the next generation and therefore are at risk of dying out [2]. In order to conserve the hichiriki and Gagaku music, we need to identify the relevant anatomical and mechanical properties of the Japanese reed. In addition, the intangible knowledge of harvesters and players should be recorded for posterity in order to maintain this traditional culture. We also need to find other potential reed fields to prepare for any unexpected environmental change in the current reed fields.

In this paper, we describe the different criteria for reed selection; this information is important to reed harvesters, hichiriki players and all those involved in Gagaku music. We also discuss a recent attempt at cultivating a managed field in order to provide a sustainable supply of high-quality reeds.

Figure 1: Hichiriki (left) and Rozetsu (right).

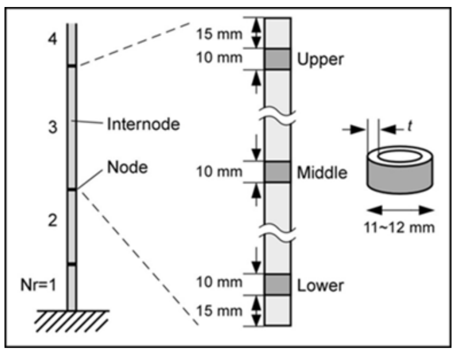

Figure 2: Reed specimens.

2. Methods

Reeds were harvested from the Udono and Mukaijima regions. Reeds in Mukaijima are not usually used for harvest, but it has been confirmed that they are genetically identical to those in the Udono area. The Udono reeds were harvested by skilled harvesters and classified based on their empirical methods into those suitable and unsuitable for hichiriki.

Figure 2 shows the shape and dimensions of the specimens that were tested. Ring-like specimens were made from the 2nd to 5th internodes (the portion of the plant that is usually used for the hichiriki reed) and their dimensions and densities were measured in wet conditions. Next, the reed specimens were dried at 25°C and 60% relative humidity (RH), and their transverse compressive strengths were measured using a universal testing machine. Some of the selected reeds were also evaluated by professional hichiriki players in the Imperial Palace.

Reed seeds were gathered in the Udono area and cultivated in a managed field (Greening Technology Center, Nippon Expressway Research Institute) in 2013. The culms of the planted reeds were harvested every winter to measure their dimensions and density.

3. Results and discussion

Selection by harvesters

According to the reed harvesters, the hichiriki reed should ideally be 12 mm in diameter and sufficiently rigid against transverse compression. A brightly colored plain surface is preferable to a dark colored surface containing brownish spots and stains. Suitable and unsuitable reeds showed no significant difference in terms of thickness and density of the culm. However, the thickness and density depended on the internode position, the upper part being thinner and denser than the lower part. Figure 3 shows the cross sections of an internode at different positions. The thick cortical parenchyma layer of the lower part explains the thicker wall and lower density. Since the upper part is usually used for the hichiriki, thinner and denser culms are therefore preferable.

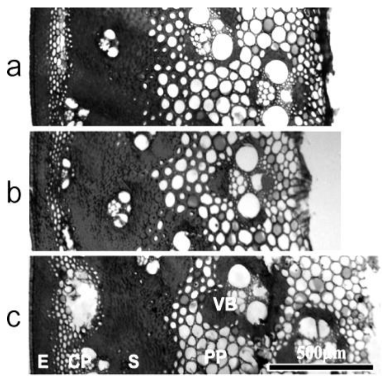

Figure 3: Cross sections of upper (a), middle (b), and lower (c) position of an internode. E: Epidermal layer, CP: cortical parenchyma, S: sclerenchymatous ring, VB: vascular bundle, PP: pith parenchyma.

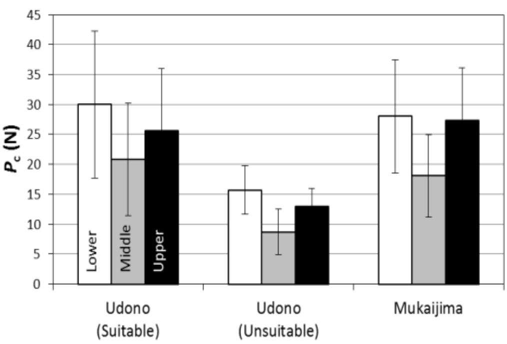

Figure 4: Critical load (P_c) of reeds under transverse compression.

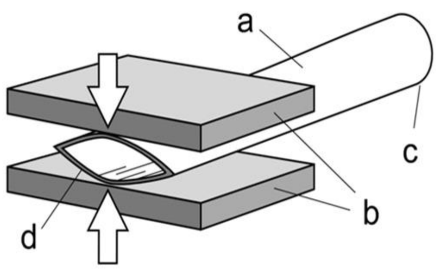

Figure 5: Traditional compression process (Hishigi) to form a "double reed".

Figure 4 shows the critical load (P_c) of the culm under transverse compression. Since the P_c

values for suitable reeds were significantly higher than those for unsuitable ones, this could be used as a selection criterion.

Figure 5 demonstrates the traditional process (Hishigi) of creating the double reed shape. Unlike oboe and bassoon reeds, the hichiriki reed is formed using a hand plier over a charcoal fire to apply transverse compression. Although the side walls of the culm are reinforced with traditional paper (Washi), the top and bottom walls need to be sufficiently tough against the bending force, otherwise the reed cannot be flattened. Therefore, fragile reeds are excluded when harvesting to prevent the failure of a culm in the subsequent Hishigi process. It is also preferable to use the upper part of an internode, since this is thinner (more flexible) and denser (tougher) than the lower part. Since the correlation between the P_c values of middle and upper parts was significant, fragile internodes could be excluded by testing their middle part while keeping the upper part undamaged [1].

Selection by players

Professional hichiriki players visually checked the thickness of the culm, with the ideal being 1.1 mm. (1.2 mm was too thick and 1.0 mm was too thin). They also measured the inner diameter using a specially designed taper gauge. Figure 6 shows the frequency related to the inner diameter of suitable and unsuitable reeds selected by the players. The inner diameter of suitable reeds was in the range 9.4–10.3 mm. Some culms were excluded due to their appearance, as shown in Figure 7. According to the players, stained culms are usually softer and less durable. This staining effect, probably due to fungi, should be explored by further investigations.

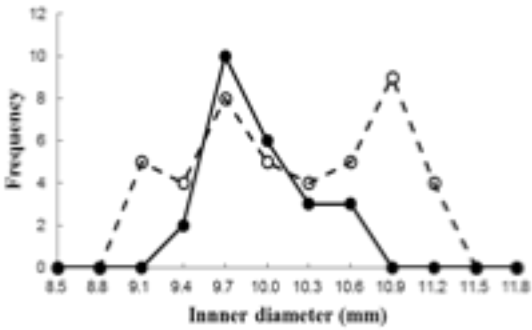

Figure 6: The frequency of inner diameter for suitable (●) and unsuitable (○) reeds.

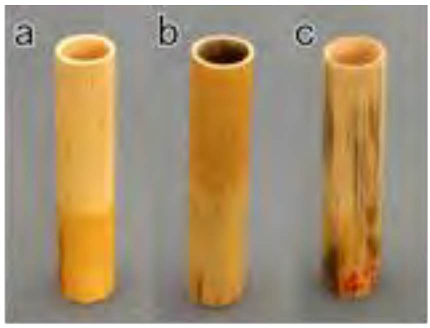

Figure 7: Appearance of a suitable reed (a) and unsuitable reeds (b, c) with black stain.

Alternative reed fields

Recent environmental changes in the conventional reed fields of Udono necessitate consideration of alternative reed fields in order to sustain the production of the hichiriki. In fact, there is no clear difference between the Udono and Mukaijima reed with respect to anatomical structure, density, and compressive strength. Therefore, Mukaijima could be an alternative area to harvest quality hichiriki reeds.

Figures 8 and 9 show the density and dimensions of reeds growing in a managed field. Although the terrestrial stems are renewed each year, the rhizome keeps growing for several years. Therefore, the density, diameter and thickness of the culm increases year on year with the growth of the rhizome. The diameter and thickness of the latest (2016) reeds were not sufficient for use for the hichiriki, however, considering the growth rate, the planted reeds are predicted to achieve sufficient dimensions within a few years. The cultivation of reeds in a managed field will allow us to produce high quality reeds that are protected from any alien invasive species.

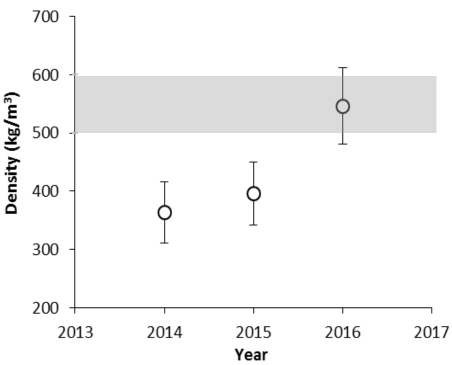

Figure 8: Density of reeds planted in a managed field.
Gray band indicates the density of "suitable" reeds.

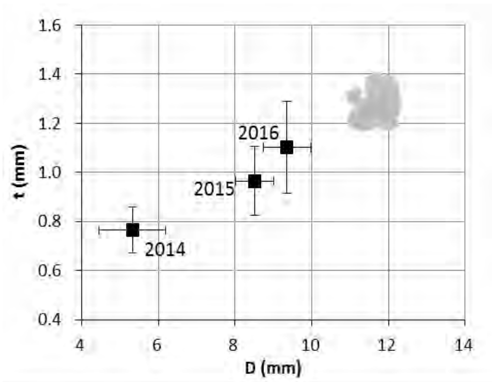

Figure 9: Thickness (t) and diameter (D) of planted reeds (upper part of internode). Gray plots indicate the dimension of "suitable" reeds.

How can we conserve this traditional culture?

As discussed above, several potential areas exist to harvest reeds for the hichiriki. However, these alternative reed beds may not be accepted by conservative musicians who believe that the hichiriki should only be made using reeds harvested from the traditional Udono area.

Perhaps we now have to reconsider which elements of the tradition should be conserved. Is the area of the reed field a vital element? If so, we have few options: we need to protect the limited reeds in Udono from invasive alien species, and musicians may have to use lower quality reeds.

On the other hand, if we identify the criteria for high quality hichiriki reeds, the area for harvesting could be widened from the traditional Udono region. Sufficient numbers of reeds could be harvested from different sites with high quality reeds being selected. Although this proposition has not yet been accepted by conservative musicians, unless the current problems in Udono of rapid urbanization and invasion of alien weeds are resolved, it may be necessary to review the proposal in the future.

Tradition or sustainability—which is more important for the conservation of this culture? This argument is also relevant to the conservation of other musical instruments made using endangered wood species. Is it sustainable to keep using traditional, endangered wood species in order to conserve traditional music? Should the use of Brazilian rosewood and African blackwood be allowed in the production of traditional woodwind instruments? With future climate change unpredictable, we need to have a clear consensus as to the conservation of tradition versus sustainability.

Acknowledgement

The authors are very grateful to Mr. Kazuo Kimura and Mr. Kenji Hiragi, professional reed harvesters, and NEXCO-West Company for their assistance in harvesting reeds. The authors are also grateful to the court musicians of the Music Department of the Imperial Household, for sharing their empirical knowledge about the selection of reeds. This work was supported by JSPS KAKENHI (Grant Numbers 16K07803).

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Vibrational Properties of Compressed Wood and Possibility of Using Compressed Wood as a Material for Repairing Cracks in Wooden Musical Instruments

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Abstract

Compressed wood shows excellent softness and ductility in the direction of compression. It may be useful for the restoration of wooden cultural objects. However, the vibrational properties of compressed wood are significantly different from those of uncompressed wood.

1. Introduction

When wooden parts are assembled, they are more or less compressed in their transverse (radial, R or tangential, T) direction. While a small deformation may have little effect on the practical performance of construction materials and furniture, but it may affect the acoustic properties of wooden musical instruments, because the stiffness of wood is drastically reduced by radial compression [1]. As the stiffness of wood is tightly connected to its mechanical loss tangent (tanδ), the tanδ value will also be influenced by the compression. Therefore, the effects of transverse compression should be considered when discussing the vibration of wooden musical instruments. Compressed wood also shows excellent softness and ductility in the direction of compression [1]. Such ductility is important for the restoration of wooden objects, because compressed wood can withstand large deformation to prevent the failure of the adjacent wooden parts that may result from shrinkage by drying.

In this paper, the softness and ductility of compressed wood are examined, along with the changes in the vibrational properties of the wood due to radial compression in the R direction.

2. Methods

Cedar wood (*Cryptomeria japonica*), cypress wood (*Chamaecyparis obtusa*), and red pine wood (*Pinus densiflora*) were cut into cubes with a side length of 30 mm. The air-dried densities of the cubes were 348-376 kg/m^3, 528-543 kg/m^3 ,and 563-569 kg/m^3, respectively. The cubes were compressed in the R direction using a press machine at 40ºC. Then, the compressed and uncompressed wooden blocks were glued into a beam with the R direction aligned with the longitudinal direction of the beam. Polyvinyl acetate emulsion glue was used to glue the blocks to the beam and were pressed at 0.3 MPa until the glue solidified. The beam was finally cut into a plate with dimensions of 60-90 mm (R) × 10 mm (T) × 3 mm (L) for a vibrational test. The sound velocity and tanδ of the plate were determined by the free-free flexural vibration method at 25ºC and 60% relative humidity (RH). Cross section of the samples was cut and observed using an optical microscope.

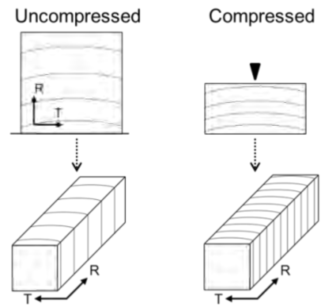

Figure 1: Procedure for samples

Cedar wood was cut into cubes with side length of 10 mm. The specimens were conditioned at 25ºC and 60% RH for more than 1 week and then compressed in the R direction by a universal testing machine at a crosshead speed of 2 mm/min. After removing the load, the specimens were compressed again to determine the remaining plastic strain. The compression rate was defined as the percentage of compressive strain experienced after removal of the load.

3. Results

Figure 2 shows the compressive stress-strain curves of the uncompressed and compressed cedar wood. The uncompressed wood shows a typical deformation of the elastoplastic cellular solid. Once it was compressed up to 6%, a 2% strain was elastically recovered by the removal of load, but a 4% strain remained. When the wood was previously compressed in the R direction by 50%, it shows a very low Young's modulus (10 MPa), and the deformation is elastically recovered after the removal of the load. This indicates that the wood becomes extraordinarily soft and elastic after transverse compression. Figure 3 shows the cross section of uncompressed and compressed cedar wood cells. In the compressed wood, the folded cell wall behaves as a flat spring to reduce the Young's modulus and to improve the elasticity.

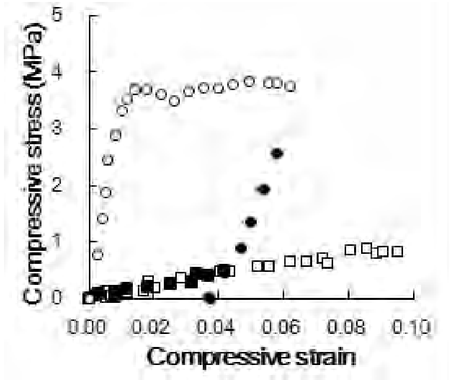

Figure 2: Compressive stress-strain diagrams of *Cryptomeria japonica*. *Circles*, uncompressed wood. *squares*, previously compressed by 50%; *open plots*, first compression of the wood; *filled plots*, second compression of the wood

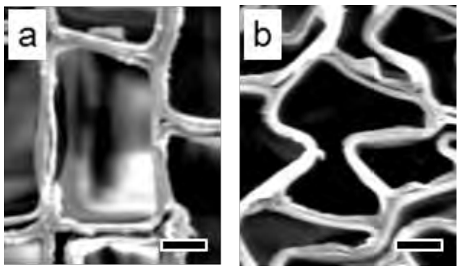

Figure 3: Cross sections of *Cryptomeria japonica* before (**a**) and after (**b**) compression. *Scale bars* 10μm

In general, unexpected cracks and failure of wooden products are induced by the shrinkage of their surface during drying. To prevent such failures, compressed wood is a promising restoration material because it is expected to follow the large shrinkage of adjacent wooden parts due to its excellent softness and ductility.

Figure 4 shows the sound velocity and the tanδ of compressed wood as a function of compression ratio. The sound velocity decreases markedly with increasing compression regardless of wood species, because of the reduction in Young's modulus and increase in density. The tanδ increases with increasing the compression ratio as well, but is affected by wood species. Even at 10% compression, the sound velocity decreases by 20% and the tanδ doubles in cedar wood. Such drastic changes in vibrational properties should be taken into account when wooden parts are compressed in assembly or the compressed wood is used for the restoration of musical instruments.

The overall densities of red pine wood and cypress wood are similar, but the tanδ of red pine wood increases remarkably upon compression, whereas that of cypress wood increases only slightly. This suggests that the tanδ of compressed wood can not be explained by the overall density of the wood. Figure 5 shows the cross sections of the compressed wood. Only earlywood cells are deformed in the radial compression. The cell walls are alternately fallen sideways in red pine wood, whereas the cell walls of cypress wood are fallen by shear deformation. It is likely that micro-failure occurs in the fiber-matrix structure of the wood cell wall and this induces additional friction to enhance the tanδ of the wood. As the folding of the cell wall is tighter in the red pine wood than in the cypress wood, the red pine wood shows a greater increase in tanδ after compression.

Figure 6 shows the density variation in the three wood species used in this study. The density of the cypress wood is relatively uniform, but in red pine wood and cedar wood, the densities of latewood and earlywood are significantly different. This species dependent density variation may be responsible for the characteristic folding of the cell wall, i.e. greater increase in tanδ, observed for red pine wood and cedar wood.

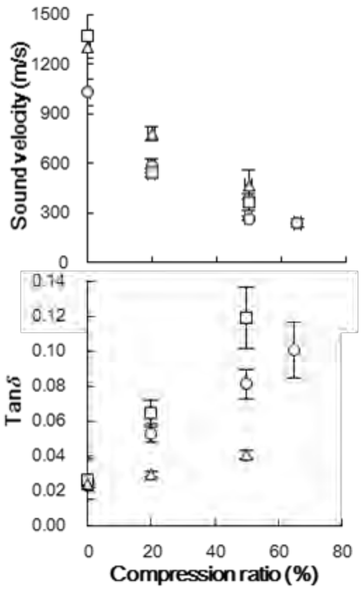

Figure 4: Sound velocity and tanδ of compressed wood as a function of compression ratio. *Circles*, *Cryptomeria japonica*; *squares*, *Pinus densiflora*; *triangles*, *Chamaecyparis obtusa*. *Bars* indicate standard deviations

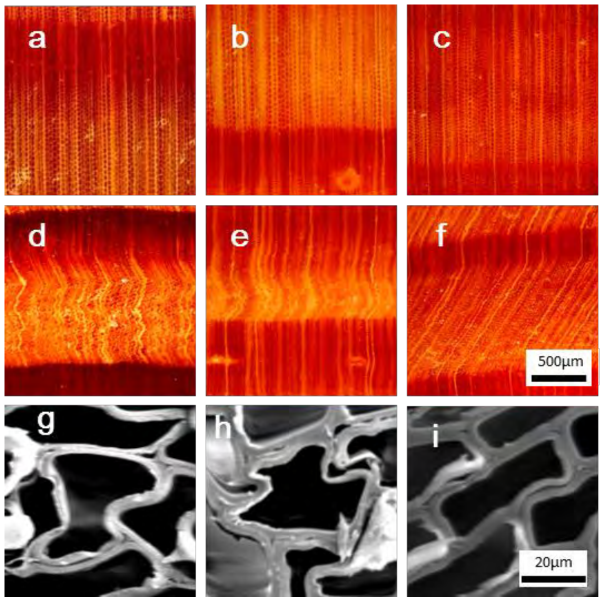

Figure 5: Cross section of three coniferous wood species before (**a**, **b**, **c**) and after (**d**, **e**, **f**, **g**, **h**, **i**) compression. (**a**, **d**, **g**) *Cryptomeria japonica*; (**b**, **e**, **h**) *Pinus densiflora*; (**c**, **f**, **i**) *Chamaecyparis obtusa*

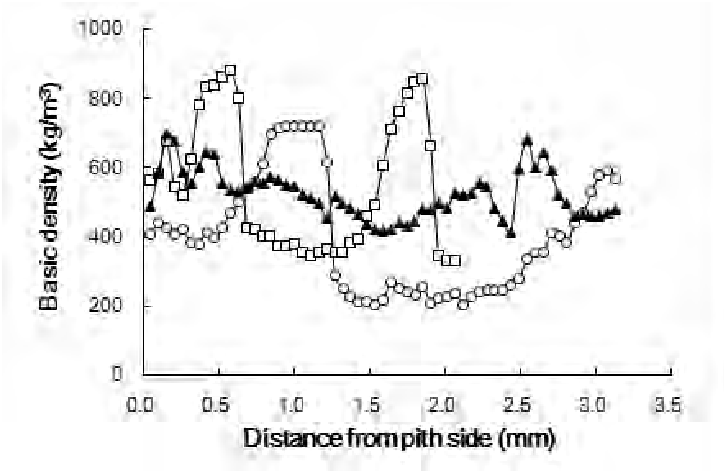

Figure 6: Density variation of three coniferous wood species along the radial direction. *Circles*, *Cryptomeria japonica*; *squares*, *Pinus densiflora*; *triangles*, *Chamaecyparis obtusa*

Acknowledgements

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CNC Milling Wood Patches in String Instruments Restoration

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Abstract

This article illustrates a typical work-flow for patch-making in string instruments restoration using CNC milling. This technique has many advantages over the traditional approach because it allows to restore complex shapes thus reducing the impact of the intervention. The process consists in four stages: manual preparation of the patch area, three-dimensional scanning of its surface, CNC milling of the new patch and its gluing to the instrument. Reported practical applications show how this procedure is less invasive and more effective than the manual.

1. Introduction

Manual patch making is an ancient technique. Restorers use it for several purposes: restoring the desired thickness maps, reinforcing cracks on areas weakened through time and rebuilding woodworm damaged areas. A very smooth surface has to be manually carved out with a simple outline (for instance oval shaped). Complex shapes such as those created by wood worms cannot be reproduced by hand.

On the other hand, 3D light scanning and CNC wood milling gives a replica of areas that cannot be reproduced manually, giving the conservators and restorers more leeway when planning their restoration work on wooden musical instruments. Due to an easier access to 3D light scanning and CNC milling technologies, more researchers and restorers can benefit from their use in daily work.

Figure 1: *Traditional patches*

Figure 2: *CNC milled Cello patch*

2. Materials and methods

Steps carried out in milling wood patches using a CNC router:

1. Surfaces preparation: areas to be replaced are manually excavated with gouges, planes and scrapers, in order to be patched
2. 3D light scanning of the surface or its replica (dental plaster or silicon)
3. CNC milling of the wood patch
4. Gluing, roughing and finishing

2.1 Preparation of the area to be patched

CNC technology has several advantages over traditional techniques; it not only adheres to the originality of the design but it is also less invasive as it reduces the impact of the first step (surfaces preparation). Once the patch is carved out, it is necessary to glue-size wood surfaces, whilst minimising the amount of water used which could cause deformations. Once dry, the surface is ready to go to the second step: three-dimensional scanning.

Figure 3 and 4 present a visual comparison on the different invasiveness of manual and CNC patching.

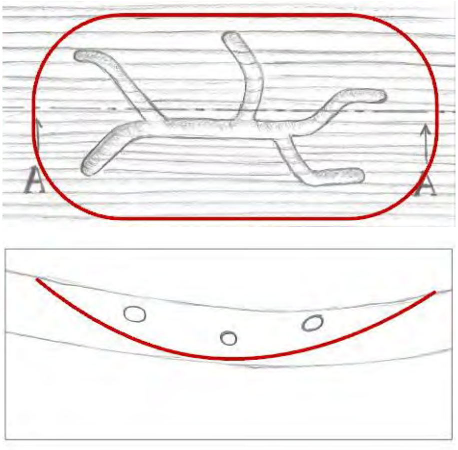

Figure 3: *Preparation for manual patch*

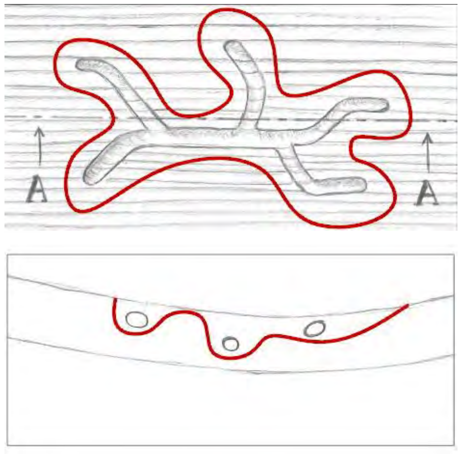

Figure 4: *Preparation for CNC-milled patch*

2.2. 3D light scanning

The second step consists in the digitalization of the patch area surfaces. The creation of the stl model is performed with a 3D light scanner either on the patch area or in its replica.

Scanning a dental plaster or silicon replica is usually preferred over scanning the original area: it is easier to move the replica to the scanning location instead of transporting valuable, delicate and rare string instruments. Moreover, plaster and silicone has greater dimensional stability compared to wood. This aspect is critical when the instrument part or its replica has to be moved to different environmental conditions: temperature and moisture content changes could affect the patch area dimensions and shapes. Finally, replica surfaces are more optically cooperative towards 3D light scanning: they are homogeneously light-coloured and non-reflective. Scanning directly the patch area wood surfaces can be problematic. Maple grain waviness, strong differences in colours between juvenile and late growth in spruce and maple can create artefacts in laser or in structured light scanning.

Figure 5: *Fringe pattern projected from a Structured Light 3D Scanner over a dental plaster replica*

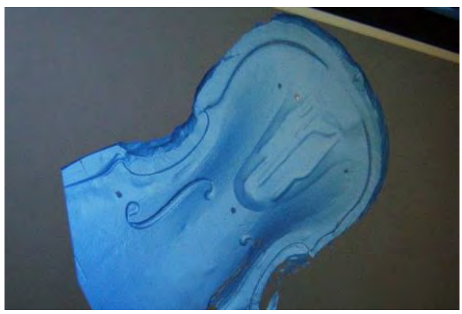

Figure 6: *Digital surfaces of the dental plaster replica, exported in Stereolitography (.stl) format*

The recent availability of high-precision and low-cost 3D light scanners and services make this technology an interesting tool for the violin maker and the restorer. Generally speaking, commercial structured light scanner are faster when compared to time-of-flight laser scanners, and offer enough accuracy for this specific application.

2.3 CNC Milling

Wood blank is chosen according to its anatomical features, in order to mimic the original material, in the same way that is performed with the traditional technique. CNC milling is usually performed with a 3-axis bridge vertical miller.
Care must be taken in order to keep the wood moisture content at a constant level. Changes in this parameter will affect shape and dimensions of the wood patch.
As an example, a 3% variation in the moisture content of red spruce results in a dimensional variation of about 1% in the tangential direction and 0.4% in radial direction [1].

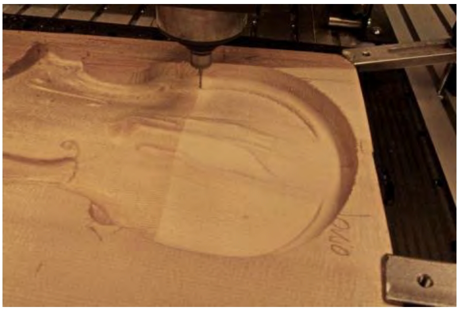

Figure 7: *CNC vertical milling of a violin top patch*

Figure 8: *Cello ribs through patch: at right the silicon replica, centre and left wood patches (courtesy Simeoni)*

Wood blank is fastened to the machine. A vacuum table can be used. A rough-pass is performed with a flat mill, for a fast material removal. Finishing is performed in several steps with ball mills of decreasing dimensions.
Wood surfaces are glue-sized before the final finishing step. A heat gun is used soon after glue-sizing, in order to speed the drying process and to avoid distortions.
This process can be repeated several times, in order to improve the surface quality and to saturate the wood fibres with glue.

2.4 Patch gluing

Gluing the patch to the original instrument requires both speed and precision in positioning the patch in its correct position. Usually CNC milled patch surfaces are quite complex and irregular, so that they fit in only one position. Additional positioning references such as studs or cleats can be applied over the instrument surfaces before making the replica. Both surfaces are already glue-sized. This shortens the time required for glue application, reducing the risk for the glue to gel. A warm ambient temperature help ensuring adequate fluidity of hide glue in this delicate phase.

3. Examples

String instrument tops and backs, together with their plaster casts, can be vacuum bagged. That means that a thin plastic film is wrapped around the plate and its mould, and vacuum is applied [2]. Plate surfaces adhere perfectly to the dental plaster mould, and the presence of plastic film allows a replica of the internal surface of the plate. Arching corrections is performed modifying the plaster cast shape (see Figure 9), moistening and pressing the plate with hot sandbags against its cast. A large patch needs to be applied to the plate, in order to fix this correction. Traditionally this patch is hand carved and fitted pressing the plate against the modified cast. Process is obstructed by the plate spring-back and the difficulty in keeping the plate homogeneously pressed to the cast.

Great improvements in therms of speed and precision can be achieved vacuum bagging the plate to the modified cast, creating a plaster replica of the patch area surface and CNC milling the wood patch. An example of internal plaster cast set-up is reported in Figure 10. Note the film wrapping both the cello back and its plaster modified counterform.

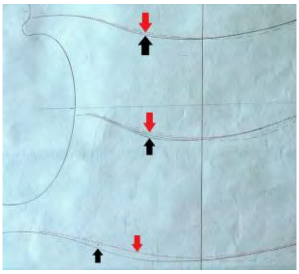

Figure 9: *Arching corrections of a cello back. In red, the final state*

Figure 10: *Preparing the dental plaster replica of the internal surface, vacuum bagging the back and its cast aft arching corrections (courtesy Simeoni F.)*

Another example of the various steps of CNC patch making is reported in Figure 11: at top the violin belly ready to be patched. At bottom left its plaster cast (made with vacuum bagging). At right its carved wood patch. Patch 3D scanning and CNC milling for this specific violin are shown in Figure 5, 6 and 7.
The restored violin top is presented in Figure 12. Here the CNC patch is used also for edge doubling of the centre and upper bout.

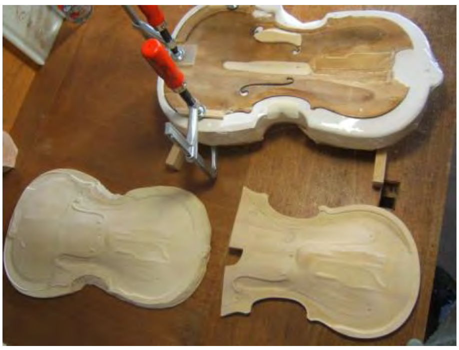

Figure 11: *three stages in CNC patch milling: bottom left the dental cast, at right the milled wood patch*

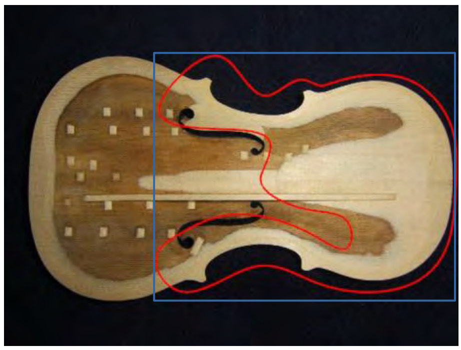

Figure 12: *The finished work. CNC patch is inside the red area.*

4. Conclusions

A variety of technologies such as 3D Solid Modellers, 3D Optical Scanners and CNC milling machines have become part of the tools available to the restorer. They made possible performing restoration tasks otherwise too complex, expensive or even impossible.
They provide more effective, quick and less invasive restoration than traditional techniques. They can be joined to the latter to expand the range of possible solutions to the restorer's daily problem.

Acknowledgments:

We would like to thank bow maker Walter Barbiero and violin maker Franco Simeoni.

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Non-Invasive Wood Identification on Historical Musical Instruments

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Abstract

In this paper, I present the results of a wood identification campaign performed non-invasively by means of portable reflected-light microscopes in the Ruckers musical instruments of the collection owned by the Musée des Instruments de Musique of Brussels (Belgium).

1. Introduction

In the field of wooden musical instruments the wood species employed are very important features because they determine the physical and mechanical properties of the wooden artefact, crucial in the prediction of his behaviour to strings tension, to stress and changes in temperature and moisture conditions and, on historical musical instruments, their knowledge is mandatory to allow a correct dendrochronological analysis, which is obviously based on the wood species. In all wooden ancient artefacts, the knowledge of the wood is indispensable for the process of historical knowledge, thus helping the attribution to a particular craftsman or artist, and to a particular period of time. In fact, every craftsman of the past had its own preferences about materials and manufacturing techniques. Last but not least, the identification of the wood gives the possibility to identify restorative interventions of the past carried out with different woods from the original ones.

The Musée des Instruments de Musique of Brussels (Belgium) has the largest collection in the world of Ruckers muselaar (Flemish virginals) and harpsichords. These instruments are an iconic heritage of extreme Flemish expertise in the field of musical instruments production. Despite their value, these instruments have not yet been exhaustively studied in order to widen the historical and organological knowledge about them. To allow it a wood identification campaign at microscopic level was necessary. Due to the great historical value and uniqueness of these musical instruments, wood identification has to be performed by strict non-invasive methods, not involving the removal of wood samples for sectioning, thus, the method that has to be applied is the reflected light microscopy on the wood surfaces.

2. Material and Method

The work was carried out *in situ*, in the museum's *atelier*. A group of 8 keyboard instruments (tab.1) representative of the Ruckers instruments collection of the Museum was studied, identifying the wood on every single visible or attainable wooden part of the musical instruments.

To allow a complete accessibility of the instrument's parts, jack rails, jacks, name boards, name battens and keyboards were previously separated from the instruments by the museum staff. This allowed the detailed study of the jacks, jack's tongues, keyboard frames, keylevers, coupler dogs, thumbnails, balance rails, racks, stop rails and, in some instruments, lower guides, wrestplanks, upper and lower bellyrails, soundboard ribs and cutoff bars.

Table 1. Analyzed musical instruments

			
"mother" muselaar n° 0275, Ioannes 1610	"child" muselaar n° 0275, Ioannes 1610	harpsichord n° 0276 Ioannes Couchet 1646	harpsichord n° 2510 'Hans' 1624
			
4 ½' muselaar n° 2511, Ioannes 1629	5' muselaar n°2927, Ioannes & Andreas 1604	4' muselaar n° 2928 Andreas 1613	6' muselaar n° 2930 Ioannes 1614

Two reflected-light portable digital microscopes with a USB interface were used to magnify the wood surfaces: the Dinolite pro AD413T, with eight white LEDs and 10x, 50x and 200x magnification; and the Dinolite premier AM4113ZT4, with a polarized light filter and magnification from 400x to 470x. Both had a resolution of 1.3 Mpixels and were connected to a laptop through USB wires to allow the vision of the magnified wood surfaces on the screen and to allow the capture of the images. The use of special filters, such as the polarized light, facilitated the observation of those surfaces treated with varnishes, making observable anatomical features which otherwise would have been masked [1][2].

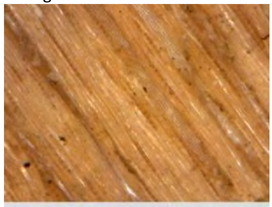
The wood identification has led to determine the botanical species or its closest taxon achievable thru the microscopic anatomic features of wood. The identification followed the anatomical features codified by the International Association of Wood Anatomists (IAWA) [3] [4].

3. Results

The identification process included viewing the structures at progressively higher magnifications. This provided an initial overview (50X-200X magnifications) of the wood tissue in order to recognize features that would be little or not recognizable at higher magnifications, i.e. growth ring boundaries, the approximate width of both the rings and of the portion of latewood, the arrangement and grouping of vessels, axial parenchyma distribution and arrangement, aggregate rays, tyloses or deposits in the lumen of the biggest vessels; furthermore, in darker woods, the prismatic crystals in the parenchyma cells showed up. Polarized light filter and higher magnification levels (400X) allowed the detection of further important features such as axial resin canals, spiral thickenings, bordered tracheid pits, structure and type of rays, type of perforation, intervessel pits. In fig. 2 some examples of anatomical features visible in single microscopic images are reported.

Figure 2: anatomical features

Quercus sp. - growth ring boundaries distinct, wood ring-porous, vessels in dendritic pattern, Ray height > 1 mm. "Mother" muselaar wrestplank.

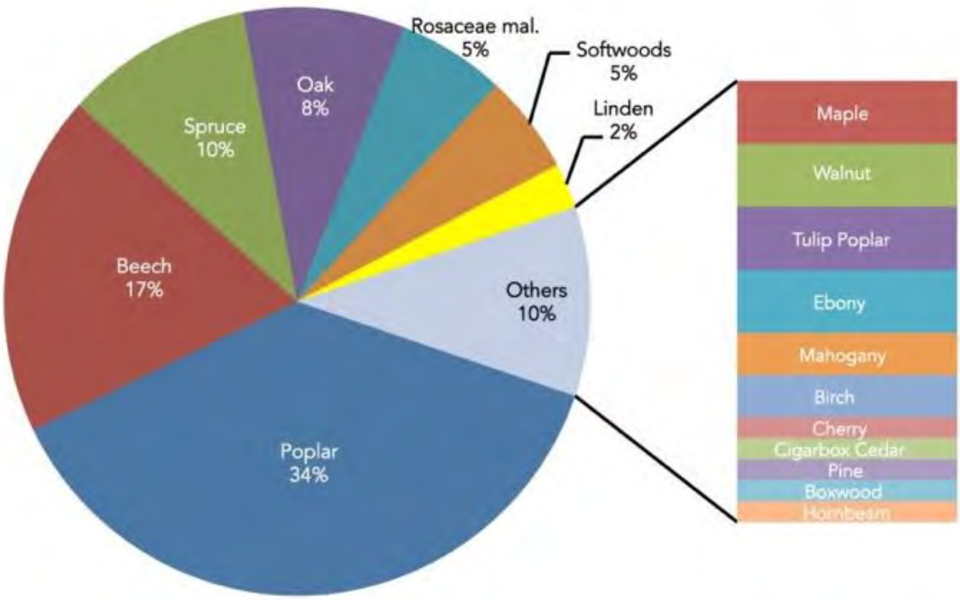


Populus sp. - Simple perforation plates, intervessel pits alternate, rays exclusively uniseriate, all ray cells procumbent. 5' muselaar keylever n°45.

Picea abies - Growth ring boundaries distinct, tracheid pitting in radial walls uniseriate, axial intercellular (resin) canals present. 6' muselaar soundboard.

The *taxa* identified during this study are 18: Birch, Boxwood, Cherry, Cigarbox Cedar, Ebony, European Beech, European Hornbeam, European Walnut, Linden, Mahogany, Maple, Norway Spruce, Oak, Pine, Poplar, Rosaceae maloideae, Softwood, Tulip Poplar; and their frequencies are shown in fig. 3 where the taxa found occasionally are grouped in a single category.

Figure 3: frequence of *taxa*



The data collected has shown that certain species recurred in specific roles. For instance, Norway Spruce was found mainly in soundboards and stop rails whereas for case sides and baseboards Poplar was the most common species although some additional species from previous restorations were found, such as Tulip Poplar and Linden. Poplar was also the largely prevailing species in keyboard frames, keylevers, balance rails and racks. Oak has been found typically in wrestplanks. Bog oak has been found in all the original sharps. Beech was frequently found in nuts, bridges, jacks, jack's tongues and wrestplanks. Jacks and jack's tongues were also frequently identified as Rosaceae maloideae.

The only cases where wood identification was not possible were parts completely covered with paint and/or paper and some inner parts of the instruments (e.g. wrestplank, lower guides, soundboard ribs and cutoff bar) inaccessible with the portable microscope due to the insufficient height of the keyboard slit to allow the entrance of the hand and the microscopic device.

4. Conclusion

- Non-invasive identifying of wood could be carried out in situ with portable digital microscopes with high magnification as well as reflected light and polarizing filters that were decisive for viewing many microscopic anatomical features necessary for the identification of the taxa.
- The wood species typically employed by the Ruckers in the production of the various parts of their musical instruments were defined. In particular, Norway Spruce was typically used for the soundboards, Poplar for case sides, baseboards, keylevers and keyboard frames and Oak for wrestplanks and, as Bog Oak, for the sharps.

Acknowledgement

The author gratefully acknowledges Pascale Vandervellen, curator of the keyboard instruments collection of the MIM, for the co-operation, hospitality and kindness, and gratefully acknowledge Giuseppina Di Giulio for the co-operation during the mission in Bruxelles, Simon Egan for the pictures of the instruments and all the MIM team for the preparation of every instrument for this study.

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3D-Reflected-Light Microscopy as a Tool for Wood Identification in Historical Instruments

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Abstract

This paper describes the technical approach and practical application of a new non-destructive microscopic identification method which is ideally suited for the wood identification of cultural (heritage) objects, e.g. music instruments. 3D-reflected-light microscopy enables the scientist to study individual components in historical instruments without destructive preparation of microscopic slides from detached wood blocks. This special technique offers a good option to determine which timbers are traditionally used for certain components in historical plucked and stringed instruments.

1. Introduction

In the history of musical-instrument manufacture, traditional instrument builders often used “bequeathed” wood species for the individual components of the instrument which are characterized by a specific texture and defined wood properties to produce a high sound quality. Based on this experience passed down for generations, there is a considerable interest of contemporary instrument builders to know which wood species the “old” masters like Torres or Stradivarius have used. The standard non-destructive method for wood identification is the macroscopic assessment of structural features. Regarding the results of a macroscopic identification, they should be tentatively evaluated (Figure 1A). It is important to emphasize that the possibilities of macroscopic wood identification are much more limited than those of a microscopic study. Firstly, the number of characters available for observation is considerably smaller. Secondly, in macroscopic identification one has to rely quite often on characters subject to a high variability due to different growth conditions of the tree (viz. formation of growth rings) or exposure to oxygen and UV radiation (viz. wood colour). This may lead to subjective judgement on behalf of the user, and errors that might result in wrong decisions. However, for identification of wood species in historical instruments, a microscopic examination is mostly impossible as such instruments are very valuable and no samples can be prepared for microscopy. In practice, the use of macroscopic characters will probably end with a choice of several likely matches whose safe separation must be left to microscopic analysis (**Figure 1B**). For “official” or “judicable” wood identification, microscopic analyses are routinely conducted. Using light microscopic techniques, up to 160 anatomical characters are available which are internationally standardized and published in the IAWA lists of “Microscopic Features for Hardwood and Softwood Identification” [1, 2]. The defined microscopic features describe the individual characters of cell and tissue types, i.e., vessels, fibres, and ray as well as axial parenchyma. Additional information is provided on mineral inclusions as part of a so called “anatomical fingerprint”. Based on these requirements, the use of digital 3D reflected light microscopy allows the microscopic observation of flat and uneven surfaces of solid wooden components down to the smallest marquetry work without damaging individual components.

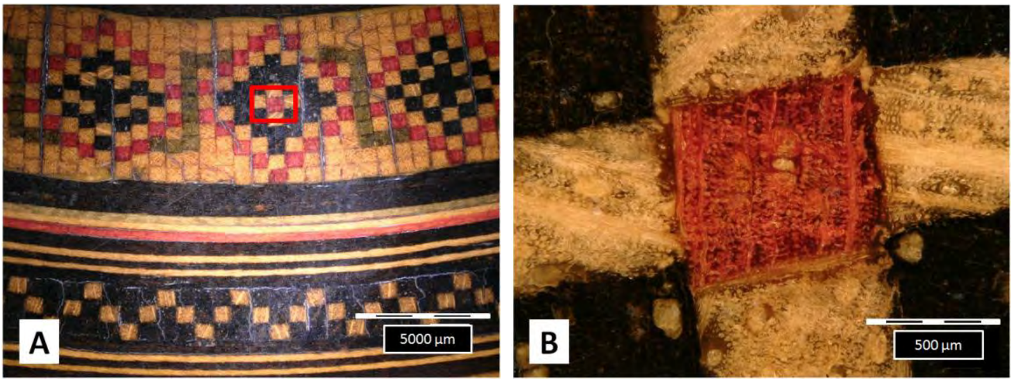

Figure 1: (A) Soundhole-Inlays on macroscopic level (red box in Figure 1 A shows Figure 1 B) of a historical guitar from Francisco Simplicio built in 1924. (right) Soundhole-Inlays on microscopic level.

2. Methods

As part of the STSM project "Non-destructive wood identification of historical Instruments based on 3D-reflected-light microscopy", the scientists investigated eleven high value instruments of the Museu de la Música de Barcelona on a standard macroscopic level using non-destructive tools (different kinds of hand lenses etc.) as well as digitized image microscope analysis systems (Cell^F®, Olympus and KEYENCE® VHX-5000/ **Figure 2 A+B**) on the microscopic level. For microscopic analysis, close-up digital images were taken as well as relevant histometrical data of the investigated instrument components. Images of anatomical structures (**Figure 4 and 5 A, B, C**) and data (measurements etc.) were compared with information available from computer-assisted wood identification systems (*Commercial timbers, macroHOLZdata* and CITESwoodID) [3, 4, 5]. The microscopic features of the investigated components of the different instruments were compared with vouchered reference specimens of the scientific wood collection (Federal Research Institute for Rural Areas, Forestry and Fisheries, Hamburg, Germany).

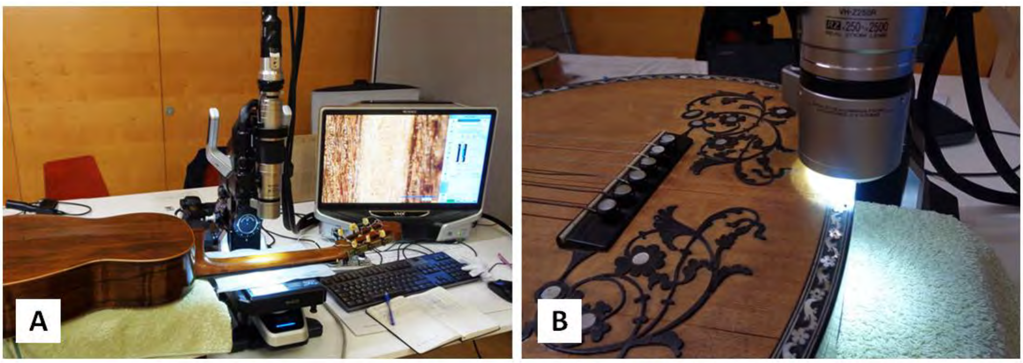

Figure 2: Microscopic investigation of a historical guitar with digitized image analysis system.

3. Results

The described methods for the macroscopic and microscopic wood identification were regularly applied for each of the eleven selected instruments (year of construction between approx. 1650 and 1950).

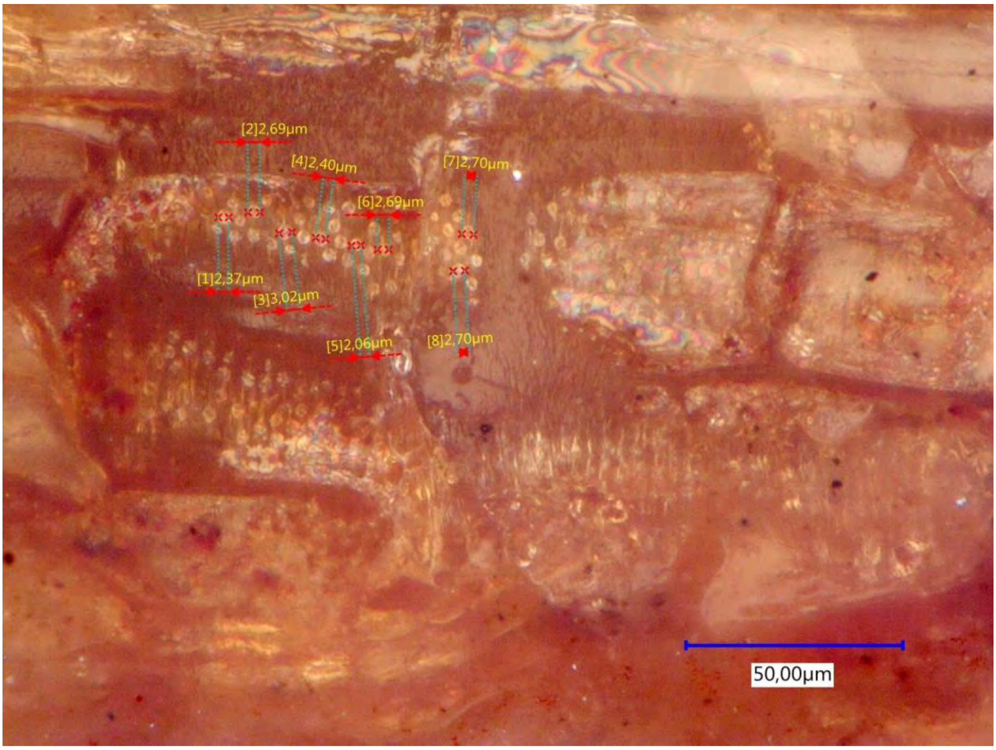

Figure 4: Measurement of the average pit size (vertical) from a vessel element in wood of the neck (historic guitar, Iganzio Fleta, 1953 /MDMB 1408).

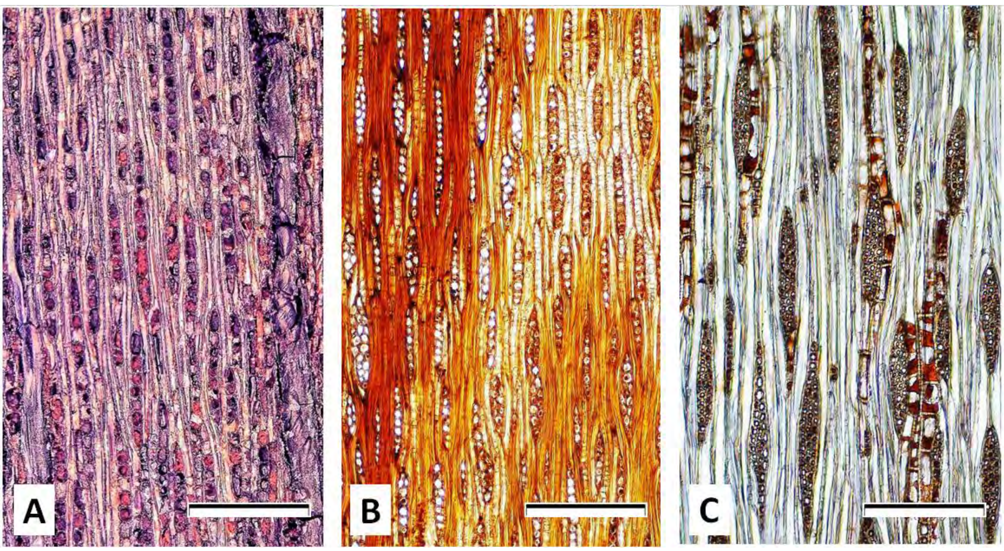

Figure 5: The wood anatomy of *Diospyros* sp. (A), *Dalbergia melanoxylon* (B) and *Juglans regia* (C) – A-C: Tangential section. Scale bars: A-C = 200 µm.

Systematic examination of the main components such as head, neck, back and sides as well as the resonance board were carried out. Furthermore, small wooden components of the mechanics, pegs, bridge, saddle, and decorative elements such as marquetry and inlays, e.g., in the case of a sound hole rosetta, were also analysed. The results of the studies reveal that the 3D-reflected-light microscopy mostly achieves the resolution of established transmitted light microscopy for non-destructive wood identification. The technique allows the differentiation of closely related species such as those belonging to the genera *Swietenia* and *Cedrela* (MELIACEAE). Figure 4 shows a surface of the neck of a guitar (Ignazio Fleta, 1953) with high microscopic magnification enabling the measurement of the average pit size. The results revealed minute pits of about 2 µm which are typical for species of the genus *Swietenia*. This excludes species of the genus *Cedrela* with a very similar colour and texture, whereas pits are distinctly larger with values of approx. 5 - 7 µm. However, in some cases the structural analysis of important sections is not possible due to constructive restrictions. For example, the important transverse sections of framed fingerboards or marquetries are inaccessible. In these cases, the analysis is restricted to the anatomical features on the tangential and radial faces. Figure **5A** shows the tangential section of a fingerboard from a classical guitar of the 19th century. The image was taken with the 3D-reflected-light microscope showing the anatomical structure of species of the botanical genus *Diospyros* spp. = Black Ebony. Such structure can be clearly distinguished from those depicted in Figs. **5B** and **5C** taken by "conventional" light microscopy and showing the tangential sections of the "lookalike" timbers such as *Dalbergia melanoxylon* (African blackwood or grenadill) and *Juglans regia* (European walnut).

4. Conclusion

The present study shows that the technical approach of the 3D-reflected-light microscopy is ideally suited for the non-destructive wood identification of cultural (heritage) objects, e.g. musical instruments. Within the STSM project 120 individual components of eleven historical instruments were analysed and identified.

Acknowledgement

The authors gratefully acknowledge the technical and scientific team of the Museu de la Música de Barcelona who have prepared every instrument for this study. Thanks go especially to Marisa Ruiz Magaldi, Esther Fernandez Cabrera, Sara Guasteví Olives, Manel Barcons Carbonell and Jaume Ayats Abeyà who have made these investigations possible.

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Restoration of a Fortepiano by Nannette Streicher, Vienna 1813

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Abstract

The main steps of the quadrennial restoration process will be presented, as the reconstruction of the pedal rail, the restoration of the soundboard, as well as the regeneration of the surface. Reflections on the scaling and a material-preserving, invisible method to restore a cracked wrestplank will be discussed as well.

1. Introduction

On the occasion of the 200th anniversary of its production year in 2013, the restoration of the fortepiano op. 961 by the famous and first female piano maker Nannette Streicher belonging to the Collection of Historic Musicial Instruments (*Sammlung alter Musikinstrumente, abbreviated SAM*) of the Kunsthistorisches Museum Vienna was clearly a project of great historical interest and emphasis. At this point in time, the instrument was in a badly damaged, partially altered and unplayable condition. Initially, the goal of the conservational and restorational measures were only partially clear, so that for purposes of documentation, a technical 1:1 hand drawing of the entire instrument had to be made. The intensive examination which necessarily resulted from this drawing, enabled to develop step by step a restoration concept; however the question of whether or not the instrument could be restored to playing condition, remained initially open, due to the fact that 25% of the remaining strings were historically informative, but badly corroded. Following a comprehensive analysis of the stringing plan and in comparison with other surviving instruments from the same workshop, the historical stringing material was ultimately determined to be not original, largely due to its overly thick diameter and therefore excessive and possibly damaging tension. Ultimately the team of the SAM decided in favor of a complete restoration with the goal of making the instrument playable. Since the early 1980s, only those keyboard instruments of the SAM were restored which had been worked over and whose general condition allowed them to be restored to playing condition. Those instruments to a large extent in an original condition, were without exception „conserved“. Thus, playability has not been a explicit goal of all restorations and each case has had to be decided on its own merits.

The principal points which spoke in favor of the restoration to playability of the Nannette Streicher fortepiano were the intact frame and structure of the instrument, the absence of original stringing material, as well as reasons of an institutionally internal nature: Since one emphasis in the history of Viennese pianomaking at the SAM is of a strongly cultural nature and the collection‘s main exhibit has, up to now, had no instrument from this prominent workshop, it seemed the perfect opportunity to „fill a gap“ which has long existed in the SAM.

As will be seen in the course of the presentation, it seemed that the existing but „overgrown“ condition of the instrument with its many alterations and changes as well as the quality and manner of their realisation and morphology were not really worth preserving. For these reasons it was decided, to return the instrument to a condition congruent with and suitable for museal presentation. Last but not least, we can regard the restoration to playability and the sound experience which results as a contribution to the maintenance of our immaterial cultural heritage.

2. Reconstruction of the pedal rail

The first alteration which was immediately apparent was the rebuilding of the original pedal system, during which in the course of the 2nd half of the 19th century the original lyre was screwed and doweled on to a new construction. The original wooden pedals were replaced by brass pedals and with a new bracket they were screwed to the bottom of the instrument, where the traces of the original lyre bracket could be seen.

The piano in its original condition no doubt had a curved pedal rail. As a comparison, there are two very similar instruments from the Musik & Teatermuseet Stockholm (1814) and from the Technisches Museum Wien (1819). Two facts are visible on these instruments: 1) Streicher produced several differing models with differing options, compass and price. 2) The 6 octave fortepiano op 961 is obviously a tried and true standard model which even 6 years later was still being ordered with almost no changes.

The reconstruction of all missing parts was done according to the Stockholm model, the legs and all decorative brass elements were based on the Streicher fortepiano in the Technisches Museum Wien and reproduced with the assistance of a metal restoration expert.

3. Restoration of the soundboard

The soundboard showed a number of large cracks, loose ribbing and deformities as well as a typical shear fracture along the spine side, caused by excessive tension and which caused, in turn, the separation of the bass hitchpin rail, which was – due to the too thick restringing already mentioned - subject to a tension of around 6000 Newton (equivalent of about 600 kg).

In order to achieve better access, it was decided to remove the soundboard from the instrument, which in view of the thin glue layer and with the help of Ethanol and heat, was completed in about an hour. In order to turn the soundboard upside down, a chipboard panel with cutouts for the bridge was made. The ribs – already partially loose – were 2/3 separated from the soundboard in order to allow it to relax. With cloth strips under the outer corners of the soundboard and with the application of small pre-warmed sacks of sand on warped areas it was possible to return the soundboard to its original flat condition. In addition, all open cracks could be closed and the quite considerable large crack filled with a strip of new soundboard wood. After reforming and glueing of all ribs, all joints and repaired cracks were secured on the underside of the soundboard with pre-dried parchment slices, and the soundboard pre-dried before it was glued back into the instrument.

4. Restoration of the wrest plank

In order to verify if the wrest plank could be dammaged, the instrument was X-rayed for any possible cracks. After the X-ray examination, it became clear, unfortunately, that there were in fact cracks in the wrest plank in several places. Most heavily damaged – as might be expected - was the bass end of the wrest plank, where the greatest tension lies. Based on a research thesis by Markus Brosig, which 7 years ago had also served as a reference point during the restoration of a fortepiano by Johann Schantz and whose method described therein was successfully employed, it was decided in this case as well to fill all cracks with epoxy resin (Araldite AY 103/HY 991). Other common treatments against the museum practice like milling out the damaged parts of the wrest plank or changing the whole element were rejected from the outset. Before the application, dowels were placed in the holes for the tuning pins to prevent filling them with the epoxy resin. Altogether only 5 ml Araldite was introduced to the wrest plank. Previous success suggested that the area around the tuning pins be reinforced with a fiberglass cloth. After a test run with a dummy, the fiberglass was glued on with bone glue, assuring that the direction of the glass fibers were placed at a 45-degree angle to the cracks in order to maximize the stability of the repair. After swelling the covering veneer parts, these were able to be glued on exactly on their original positions, before drilling out the dowels.

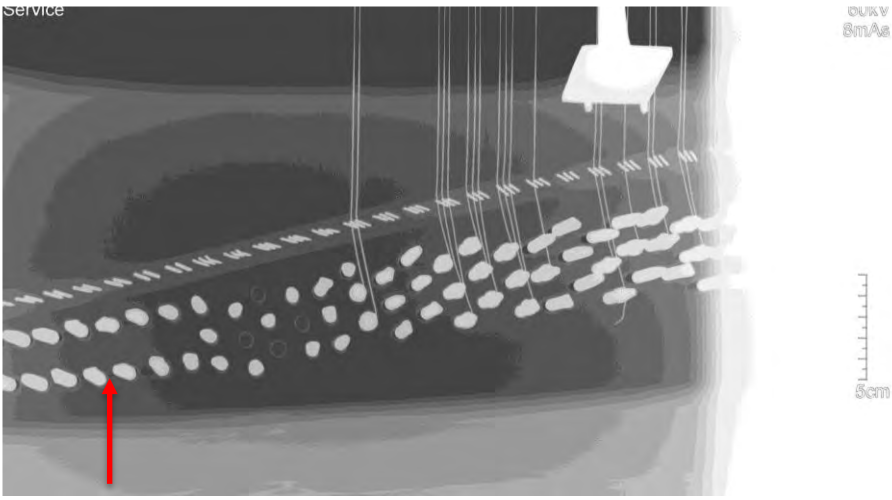

Figure 1: X-ray image of the cracked wrest plank

5. Scaling and stringing

Precisely in view of the rapid developments in piano-making in this period, it could not be initially ruled out that among the rather unhomonogenous stringing found on the instrument, the traces of the original stringing might also be found. The stringing as it was found was then completed, by way of interpolating missing strings etc and the resulting tension calculated. With brass strings (1.25 mm) in the bass and steel /iron strings (0.49 mm) in the treble (this corresponds roughly to similar instruments around 1830) a total tension of around 34 000 N (equivalent to 3 400 kg) was calculated.

In comparison with other somewhat earlier Streicher instruments with original strings and string numbers, and with an almost identical instrument from 1819 with original string numbers intact, it was apparent that the later stringing compared with an assumed earlier stringing (22 600 N, equivalent to 2 260 kg) was 1.2 tons higher, an explanation for the damages to the instrument.

The tension of the final stringing at 435 Hz, particularly in tenor and bass registers (with 0.90 mm brass in the bass and 0.36 mm iron in the treble is 7 % less than the original tension. The trick to obtaining the maximum of sound potential from the instrument is to choose thinner strings in combination with an adequate pitch level to achieve maximum allowable string tension.

6. Surface

The veneer of the spine was heavily damaged and had a number of deep scratches, dents and damages to the finish. Differences in veneer, their color and the lacquer as well as the different wood texture of the inlayed banding, suggested that the veneer in the last 1/3 of the spine had at some point in the past been replaced. Examinations with UV light confirmed the assumption. Since differences in color/tone were considered to be disturbing (incongruent with the general aesthetic of the instrument) the decision was made to match the color of the restored surfaces to the original. Following the cleaning of the entire surface of the instrument, a mixture of Methoxy-2-Propanol and Tungoil was prepared and with Orasol®-

Pigment matched to the original varnish. Surface areas that were not original, were finely dyed with this mixture. At a later point in time, the outer side of the lid had been painted over in a very rough and unprofessional manner with a dark brown, soot-colored varnish. The finish was so aesthetically unpleasing, that there was never any question of leaving it in this condition. Since nearly all the original varnish at the outer side of the lid had been sanded off previously, it was decided to remove the black layer with solvent made from Ethanol and Aceton. In order to match the stripped veneer surface to the general color and appearance of the rest of the instrument, a base coat of colored, modified linseed oil was applied and then finished with a polish (contemporary recipe with shellac, sandarac, mastic, and ventian turpentine).

7. Conclusion

The irreversible nature of the glueing procedure utilized on the wrest plank was considered a small price to pay for the complete preservation of the original substance. Keeping in mind the previous condition of the instrument with its extensive damage and its earlier crude repairwork, the consolidation of damages, regained playability and restoration of a congruent and consistent overall appearance (in spite of massive and in some instances irreversible restorative measures) may be considered to be clear advantages.

The sound of the instrument is generally warm and full, exhibits however, clearly-defined registers.

Figure 2: the fortepiano op. 961 by Nannette Streicher after the restoration

Acknowledgement

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In closing, it should be mentioned here, that all the complex and at times contradictory aspects of such a project were discussed by the entire team of the SAM and all decisions reached congenially and unanimously. Particularly Dr. Alfons Huber, Head of Restoration at the SAM, Dr. Rudolf Hopfner, director of the collection, and Dr. Beatrix Darmstädter, curator of the SAM, are gratefully acknowledged here.

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Restoration of the Ioannes Ruckers' Mother-and-Child Virginal, Dated 1610 (Musical Instruments Museum, Brussels)

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Abstract

The idea of this paper is to explain the options for a presentation of a virginal. We will discuss the delicate problem of cleaning the soundboards.

Introduction

The instrument is a double virginal « Mother and Child » made in 1610 by Ioannes Ruckers. The instrument has been restored after a comparative study of the eighteen Ruckers harpsichords and virginals of the MIM collection, initiated and conducted by Pascale Vandervellen, keyboard instrument curator. This project is sponsored by the Baillet-Latour foundation and coordinated by the King Baudouin Foundation.

Figure 1: Mother-and-child virginal before treatment

1. Historical Background

The mother and child associated a six-foot virginal with a smaller three-foot instrument tuned an octave higher. The smaller virginal was placed inside the case of the larger instrument, on the left-hand side. The two instruments could be played separately (the child could be completely removed from its compartment), or simply slightly pulled out and played side by side. The child, which baseboard is cut out under the key-ends, could be placed on top of the mother so that its keys were actioned by the jacks of the mother[1].

Ioannes Ruckers belongs to the second generation of a famous harpsichord maker's family in Antwerp, active between 1580 and 1680. Today, about a hundred Ruckers instruments are preserved worldwide, more than a quarter of them in Belgium.

Both instruments have a rose and have the date 1610 painted on the soundboard. The serial numbers[2] inside of each instrument enable us to confirm that they belong together. It is exceptional that the instruments stayed together.

Both instruments have known structural modifications and changes of the decoration since the 17th century. They underwent a *ravalement*: an extension of the compass of the keyboard in order to suit the latest musical needs. The mother underwent the most profound modifications, like the shutdown of the front panel in which the child was stored. Many elements have been added, surely to keep the instrument up to date like the mouldings on the bottom of the case and new feet, while other elements have disappeared like the lid, the fallboard and the jackrail.

2. Study of the decoration's case

In the 17th century the decoration of the Ruckers instruments gets standardized to a model type that will vary little until the decline of the Ruckers production. The decoration of the Ruckers instruments was finished in a minimum of time but seems nevertheless elaborated and expensive.

The outsides[3] of the virginals were usually decorated to imitate the appearance of marble. The virginals were probably all painted a dull green spotted with off-white to imitate the effect of green porphyry marble. The insides of the case and keywell were covered with black and white printed paper in various standard designs. The wood-block patterns used by the Ruckers family and many other builders from Antwerp, were designs taken from pattern books printed long before the period in which the family was active. On standard instruments, lids were decorated with larger printed papers that imitate figured ash. This was enhanced with black hand-inked Latin mottoes and sporadically painted vermilion arabesques. The soundboard was decorated with flowers, birds, fruit, insects and shellfish. Close to the bridges and the edges is a scalloped border interrupted with elaborate arabesques, in blue paint. The rose, mark or sign of the builder, was the focus of the soundboard decoration. It is frequently emphasized with a surrounding red and white painted ring of geometric motifs. Around this, there is a stylized wreath of flowers or leaves. The ogee-form case-top mouldings, cut directly into the case walls, were left in bare pale poplar. They seem to be gilded, but are simply glossily varnished. The surrounding non-reflective paint and paper reinforce this effect.

The two concerned instruments currently do not occur in their original state. As mentioned before, change of decoration was usual. In order to choose the best presentation for our two instruments we have examined the condition of their decoration. Relying on the results of the chemical analysis[4] and the data found during our investigation we found five layers including the original one on the mother's case and two layers including the original one on the child's case.

In 1610 when the mother and child left the workshop of Ioannes, their decoration corresponded faithfully to the standards of Ruckers, which are mentioned above. The outside of the mother's case was decorated with a green porphyry imitation while the inner parts were covered with printed papers. The case of the child was also covered with printed paper because it was considered as an inner part of the mother. The mouldings of the child are left in bare wood, varnished and highlighted in black on the flat parts. The mother doesn't have its original mouldings nor its porphyry decoration on the sides of the case. The first layer on the original decoration of the mother is a dark green, rather close to the colour of the porphyry. We did not notice any modifications of the inner decoration. The second layer is a medium grey on the outside and blue on the inside embellished with a gilded band. This is the actual decoration of the child. Thanks to the identification of Prussian blue[5] we can date this intervention in the 18th century. Only the mother has two more *faux-bois*, mahogany style layers. Their colour is very similar, only the last layer has an undercoating containing barium sulfate[6]. This enables us to date the latest intervention in the 19th century. The child stays unaltered when the mother receives its *faux-bois* decoration.

3. Restoration with intention of a new presentation

The non-corresponding history of the overpaintings of the two instruments has led us to consider different possibilities of presentation. The first option was to present the instruments with their original decoration. We know that the modifications on the mother have led to the loss of many parts of its original decoration. On the other hand, the child kept its original decoration under its actual decoration. Considering the extent of actions to un-restore and reconstruct the mother to its original state is not possible and does not fit with the actual ethics of restoration. The second possibility for a presentation was to go back to the corresponding decoration of the child. For similar reasons as we had with the first option this choice was discarded.

Therefore we have chosen to consider both instruments separately. Because the child still has its original decoration, from case to soundboard, we decided to take away the overpainting. We esteem that presenting an instrument of Ioannes Ruckers with its authentic decoration is an exceptional opportunity. The mother will be preserved with the latest decoration of *faux-bois* because it suffered too much from structural modifications so a return to earlier decorations is out of the question. This choice permits the preservation of different decorations and in this way we are able to respect the material integrity as well as the aesthetical integrity of the object.

4. Focus on the soundboard's cleaning

Figure 2: Soundboard of the mother during cleaning

Where the choice of presenting the mother and child has raised controversial questions, seen from the technical point of view, it is the cleaning of the soundboards, which was tricky. The binding agent of the decoration on the soundboard was not analysed[7]. Regarding the aesthetical aspect, the water sensitivity of the paintings and literary sources[8], we can assume that the painted patterns are gum Arabic based. Moreover, these patterns are more water sensitive than really water-soluble[9], so the use of a gum Arabic and oil emulsion is very probable.

To answer the question how to execute a cleaning of dirt that needs a supply of water on a wooden surface which is punctually covered with water sensitive patterns, we referred to recent studies concerning the cleaning of acrylic paintings who also present a water sensitivity. The last 20 years we have seen, thanks to research of R. Wolbers[10], Ch. Stavroudis[11], P. Cremonesi[12] (…), the emergence of cleaning methods with emulsions, agar gel, silicone gel and through the research of Baglioni & co[13], the use of nanogels. These techniques allow limiting a supply of water when cleaning a surface. The water is, so to speak, held in a system that releases it in very small doses while cleaning.

Following a series of tests, Nanorestore Gel® has given interesting results. Nanorestore Gel® Max Dry[14], is a transparent gel made of polyhydroxyethylmethacrylate - p(HEMA) – and of polyvinylpyrrolidone - PVP - in equal parts and 50% of water held captive in its nanopores. This gel, which cohesion is based on covalent bonds presents no danger of residues, has been chosen for its high holding capacity. The swollen clogging is collected dry with a cotton-tipped stick and the cleaning continues with thin emulsion based on Pemulen® TR2[15]. It concerns a modified polyacrylic acid with a high emulsifying capacity. Working with a base like Ethomeen® C12, an aprotic solvent based gel can be made. In this case, we use Shellsol® D40 and a small amount of water, 10%, is added. This gel[16], so obtained, is applied on the surface of the soundboard with a cotton-tipped stick so that a temporary contact with small drops of water contained in the gelled matrix is permitted. The gel is picked up before the surface is rinsed with heptane, a volatile aprotic solvent. This method gives excellent results and is sometimes sufficient in the less dirty zones.

Figure 3: Soundboard of the child during cleaning

5. Conclusion

During the comparative study of the eighteen Ruckers harpsichords and virginals of the MIM collection we have examined the mother-and-child virginal made by Ioannes Ruckers in 1610. Within the framework of a new presentation of these two instruments we took the unique opportunity to bring back the original decoration of the child, which was hidden, under a later decoration. Concerning the mother, we decided to present it with its latest decoration dating from the 19th century so to respect its material and aesthetic integrity. Thanks to very recent techniques, the cleaning of the soundboards allows us to admire again the subtlety of the painted patterns and to read it better.

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Restoring the *Piano-Viole*: an Adventure in Sound

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Abstract

This paper will summarise the rationale, progress and prospects of our ongoing restoration project of the *Piano-Viole* at the Musical Instruments Museum (MIM) in Brussels, which will be supplemented with photos, videos, sound clips and a short live performance in a 20-minute presentation at the COST Action FP1302 4th Annual Conference on 'Preservation of Wooden Musical Instruments. Ethics, Practice and Assessment' at the MIM in Brussels, 5-7 October 2017.

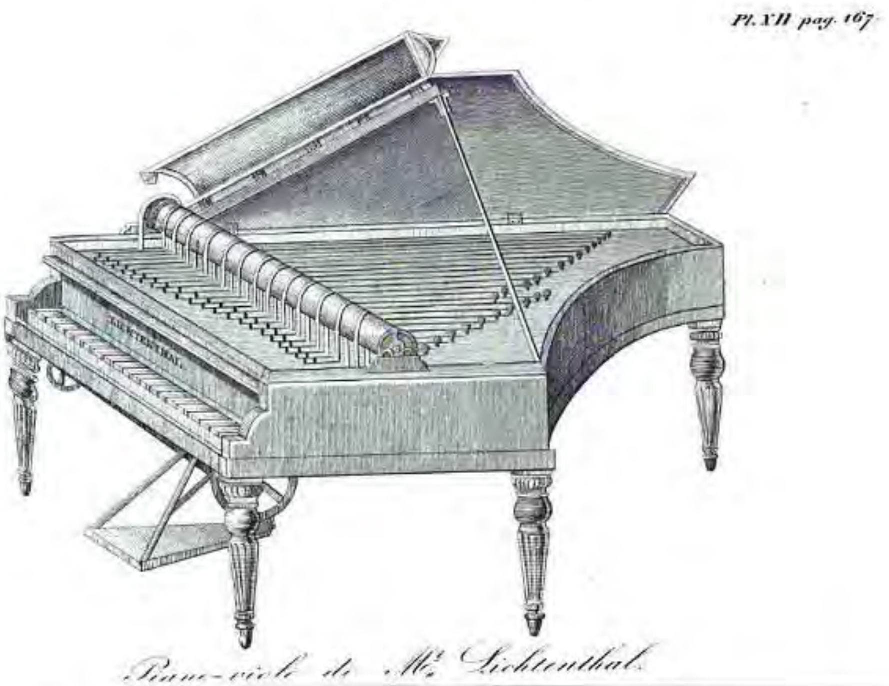


Figure 1: *Piano-Viole de M. Lichtenthal, La Belgique Industrielle (1835)*

1. Introduction

In 2006, an exciting discovery was made in the attic of the Belgian royal palace: a unique mechanically bowed keyboard instrument, the *Piano-Viole* of c.1830, invented by the renowned Brussels piano firm H. Lichtenthal.

Herman Lichtenthal (b. Silesia? Bielitz [Bielsko]?, 1795 ; † St-Petersburg, 15 October 1853) was one of several talented and famous piano makers in Belgium in the first half of the nineteenth century, despite only a short period of activity in the capital from 1829 to 1840. The discovery of the *Piano-Viole* was of particular interest because King Leopold I had acquired the instrument after the 1835 Exposition bestowed it a *Medaille d'or*, and Lichtenthal received the honour of a royal warrant (Vandervellen: 179). Known only in the literature until its discovery, it is one of over 200 bowed keyboard instruments invented in the last 400 years (Lloyd: 152). With a six-octave range, each string (one per note) is bowed individually by a vertically turning leather belt-bow pedal-operated (and flywheel-assisted) cylinder pulley mechanism. Its unique belt-bow mechanism, of which it is so far the only extant example in this particular format, can be traced back to one of three recorded Leonardo da Vinci drawings of bowed keyboard designs for the *Viola Organista* circa 1490: manual bow, wheel bow, belt bow (Lloyd: 165).

Since early 2014, the *Piano-Viole* has been on permanent loan at the MIM with the objective of restoration for public display, with respect for the techniques and materials from that period in the reconstruction and replication of missing parts. Beyond conservation, however, the brief for our project is also to make the instrument playable insofar as this proves possible.

Conservation guidelines for musical instrument collections set by ICOM suggest that restoring an instrument to playable condition may lie in tension with its cultural heritage. Nevertheless, the *Piano-Viole* has a unique place both in a tradition of the pursuit of unusual non-standard sounds of acoustic bowed keyboard instruments, which is still relevant today, and in a period of great experimentation in piano construction and design. Our aim of reviving the *Piano-Viole*'s musical as well as mechanical function will help to enrich our understanding of a particular sonic moment in history.

2. Methods

On discovery, the *Piano-Viole* was missing its strings, pegs, pedal and flywheel, driver and cylinder pulleys, and leather belts, leaving only some of the action mechanism and keyboard, ravaged by woodworm. The inner and outer threads of all four legs were broken and destroyed by woodworm and the casework was seriously damaged and split. It spent two months in instrument quarantine in the basement of the MIM upon arrival, where it was deprived of oxygen and then cleaned. Apart from two imprecise drawings, a basic description from an 1832 patent and varying reviews from the time, only limited information about the instrument was available. As a process of reinvention, research and exploration of how the instrument might have worked and sounded, our project therefore involves dozens of experiments regarding sound quality, consistency, dynamic and tonal potential, focusing on mechanism prototypes and interaction of different materials such as types of leather, strings, their advantages and disadvantages.

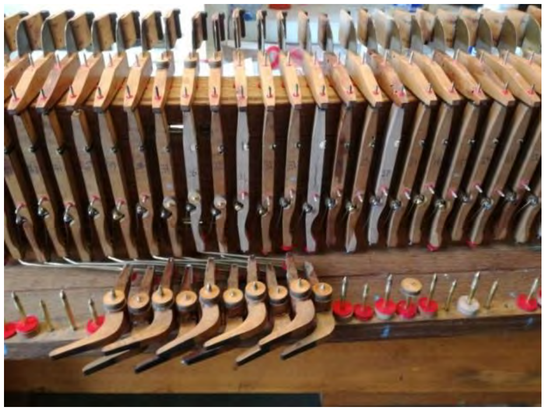
The starting point is what we know from historical sources about the materials used, and the operating principles. What remains of the instrument also provides certain clues about the function of different parts and their mechanical operation through where they have worn down through surface contact, and so on.

For an informed view of the mechanical possibilities of the time, we studied other late eighteenth-century keyboard instruments with belt-bow mechanisms (in the Cité de la Musique, Paris), early nineteenth-century flywheels and cranks (in the Musée des Arts et Métiers, Paris), as well as the pulley and flywheel-operated mechanisms seen in machines in textile factories preserved at the Museum of Industry, Work and Textiles (MIAT) in Ghent. We constructed models for the four main driver pulleys in cardboard, wood (Unalit hardboard), and aluminium, and for the cylinder in cardboard, iron, and wood (ash).

Instrument researchers, makers, and the instrument-making faculty at Hogeschool Gent, bow makers, string makers and scale designers, harpists, Belgian royal leather suppliers Delvaux, metalworkers, and the metalworking faculty at UCL (Louvain-la-Neuve), Brussels-based woodworking company Thoen, and wood analysts, have all been consulted on the project.

3. Progress

State of the action mechanism in early 2014 and in July 2017:



The instrument has been cleaned, analysed and measured and its general structure has been solidified. What was left of the wrest pin bridge after a woodworm feast was treated with epoxy resin. The screw threads of all four legs were renewed. The casework, in particular the lid, has been reglued and veneered in places. The bridges were refastened to the soundboard, cleaned, treated, and painted with graphite and the soundboard and bridge pins were cleaned. The oxidised brass plates were cleaned, and the belt-bow wooden pulley supports were repaired. The keys have been repaired, missing keys have been made and ivory key covers have been reglued. New parts, such as wooden action levers, driven pulley wheels, pegs, springs, and felt washers have been made where the originals were missing or irreparable: in collaboration with Hogeschool Gent, original action parts were measured and replicated, and the main four driver pulley wheels were redesigned and will be made in brass. Parchment was used to strengthen brittle action parts where possible.

The pedal mechanism was manufactured and in collaboration with UCL (Louvain-la-Neuve), the V-fork for the axle of the flywheel pedal mechanism was created. In collaboration with Delvaux, the leather belt-bows have been cut to measure. The mechanism is now being reassembled and optimised for reliable response and sound quality, touch and tone. Friction and rotation points have been cleaned and treated with liquid graphite (for wood) and polished (for pins), and mechanical noises have been minimised where possible. A set of 65 Savarez gut strings was ordered after their scale design and has been strung on the instrument to pitch; the bass strings are overwound with silver. Overwound silver gut strings for the eight lowest notes were made by Toro Strings in Italy. Down pressure on the bridge and tension on the soundboard is regularly measured while gradually raising the pitch and overall tension to around 900kg. We have kept photo and video documentation.

4. Conclusion and prospects

We hope to present the instrument in playable condition at the COST Action FP1302 4th Annual Conference on 'Preservation of Wooden Musical Instruments. Ethics, Practice and Assessment' at the MIM in Brussels, 5-7 October 2017. We hope to continue refining the instrument's playability and in future, we hope to compare the *Piano-Viole* by H. Lichtenthal c.1830 to the *Viola Organista* by Sławomir Zubrzycki 2012. The instrument is an important addition to the MIM collection.

Many questions remain unanswered.

- What is the significance of restoring an instrument's musical potential?
- Can we discover more about the sound potential of the *Piano-Viole* through learning to play it?
- How does the museum context support this responsibly?
- What is the impact of our focus on playability on the conservation techniques we select?
- Where is the missing repertoire for the *Piano-Viole*?
- Can we view instruments like the *Piano-Viole* as attempts to refashion the popularity of the hurdy-gurdy?
- What is the attraction of such a sound through the ages and why has it never really made it?
- As a hybrid, what can the lightweight soundboard construction of the *Piano-Viole* tell us about acoustic engineering?
- Are there any other *Piano-Viole*s out there?

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Ukrainian Hutsul’s Wooden Musical Instruments and Their Preservations

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Abstract

In the article the musical wooden instruments, which have an important historical and cultural value for the ethnic groups of Hutsuls, who live in the Ukrainian Carpathians has been reviewed. Historical facts are shown the roots of the origin of musical wooden instruments originating from Kiev Rus. In the cultural aspect, Hutsul’ musical instruments were and are an integral part of the preservation of ethnic traditions and have a great influence on the development of their designs. Hutsul’s musical wooden instruments are mostly represented by pipe, violin, bukhalo (drum), tsymbaly, bandura etc. Traditional aspects in the preservation of musical wood instruments are described.

1. Introduction

Hutsuls are one of the southwestern ethnic groups of Ukrainian people living in the Carpathians, which is the best preserved their traditional ethno-cultural characteristics, manifested in their language, dress, rituals and folklore, decorative art and music.

Historical background of Ukrainian music instruments come from the Kiev Rus’ times. Interconnection with different nations had a great influence on the development of the music instruments' construction in Ukraine. Every important event in the Ukrainian lives had music. Ukrainians used music and songs to celebrate the wedding and birth of child as well as to organize the agricultural work and to make it more efficient and pleasant.

Three key groups could express Hutsul’s musical wooden instruments: (a) percussion, (b) wind and (c) stringed instruments. Ukrainian percussion musical wood instruments are already used starting from XI century.

High Hutsuls musical talent and importance in their culture instrumental music occurred in the first literary works belonging to the 18-19 century. Today's musical instruments Hutsuls formed be use of a long historical development. Scientists were certain different processes in different parts of the Hutsul region, which led to the micro dialect stylistic differentiation musical instruments [1].

2. Methods

Analyse of the historical background of musical wooden instruments in the Ukrainian Carpathian region was one of the main research methods. The discussions with of Hutsul’s artists and instrument makers about the musical wooden instruments allowed collecting the information about the cultural role in the development of Hutsul’s tradition. Instrument makers have delivered some specific features about the preservation of musical wooden instruments in the region of Ukrainian Carpathians.

3. Musical wooden instruments

Musical instruments has always been particularly vital attributes for Ukrainian people living in the mountain region. Hutsul’s instrumental traditions are harp, pipe, bagpipe, horn edge, bell, corncrake, lyre, violin, dulcimer etc. (Figure 1).

Figure 1: *Hutsul's musical instruments.*

The most used material by the making Hutsuls musical instruments was and are wood of the following tree species like spruce, sycamore, pear, willow, walnut, cedar, beech, oak, hazel, elder, yew etc. The unique combination of woody sounds in the musical wooden instruments is almost unlimited and mostly linked to the professional experience of musical instrument makers. Although, wood properties under certain circumstances may create severe problems continued dimensional reaction to changes in the humidity of the surrounding air, fragility when in thin sections, and vulnerability to attack by fungus and insects.

One of the most popular and beloved in Hutsul' musical wooden instruments are trembita (Fig. 2). In the minds of Hutsuls, it is specific poetic symbol of the Carpathians and Hutsul culture [1].

Figure 2: *Trymbita made from spruce wood damaged by thunder*

Trembita is the main and best among musical instruments. It announces of every summer morning sun in Hutsul Carpathians, and in winter - New Year. Trembitas made from Carpathian spruce wood damaged by thunder. It is believed that the thunder transmitted the heaven voice.

One of the large volumetric musical instruments is called a bukhalo (drum) (Figure 3) and it is used in dance music. It is particularly popular in all regions of Carpathians. The instrument is fixed to the musician belt so he can move and even dance. Integral parts of the drum are a wooden stick and cymbals with metal sticks. By performing strikes, the bukhalo produces unique sounds through wooden stick and cymbals.

Figure 3: *Bukhalo (drum)*

Ukrainian wind instruments were used from ancient times. First instruments were made of household goods such as animal horns and bones, bulrush stems [2].

A hutsul sopilka (pipe) is belong to one of the smallest musical instruments. It is a short open flute (260-360 mm in length), structurally is related to flute, usually with six confidential holes, but other than in the flute their location (Figure 4).

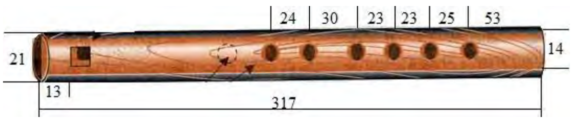

Figure 4: *Sopilka (pipe).*

The sopilka is made of sycamore and hazel wood. The strength and sharpness of the sound of the sopilka is so great that it easily overrides the other musical instruments and stands out clearly in the composition and quantity of instruments of the Hutsul ensemble or orchestra.

Surma is a wind instrument. It can have many forms but the most common is a conical wood tube with a pirouette (small disc that lies against the player’s lips) and double reed, widening towards the end (Figure 5).

Figure 5: *Surma*

Surma has 9 to 10 finger holes. It is thought that the instrument was introduced into Ukraine from Turkey or the Caucasus [2].

Tsymbaly is Ukrainian music instrument similar to husli by its construction. This instrument looks like a large wooden box with a soundboard (Figure 6).

Figure 6: *Tsymbaly*

On this soundboard strings are strung across in groups of three or five strings. To strike the strings player uses small wooden hammers. The instrument can be played in a seated or in a standing position. Tsymbaly existed in Ukraine since IX century and were widely used in performing Hutsul music.

Bandura is uniquely Ukrainian string instrument that combines the acoustic principles of the lute and the harp both. This Ukrainian plucked instrument is considered to have evolved from a line of lute-like instruments (Figure 7).

Figure 7: *Bandura*

Early instruments had from 6 to 12 strings, but modern variations can have up to 68 strings. From XV to XVIII century banduras were widely played by kobzari (blind wandering minstrels who sang songs about exploits of Ukrainians) and Cossacks [2].

Preservation of musical wooden instruments

By the packing, every musical instrument originally wrapped in paper or polyethylene bag and then placed in a bag or case. Musical instruments should not move freely in the case. In winter, they can not bring musical instruments into a warm room. Previously before unpacking them must endure train 10-12 hours in a cool room and only then unpack and move in the room with room temperature.

Hutsuls keep necessary musical instruments in a dry, heated, ventilated, and enclosed area with air temperature 10...+ 25 ^{o}C at a relative humidity of 50...60%. Musical instruments should be protected from drafts, harmful vapour direct sunlight. They don’t keep musical instruments together with chemically active substances and stacking bulk. Some musical instruments are stored on racks, shelves in the unpacking form or are suspended or in stacks of at least 1.5 m from heaters m from heating devices.

Conclusions

In Hutsul' traditions are honour to used music and songs to celebrate holidays and to make effective field works. Wind instruments are mainly used by the hunting and to announce summer morning sun. Percussion and string musical wood instruments are basicly not used for work activities demands, but for people's own pleasure. Traditional wooden instruments of Ukrainian Hutsuls qualified as stringed are very popular in modern Ukrainian music.

Acknowledgements

We would like to thank the director of the museum of Hutsul' magic Mykola Danylyuk for some pictures and practical issues in the preservation of musical instruments.

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Restoration of Keyboard Instruments: Two Case Studies from the Varaždin City Museum, Croatia

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Abstract

Among the artifacts, the main material evidence of human activity in time and space that is preserved in museums, a special place belongs to musical instruments. Thanks to the skill of musicians, instruments were mediators between musicians and the environment, the individual and audience who listened to them. Back then, the playing could not be paused or recorded, but instruments are preserved to this day as witnesses of the past. The paper deals with the history and restoration of two valuable instruments from the holdings of the City Museum of Varaždin (Croatia), which have not only regional and national, but also international significance.

1. Introduction

Since its foundation in 1925, Varaždin City Museum has kept, collected and presented tangible and intangible cultural heritage of Varaždin and the surrounding area. What makes the group of keyboard instruments in the Varaždin City Museum relevant not only to regional, but also national cultural heritage are five *Hammerflügels* (pianos with hammers), especially in light of historical circumstances – the two world wars and the Homeland War – during which cultural heritage was destroyed and lost to a large extent. The majority of keyboard instruments in Varaždin City Museum come from Austria, which reaffirms Varaždin as part of that cultural milieu and sphere of influence. The quantity and variety of keyboard instruments preserved in the Museum are a testament to a lively musical scene and advantageous economic setting of Varaždin, in that time also called "little Vienna". Two keyboard instruments from Varaždin City Museum had been restored in Heferer's workshop in Zagreb, the first Croatian organ, harmonium and piano manufactory established in Graz in 1849.

2. Materials and methods

2.1 The positive organ by Rudolf Rapoldt

During the restoration of the positive organ in 2007, the organ builder's autograph was found on the inner side of the bellows, revealing that the instrument was built in 1668 by the Swiss Rudolf Rapoldt, who worked in *Bruck* an der Mur in Austria from 1664 to 1688. The positive organ from Varaždin is Rapoldt's only preserved instrument with the constructor's signature, and has more than 80% of its original phonic material. It is the most well preserved instrument in comparison to the three positive organs in Styria that have also been attributed to this manufacturer: in Bruck an der Mur, Sankt Peter-Freienstein and Heiliger Berg (Bärnbach). The positive organ from Varaždin was originally intended for the performance secular music, in contrast to other aforementioned instruments which were used for sacral music. Historically, the positive organ from Varaždin was linked to the Castle Borl, in present-day Slovenia. It was acquired in 1674, when the castle was renovated after fire. It was kept in the knight's hall, which also served as a court theater. It can be assumed that there was a little chamber ensemble in the castle that played at court festivals, dances, and theatrical performances. The inventory of Franz Anton Sauer, the brother of the owner of the castle George Friedrich Sauer, lists a number of instruments: harpsichord, violins, two violas da braccio, violone, double bass, two timpani, two trumpets and five hunting horns [1].

The positive organ has two main parts: the lower and upper part of the casing. The total height of the casing measures 212.5 cm. Dimensions of the lower part are 81 x 109 x 91.5 cm; dimensions of the upper part are 131.5 x 107 x 68.5 cm. The central and most spacious part is the cupboard with pipes, with a tastefully decorated prospect. It is made of pyramid-shaped pipes, while unfinished frame parts are filled with carved acanthus curtains in gold and dark-blue colors. The lower keys are white, coated with ivory; the upper are black, coated with ebony. The keyboard's range goes from C/E to c'''; three octaves and one short octave. The first key that looks like E gives the tone C (hence C/E), and the D and E tones are located on the black keys. Keys of the deepest octave do not have chromatic tones (except for B-flat). From small c the keyboard has the full chromatic range up to c'''. This layout originates from the organ practice of the 17th century and has been preserved in Croatia until the 19th century [2]. The positive organ has five registers of the following disposition: *Copula maior 8 ', Portun 4', Quinta 2⅔ ', Principal 2' and Octav 1 '.*

Figure 1. Keys before and after the restoration

During the restoration, special attention was given to the original phonic material in order to preserve as much of it as possible. All the parts of the phonic material that had been previously restored were replaced. During the restoration of the phonic material, inadequately built pipes were reconstructed, with all the restored pipes being identical to the original ones. The restoration of the wooden belts for operating the bellows manually was an important contribution to the authenticity of the instrument. The tuning adjustment of the ⅙ syntonic comma was used, which adds to the authenticity of this instrument's sound.

2.2 The historical piano Hammerflügel by Michael Rosenberger

The *Hammerflügel*, built in Vienna around 1810 by Michael Rosenberger, was restored in 2009. It is especially valuable as one of few originally preserved keyboard instruments in Croatia, which were built in Vienna at the end of 18th and early 19th century. Furthermore, this is the only known and preserved Rosenberg's piano in Croatia. His instruments are kept in three other collections: in the Kunsthistorisches Museum in Vienna, in the Finchcocks Musical Museum in Kent and in the Collection of Fritz Neumeyer in Bad Krozingen [3]. The instrument was found in the Varaždin City Museum in very poor condition. The legs and music stand were missing, it had no mechanism for knee levers, and along other damages it had cracks at the bottom of the soundboard. Careful restoration and reconstruction included renewal of the exterior, fitting the missing parts, restoration of the keyboard, as well as the functional and phonic shaping of the instrument. The tuning of a' equals 415 Hz.

Figure 2. Rosenberger's *Hammerflügel* during the restoration

Michael Rosenberger (1766 – 1832), originally from Bavaria, studied piano making with the famous Viennese instrument builder Anton Walter (1752 – 1826). He was proclaimed a citizen of Vienna in 1796. His earlier pianos, originating between 1800 and 1810, had two knee levers and keyboards ranging from 5 (F, to g’’’) to 5½ octaves (F, to c’’’’). From 1810 he built pianos with six octaves (F, to f’’’’), which had up to six pedals [4]. This piano has a six-octave keyboard (F, to f’’’’). The lower keys are white, coated with ivory, and the upper are black, covered with ebony. It has the so called Viennese action (Ger. *Prellzungenmechanik*). Its appearance is typical for the beginning of the 19th century. The case is made of spruce, coated with a walnut veneer and polish. It is closed from above with spruce boards. Its narrow and long form (dimensions 113 x 220 x 91.5 cm) is supported by four slender, quadrilateral legs. There are four knee levers: bassoon, forte, piano (single moderator), and pianissimo (double moderator).

Figure 3. Restored Rudolf Rapold’s positive organ in the permanent exhibition of the Varaždin City Museum

Figure 4. Concert presentation of the restored Rosenberger’s *Hammerflügel* by the ensemble Camerata Garestin

3. Conclusion

After the restoration, both instruments were presented in the permanent exhibition of Varaždin City Museum. They are frequently played at festivals Heferer Organ and Varaždin Baroque Evenings. As part of Croatia’s cultural heritage, they foster historically informed performance of Baroque organ music, as well as piano and chamber music from the Classical period. As such, they play an important role in the concert life of Varaždin. They represent the model examples of care, preservation and use of musical instruments owned by museums. They are not just museum exhibits, but “living instruments with a soul, whose magical and refined sounds will be enjoyed by generations of music lovers to come” [5]. The efforts of the City Museum of Varaždin for the restoration of musical instruments are not finished. Two more instruments are in the process of the restoration: the square piano (Ger. *Tafelklavier*) made by the Viennese builder Johann Jakesch (1763 – 1840), the oldest keyboard instrument in a museum’s holdings originating between 1790 and 1810, and the historical piano *Hammerflügel* by an unknown builder made between 1810 and 1820, previously owned by the Ban of Croatia Josip Jelačić (1801 – 1859).

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Conservation of a Portable Wooden Pump Organ

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Abstract

This paper presents a case study on the conservation of a wooden reed instrument. Detailed documentation of its construction and decoration technology along with its condition assessment, led to the design of its conservation plan. As its functionality and playability weren't demanded by the owner, all interventions were kept to a minimum in order to safeguard instrument's historic course. Cleaning, gluing and aesthetic reintegration procedures took place in order to prevent, arrest or retard further deterioration and improve its aesthetic appearance.

1. Introduction

A portable wooden reed instrument constructed possibly in Europe around the late 19th century, was handed over to the conservation lab of the Directorate of Antique & Modern Monuments Conservation, in order to be conserved. The organ -which belonged to a private collection- measured ≈ 52x26x30 cm, had 39 ivory faced keys and was constructed by at least three wood species. Its seven-fold bellows were made of paper (fig. 1).

It was found in a relatively good condition, with damages including accumulation of dust, abrasion, wear and tear, breakage of wooden and metal parts, discoloration, and past interventions with fabric and plastic strips.

Figure 1: the wooden pump organ before conservation

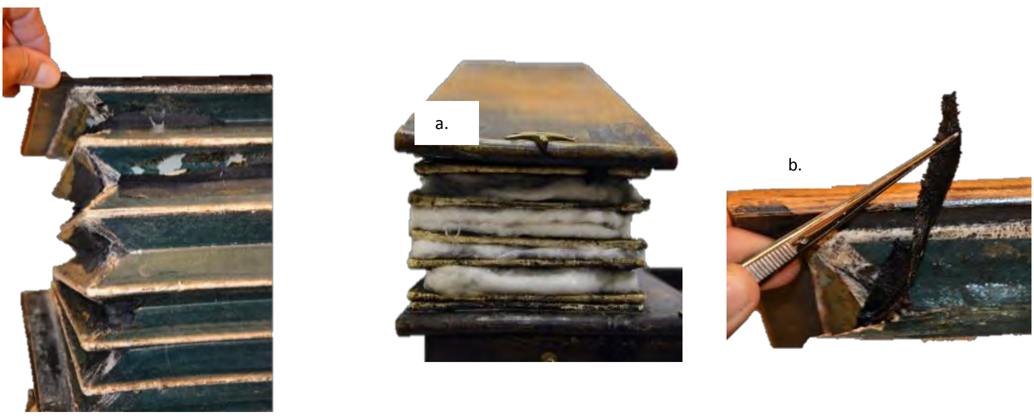
In order to plan its conservation, detailed documentation of the object was initially carried out, followed by a study of its construction and decoration technology and a systematic condition assessment. Results obtained, supported by the fact that the organ had only sentimental value to the owner who wanted to preserve it without regaining its playability, led to the decision to deal with it, by keeping any intervention to a minimum. Thus, major restoration or repairs were avoided so, as much as possible of the original material to be protected and the historic course of the organ to be preserved. The main goal was to safeguard the instrument for future generations by preventing, arresting or retarding further deterioration.

2. Materials and Methods

Superficial cleaning firstly took place, using soft brushes and a museum vacuum cleaner. Spot tests followed with deionized water and solvents combined with mechanical cleaning in order to choose the most appropriate for the removal of a) superficial dirt of wooden surfaces b) fabric strips c) residues from the plastic tapes used to keep the pumps folded after the breakage of the hinges and d) glue residues.

The removal of superficial dirt and greasy substances from uncoated wooden surfaces, was achieved with white spirit as it wasn't' affecting the wooden substrate. For the varnished surfaces however the use of solvents (white spirit, ethanol, acetone) was rejected, as they dissolved the original coating of wood. Thus, deionized water was used instead through soaked cotton strips that were left for 1,5 minute on top of the unwanted material. This approach was proved also capable to soften the fabric and plastic patches, and facilitated their removal without harming the underlying paper layer (fig.2).

The removal of the residues from the plastic tapes was made possible mechanically, by the use of scalpel and deionized water, leaving unaffected the residues of the black-brown coating underneath (fig.3). Glue residues were removed by the use of pure ethanol.



c.

Figure 2: a. fabric strips that were put to reinforce the foldings **b.** cotton strips soaked in deionized water to soften the attached strips **c.** removal of the fabric strips

Figure 3: removal of the residues from the plastic tapes

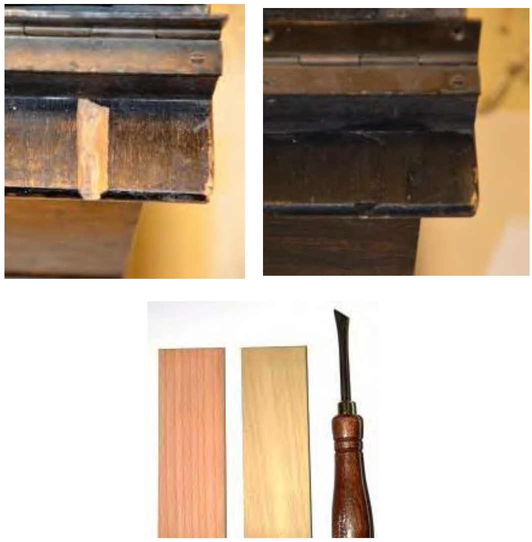


Figure 4: missing wooden parts, reproduced by wood of the same wood species

Iron corrosion stains were removed with gelled chelators (deferoxamine) (Rapti et al 2015). For avoiding further damage of the construction through handling and aesthetic reintegration, fixing of the detached wooden parts was done with animal glue which was also used to glue the missing wooden parts, reproduced by wood of the same wood species (fig.4). The fold bellows, were reinforced with Japanese paper glued with CMC/water 3% w/v, coloured with watercolours in the original shade. The losses of ivory parts of the keys facings were filled with microballoons in polyester resin (Paraloid B72/aceton, 15% w/v) and painted with acrylic colours (fig.5). The brown-black finish was found not to be a later intervention as originally was assumed as it was under the varnish. Due to its wear in an irregular way, minimum aesthetic intervention took place, above the varnish, in order to unify its aesthetic appearance (fig.6).

Figure 5: organ keys before and after restoration

Figure 6: the wooden pump organ after conservation

3. Results and Discussion

Conservation of musical instruments is a fragile balance between the preservation of an instrument in its current state and the restoration of elements reflecting its previous or its original state. This equilibrium becomes more difficult when the instrument has to be functional again. Therefore, decision making process should be a result of a transdisciplinary collaboration which will also be defined by a diversity of factors, such as instruments condition, uniqueness, the owners' desire, materials limitations, cost and time etc, making the safeguarding of each musical instruments a unique and very complex process.

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Organs, Music, Architecture: the Restoration of Julián de la Orden's Organs in The Cuenca Cathedral

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Abstract

The point of this paper is to discuss the impact that the restoration of Julián de la Orden's organs in the Cathedral of Cuenca had on the town, as well as the new works of research that emerged after it.

1. Introduction

The restoration of the organs in the Cathedral of Cuenca was a joint project of the Fundación Caja Madrid and the Cathedral itself that started in the year 2000. The restoration of the Epistle Organ (also called Major Organ or Bishop's Organ according to the different nomenclatures used in Spain at the time) was approved by the French organ builder settled in Cuenca, Frédéric Desmottes. The disassembly of the instrument was a complete revelation; on the one hand, many of the tubes were part of its twin, the Gospel Organ, Minor Organ or Dean's Organ. This led, almost from the outset and in view of the recovery of sufficient original elements, to undertaking the restoration works of the second organ. It was the first ever restoration of a set of twin instruments and gave many clues to future musicological research as well as musical performances. (1)

2. Twin organs

Twin organs in the Iberian Peninsula have a thrilling history. We could mark their origin in the 16th Century with Brebos' organs in the Monasterio de El Escorial, but there are lots of examples: Santiago, Lugo, Tuy, Sevilla, Málaga, etc., although not all of them have survived until today. This model was exported to Portugal (Braga, Evora, Coimbra, Mafra, Lisbon...) and the Guadalajara Cathedral, as well as the Mexico Cathedral. Sometimes the second organ was empty: only the box was built in order to have symmetry and an aesthetically pleasant architecture within the building.

We consider as twins (and not just symmetrical) the organs with the same tuning in the flute stop, the same number of keyboards, the same spatial distribution and more or less the same stops.

El Escorial, Monastery	Gilles Brebos and sons, 1578-85. Twin organs in the transept. Twin organs in the choir.
Lerma, Colegiata	Diego Quixano, 1616-8.
Santiago de Compostela Cathedral	Manuel de la Viña, Gospel Organ (1704-8) Epistle Organ 1712.
Tuy, Cathedral	Floor by Antonio del Pino y Velasco (possibly an organ builder from Palencia), 1712-5.
Mondoñedo, Cathedral	Manuel de la Viña, 1714-15.
Sevilla, Cathedral	Fray Domingo de Aguirre, 1724-5. With Domingo de Galarza y Domingo Larracoechea.
México, Cathedral	José Nassarre, 1734-6, after Sesma (c. 1690): installed in 1695 by Tiburcio Sanz.
Granada, Cathedral	Leonardo Fernández Dávila, 1734-9.
Cuenca, Cathedral	Julián de la Orden & José Martín de la Aldehuela (1767-1770).

Málaga, Cathedral	Julián de la Orden & José Martín de la Aldehuela (1778-1783).
Murcia, Cathedral	Fernando Molero, 1797-8. Burned in 1854.
Mafra, Monastery	A. X. Machado e Cerveira, J. A. Pere Fontanes. Four organs in the transept. Two organs in the presbytery. (2)

3. The Cuenca organs

The history of the Cuenca organs tells us how important they were for the Cathedral's life. We now know that since 1540 (the first written notice that we have) the organs have been modified and changed several times in order to adapt them to provide the necessary services. After two fires, the chapter asked Julián de la Orden to build two new organs for the new choir place (1756) designed by the Cathedral's architect, José Martín de la Aldehuela, who also designed the organ boxes, although in the first contract it was De la Orden who was intended to build them. There was an ordinance issued by the new Academia de Bellas Artes which tried to regulate the aesthetic canons for important buildings (such as the Cathedral), giving more influence to architects over the traditional guilds. It was because of that ordinance, arguably, that the architect Martín de la Aldehuela ended up designing the boxes. In fact, after this resolution, the Bishop of Málaga made the same decision in order to obey the ordinance. (3)
In my opinion he thought very wisely about acoustic questions (echo effects, for example) placing the organs in a position in which they grew up vertically, like all the Spanish organs at the time, as there was very little space in the organ gallery (as opposed to the Málaga Cathedral). The communication between architecture, sculpture and music was perfect and made the organs capable of channeling all the Baroque principles about exciting the parishioners' feelings (4). During the Enlightenment, not only knowledge itself, but also the transmission of knowledge, was valued; therefore, several schools of organ builders were established, although preserving their guild-like character. I also have to mention that since 1750, most of the organists in the Cuenca Cathedral were pupils (seises) from the Cathedral's Music School, San José. Thus, they grew up with its aesthetics and its organs' sonority.
The result of these instruments was so good that, after building them, both Julián de la Orden and José Martín de la Aldehuela were asked to build another two organs for the Málaga Cathedral. This time the instruments were bigger, with three keyboards and two facades each. Unfortunately, the restoration process has destroyed the concept of "twin" organs. We could easily consider these instruments as masterpieces; they were so novel at the time that Julián de la Orden had to write a description with indications about their use.

Fig 1. Cuenca

Fig 2. Málaga

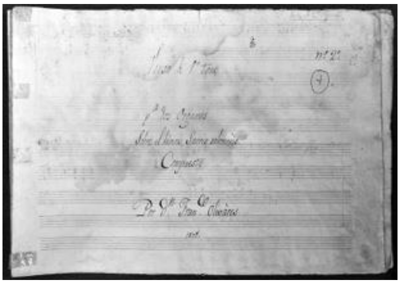
RELACION
DE LA STA. IGLESIA CATEDRAL
NUEVAMENTE CONSTRUIDOS
POR D. JULIAN DE LA ORDEN,
AL ILLMO. SR. D. JOSEF DE MOLINA,
AL ILLMO. SR. DEAN, Y CABILDO DE

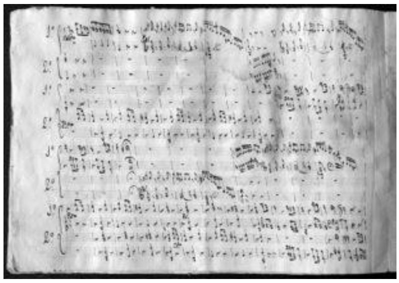
Fig 3. Julián de la Orden's description

4. Musical repertoires

There aren't any musical pieces written for two organs (to be played at the same time) until the 18th Century. That could mean that the two organs (major and minor) weren't played together, or perhaps it was a matter of them having different tuning. In Cuenca and Málaga this issue disappeared: as the instruments were twins, the Cathedral's organists at the time composed several sets of music pieces both ON the instruments and FOR them (5). The number of music pieces composed for Cuenca's instruments is 27. The Instituto de Música Religiosa de Cuenca published in 1983 a selection of eight of these pieces made by Fortunato Saiz de la Iglesia, including compositions by Francisco Olivares, Nicolás Gallardo and Julián Paxarón.

In Málaga, Adalberto Martínez Solaesa (6) has also published an inventory in which, perhaps because of the measures, there are several compositions for obliggato organ and orchestra and/or chorus. In any case, the catalogue is still a work in progress and we can't be sure of the total number of pieces.

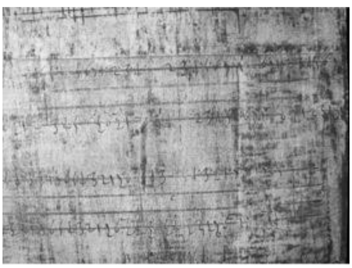


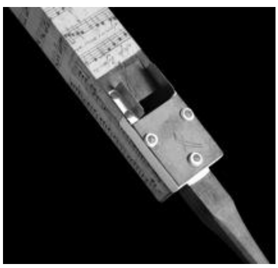


Figs 3 & 4 Olivares's manuscript for Cuenca organs

5. Catalogue of musical fragments

As was usual at the time of their construction, the wood tubes, wind conducts and other wood pieces were covered with paper to grant protection against xylophagous insects and to make them airtight. Examples of this practice can be found in Cardenete, Palacios de Goda, Torre de Juan Abad, etc. Luis Priego undertook the task of restoring the boxes (all the wood and gold pieces). During the restoration, he took photographs of all these pieces of paper, which provide us with very important information about the music that was then played at the Cathedral and is now lost. For instance, in the Gospel Organ we can find a piece of tablature. (7) We can also find a page from Tomás Luis de Victoria, as well as manuscripts and all sorts of other documents that might open our eyes to new researches.





Figs 5 & 6 Musical fragments. Cuenca organs

6. Conclusions

- After the restoration, some activities have been ongoing. Each year, we hold a cycle of concerts and courses to show the instruments and let them live. These activities have been organized by the Academia de Órgano Julián de la Orden for the last seven years.
- The Instituto del Órgano Ibérico is trying to make a facsimile edition of the musical pieces from Cuenca.
- The Instituto del Órgano Ibérico is also working on the identification and classification of all the musical fragments glued to the wood tubes.

Acknowledgements

I would like to thank Daniel de Labra, Andrés Cea, Cristina Bordas, Louis Jambou, Sing d'Arcy, Luis Priego and Frédéric Desmottes for their help. Also, of course, Mr. Miguel Ángel Albares, Director of the Cuenca Cathedral, and Mr. Antonio Chacón, Director of the Cuenca Cathedral's Archives.

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A Zither Resonance-Table with an Integrated Tuning-Button

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Abstract

If we inspect old and broken musical instruments for a restoration we get lots of documentation material which helps to choose the right direction, how to work with the object and how to conserve it. For the usual visitor it might be interesting to take these single elements and disaggregate contexts. At the end of the process we get a replica, different concepts for a repair or an object in a restored condition.

Introduction

Inside the german zither of Friedrich Idinger, Berlin 1892 (Kat.- Nr. 4382) and the zither resonance-table of Eduard Bock, 1874 (Kat.- Nr. 5563) a small sound-producing-system is integrated. The devices are not visible from the outside. Gravures with the letter "A" on the metal cover and a button refer to the sound for tuning. The principles of sound production are different when released at the touch of the button. At the zither of Idinger a small lever plucks a reed of metal. At the zither resonance table parts of the hammer-mechanism are missing. Different methods help us to decode the meaning and effectiveness of these objects.

Fig 1: Zither, Friedrich Idinger, Kat.- Nr. 4382 Foto: Irmgard Otto, Berlin 1960

Zither

The tuning is always in focus of literature about instruments. Kennedy wrote about the Konzertzither*: „Die Konzertzither ist, weil mensurlänger als die Primzither, von vollerem, kräftigerem Tone. Da sie aber trotzdem nicht tiefer gestimmt sein darf, **) ist sie saitenstraffer als jene und bedingt kräftigere Hände." [**) Vielfach wird sie allerdings in* $\overline{as}$ *gehalten.]"* [1]

The zither of Friedrich Idinger has a long scale-length, like the one Kennedy described. The instrument is not in a playable condition. Most strings are fastened on the tuning pins though under very low tension. Some strings broke at the bridge, others broke close to the nut at the winding and part from the core made of silk. The bridge separated from the soundboard. Shrinkage and deformation are found quite often on plucked instruments. Apart from the fatigue of material all these damages indicate to a wrong stringing.

Kennedy described in the year 1896 different zither types with several sizes and tunings. The tension of the string is very important for the development of an instrument. A wrong stringing can cause damages. Hundred years ago it was not common to have a discerning choice of replacement strings, for long or short string length. What Kennedy means with tight strings and strong hands we can show evocative to the visitor of a museum. Just 20mm difference of the scaling would increase the tensile force of one string by 11 Newton.

There are different parameters which allow a reconstruction of the tensile forces from the blank fretboard-strings. The small metal reed is in a sounding condition and refers to the note pitch for tuning. It produces a frequency of 431,8 Hz. An example of the sound one can find online on the website vimeo.com (cue: Zither, Friedrich Idinger). The diameter and material are also important for the calculation. With a formula developed by Brook Taylor in 1708 the string tension can be calculated. [2]

Saitenzugkraft [kg]	Dichte [g/cm³]	Länge [mm]	Frequenz „a1" [Hz]	Durchmesser [mm]
12,5	7,8 [Eisen]	435	431,8	0,38
13,8	**8,6 [Messing]**	435	431,8	0,38
10,6	7,8	435	431,8	**0,35**
11,4	7,8	**415**	431,8	0,38
11,5	7,8	435	**415,3**	0,38
13	7,8	435	**440**	0,38

Fig. 2: Table with different parameters of a string, Heidi von Rüden 2017

The table shows how the alterations of single parameters affect the tensile force. The museum keeps five little reels with blank strings for zither on stock. These parts are from the time when the zither of Idinger was in use. The diameters of these replacement-strings are smaller, the a1-string from iron is just 0,35mm strong. The graphic shows the difference from 0,01mm in the diameter which changes the tensile force to 5 Newton which correlates to about 0,5kg. It is not easy to imagine that the influence is that strong. A one-dimensional string is a good example to explain a visitor the connection between the physics and acoustics. To engage the interest practical experiments with weights are a good opportunity.

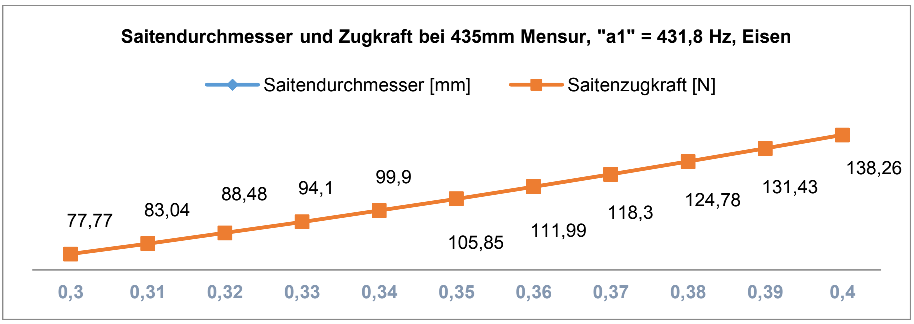

Fig. 3: Diagram with different iron string diameter and its tension, Heidi von Rüden 2017

Zither-resonance table

Nowadays a musician needs his own table where to put and play the zither. Damaged table-surfaces caused by playing an instrument in public houses are no longer incurred by the barkeepers. For the last hundred years the playing position of the zither did not change remarkably. The center line of the fingerboard lies nearly in an angle of 35 degrees to the front of the player. The peaks of the little feet are pressed into the table top and stabilize the position of the instrument. The modern zither combines the principle of the stringing in a line and the contrary dividing the string on a fretboard. Therefore the right and the left hand operate in a very different way. The right hand is actually the sound producing element. [3]

The resonating body of the zither encloses a quiet small air volume because the sides have a very low level. This is a disadvantage for the deep sound of the low strings because the vibrations have no place to develop. Examinations show contrasts in radiations by the use of different playing-tables. A zither-table is relevant for the sonority and character of the sound. [3, 4, 5] Already at the beginning of the 20th century many inventions with patent specifications were made to improve the sound of the very popular instrument.

The undamped and covibrating strings of the stringed keyboard instruments are part of the sound producing system for many hundred years. The sound of the zither gets a special character because of the sympathetic strings. The aliquodium is a development of this principle. It is like a substructure underneath the zither which amplifies the sound by resonating strings, made in the 1890s in a transportable size.

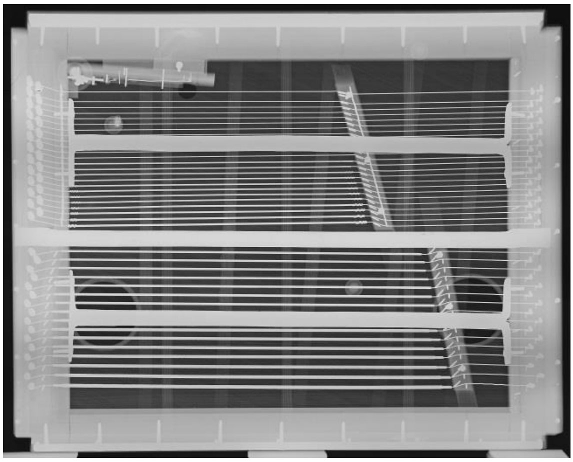

Fig. 4: Zither resonance-table, Kat.- Nr. 5563, Foto: Sophie Kleinbeck, Berlin 2016,

Fig. 5: Zither resonance-table, Kat.- Nr. 5563, X-ray: Christoph Schmidt, SMB, Berlin 2016

The zither resonance-table with its integrated tuning-button consists of two parts. The actual resonance box is buildt in a table rack. Fit in the ribs the box just fastened by small wooden strips and a few screws. For studies with the endoscope, for acoustic measurements, the record of an x-ray picture and other reasons this part was separated from the table frame. [6, 7] The speciality of the resonating soundbox is the chromatic stringing. On the bottom side there are 40 sympathetic strings. They range from Contra octave C1 to d and complete together the already existing strings of a zither. The notation is marked near the tuning pins. The last string with some space to the neighbor is the a-string. Through a hole in the soundboard it was possible to tap this single string by the hidden mechanism inside the box. Unfortunately this part is not complete any more but the movement is still working when activating the button on top. A video with the endoscope one can find online at vimeo.com (cue: Zitherresonanztisch). Probably there was a solid sound generator integrated, like the small reed in the Idinger zither, which gave orientation for tuning.

The strings are no longer in tune. A metal frame and metal braces hold the huge tensile force of the strings which has an effect on the whole sound body. The tension is about 80 Newton for a 1mm diameter iron string, or 3200 Newton at all.

For a trial of the acoustic a playable zither, the resonance box of the zither table and both objects together were measured in an anechoic room. A sinus sweep signal was given to the objects and the reaction was recorded by microphones. The graphic of a spectrograph shows the sonority of the only zither and the improvement while putting the zither on the resonance box. A rehearsal confirmed this effect.

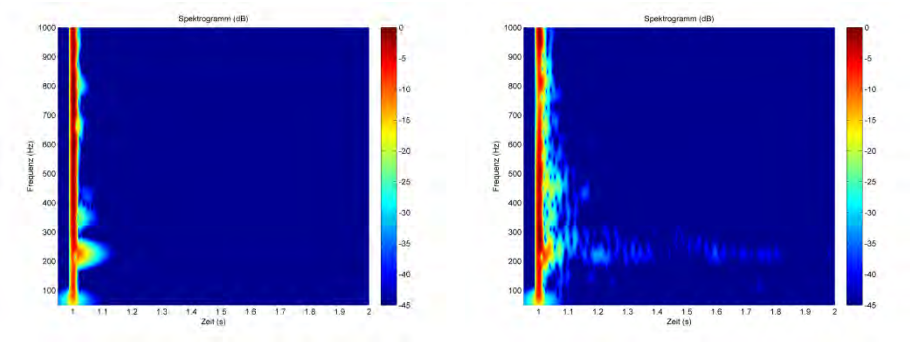

Fig. 7: Schlesinger, Anton: Spektrogramm einer Zither und einer Zither auf dem Resonanzkasten, Kat.-Nr. 5563 aufliegend [Akustische Vermessung am SIM], Berlin 2016

The zither table from Eduard Bock was probably made for private setting. The soundboard has three little knobs turned from hardwood. Their position fit to the outline and small feets of a small instrument lying on top. To improve the transmission of the sound there is a soundpost located directly underneath one of the knobs.

Conclusion

With present-days methods it is impossible to incorporate visitors of a museum to musical instruments. Every part of a zither has its special task and the applied function of a resonance table can engage the visitor interest. These two zither objects have many capabilities to copy and learn from.

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The Collection of Musical Instruments of the Museo Nazionale della Scienza e Tecnologia "Leonardo da Vinci" in Milano: an Interesting Study-Case of Conservation and Restoration

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Abstract

This paper will focus on the past-presente and futur setup of the «Emma Vecla» collection of musical instruments and its problems inherent the state of preservation of the instruments, their history and their future utilization.

- **Introduction**

The «Emma Vecla» collection of the *Museo Nazionale della Scienza e della Tecnologia* in Milano, entirely devoted to musical instruments, was born in the early Sixties of the Twentieth century thanks to the singer Emma Vecla who donated a large amount of money and to the scientific advice of Benvenuto Disertori and of the Milanese violin makers Bisiach brothers.

Its general purpose was to enrich the Museum with a didactic section entirely devoted to the art of violin making and, in particular, with a typical atelier of violin making of the past in order to illustrate their evolution and their constructive technology thus in line with the main purposes of this particular scientific and technological Museum that aims to be a fundamental place for the understanding of scientific phenomena and for their technological and practical employment.

Since 1956 the Museum was feeling the need to have such a collection. In fact in that period a renewed interest in violin making was being fully felt: in 1949 the National Museum of the Musical Instruments in Rome had bought the «Evan Gorga» collection and in 1958 Milan's Museum of the Musical Instruments (today located in the Sforza Castle) acquired the «Natale Gallini» collection. It was only in 1960 that the idea of the Museo della Scienza became reality thanks mainly to the generous financial contribution of Emma Vecla, name of art of the singer Ernestina Telmat (1877-1972), first interpreter of the Merry Widow's main role and protagonist of the musical scenes between 1907 and 1915. She had long been active in the field of the musical promotion and in the protection of beneficial entities such as the Rest Home for Musicians – Giuseppe Verdi Foundation or the Institute of the Blind in Milan. So when she heard about this exigency of the Museum she decided to give her help in order to give life to this musical project. Through a particular insurance policy system, Emma Vecla on ine side could give the Museum a very conspicuous financial source for the purchase of musical instruments and on the other side she could enjoy a good income in the last years of her life. This new section was inaugurated on 22nd January 1962 and was titled «Emma Vecla».

- **The «Emma Vecla» collection from 1962 to today**

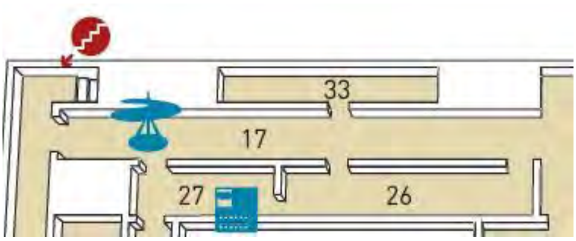
One of the main duties of the collection was to didactically exhibit the musical instruments through the different ages thus illustrating their particular technical evolution and (not secondarily) to emphasize the great Italian tradition in the field of violin making not only by exhibiting the instruments created by thee most famous makers, but mainly through a sample of instruments that, albeit sometimes anonymous, could illustrate the paths of the Italian "liuteria" that they represented.

In 1961 the famous engraver, musicologist and musical iconographer Benvenuto Maria Disertori was chosen as scientific adviser and the technical advice was entrusted to the brothers Leandro, Andrea and Carlo Bisiach, that belonged to one of the most prestigious Milanese families of violin makers.

They not only made all the necessary equipment available to create a typical atelier of violin making (with its furniture, tool and instruments, but they made available also their web of contacts within the antiquarian market in order to find all the instruments that could illustrate the evolution of the string, wind and keyboard instruments.

Today, thanks to the archival documentation it is possible to go through the various stages that led to the creation of the setup and we can become aware of the choices made and — very interestingly — of the musical market of those years (its main actors and the evaluations of the instruments).

The collection was set up on the first floor of the Museum in a rather large corridor (n. 26 below) parallel to the great section dedicated to Leonardo da Vinci (n. 17 below).



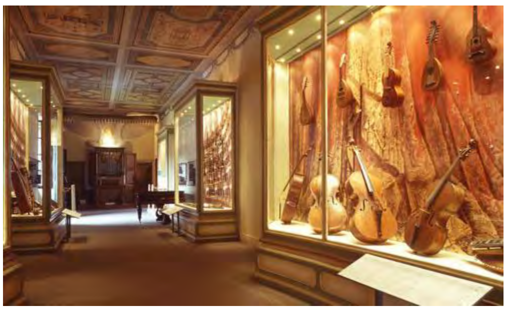
At the same time a goldsmith section was created and accompanied by an old watchmaker's shop. The corridor was divided into two parts: 1) the atelier of violin making, 2) a space furnished with large showcases on the longer sides, the Giosuè Agati organ on the shortest side and some other instruments (two harps, one harmonium, one piano).

The atelier of violin making was entirely lined with wood and was furnished in an antique style; the visitors were allowed to enter.

Firstly the Bisiach brothers intended to setup a really working atelier with a real violin maker at the work. This idea was rejected by the management of the Museum because it was not in line with the other Museum's collections.

The great showcases were filled with copies of famous works of art with musical instruments (particularly Praetorius' xylographs.

In 2003 it was decided to proceed with the modernization of the section: the visitors were no longer allowed access to the atelier (they now can look at it through large windows) and Disertori's illustrative equipment was replaced by great gigantographs that reproduce the Orchestra of the La Scala Theatre. And some bow instruments were placed inside this gigantographs above the photographed instruments: for instance, some violins were placed above the analogous instruments while played by the violinists in the picture. The result is visually very chaotic.



For some years, the piano Erard 1821 has been played weekly and a Klotz violin (2nd half of the 18th cent.) has been played three/four times a year.

- **Rethinking the setup**

Thanks to a 300 hours training project done by three students of the Restoration School of CrForma in Cremona (Italy) — Triennial Course for "Tecnico del restauro di beni culturali: strumenti musicali della liuteria classica a pizzico ed archetteria" — this year more than 80 instruments (bowed and plucked) of the collection have been checked up for the first time. Each of them has been described in a proper datasheet with photos and, whenever possible, with the results of endoscopic analysis. Such a detailed check up, together with the archival resources of the museum, has made available to the curators of this section a very important amount of historical, conservative and technical information that will be taken into account for the renovation of this section. Renovation planned for 2018-2019.

The educational approach expected since 1962 remains a priority and the renewed collection will join the pioneering spirit of the Sixties with the guidelines of the modern museography and museology (particularly as to the exhibition of scientific tools) in order to give to the «Emma Vecla» collection a homogeneous layout with other sections of the museum.

As a collection of musical instruments, it will have to be able to create a sort of 'dialogue' between the acoustical and the constructive features of the instruments as well as between the cultural-historical elements with the aspects peculiar to a collection and — particularly relevant — allowing the visitors to perceive and understand their organological (and sound) evolution.

Because of the redistribution of the exhibition space, the large showcases will be removed and it represents a challenge: which instrument will be exhibited? In which way?

Certainly, the new collection will remain adjacent to the large and renewed space dedicated to Leonardo da Vinci and this circumstance suggests to focus on the relations between Leonardo and the Music as a starting point for visiting the collection.

- **To store and renew the collection**

The detailed analysis of the instruments focused on the general conditions of the collection. Particularly pressing will be the recovery of many instruments (as well as other objects such as the furniture of the atelier) from the xylophages' attack. A remedy to this problem is still in place thanks to the collaboration with the Restoration School of Cremona that will made available its own facilities for anoxic treatment.

The checkup of the instruments had revealed their true history, their provenance and has been able to correct some wrong attributions. Besides, some instruments purchased for educational purposes, will even be played by visitors.

The exhibition will be integrated by 3D copies of some instruments, virtual reality proposals, laboratories of construction, analysis and scientific diagnostic suitable for all visitors' ages. Some instruments will regain their voice and the visitors will be invited to interact with them and to live new historical sound experiences.

The atelier of violin making will continue to fulfill its role as an illustration of the various steps of the creation of bowed and plucked instruments. It will be an attractive point thanks to the possibility to host violin makers and their students. The «Emma Vecla» collection will become a place of study and technological knowledge where it will be possible to learn the history, the restoration and the cultural promotion of the instrumental and musical heritage both Italian and international.

Acknowledgement

The author gratefully acknowledges Dr. Claudio Giorgione curator of the *Leonardo Arte e Scienza* Department of the *Museo Nazionale della Scienza e della Tecnologia «Leonardo da Vinci»-Milano*, Dr. Paolo Mariani coordinator of the Restoration School CrForma-Cremona; Fabio Federico De Lorenzi, Alvaro Jimenez Gomez and Salvador Maura Riera the students of the Restoration School of CrForma in Cremona (Italy) — Triennial Course for "Tecnico del restauro di beni culturali: strumenti musicali della liuteria classica a pizzico ed archetteria".

Web Based Visualization Software for Big Data X-CT Volumes with Optimized Datahandling and Workflow

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Abstract

Within this paper we would like to present the idea and first realization of a novel web based visualization software for 3-D x-ray computed tomography (X-CT) data. High resolution X-CT is gaining more and more importance in the field of cultural heritage because external and internal structures can be created without any mechanical stress on the original. While the access to these big data volumes is limited due to technical limitations we developed an easy, quick and comfortable web browser solution.

1. Introduction

High resolution 3-D x-ray computed tomography (X-CT) is gaining more and more importance in the field of cultural heritage. While using X-CT to support examination and investigation of physical cultural property, like wooden musical instruments, a more detailed three dimensional digital twin, with all external and internal structures can be created without any mechanical stress on the original.

To briefly describe the recording and reconstruction process: For data acquisition the object must be placed between the detector and the x-ray source on the turntable (see Figure 1).

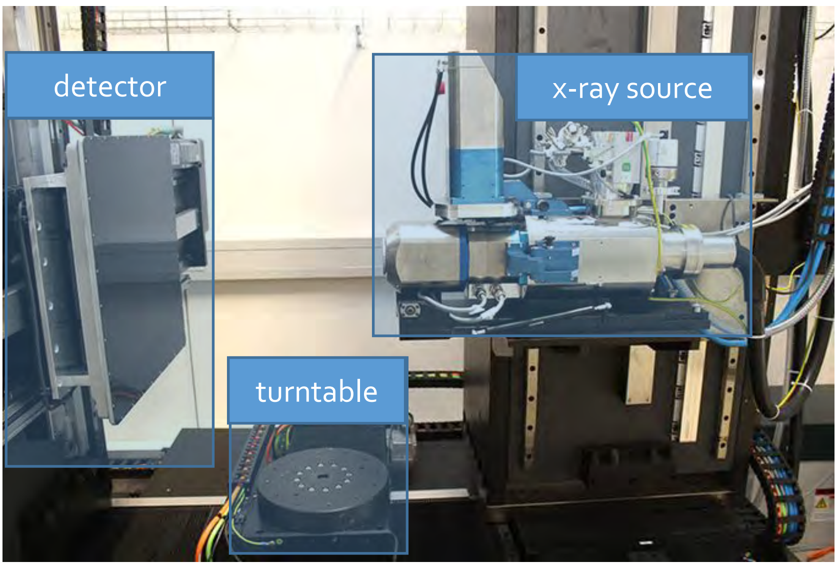

Figure 1: Industrial high resolution XXL-CT system, developed by Fraunhofer EZRT

While the object is rotated, usually 360°, a set of 2-D projections is acquired. Depending on the necessary resolution and object dimension, the 2-D projection dataset consist of typically 2000 – 6000 projections for one 360° scan. Depending on the object height, several 360° scans a necessary. Based on the fact that a file has a size of typical 8 megabytes, during one 360° scan data of 16 to 46 gigabyte are collected. For the reconstruction process each file must be transferred to the reconstruction computer (or cluster of computers) where the final 3-D volume will be reconstructed and stored. Each time, with typical and available software tools, the reconstructed volume (the digital twin) will be visualized, the whole volume must be transferred and loaded.

For easy and quick access to the digital twin we developed a web based viewer software (RecoWebViewer) which could be used on a state of the art device (PC, mobile or tablet) by using a typical web browser (see Figure 2).

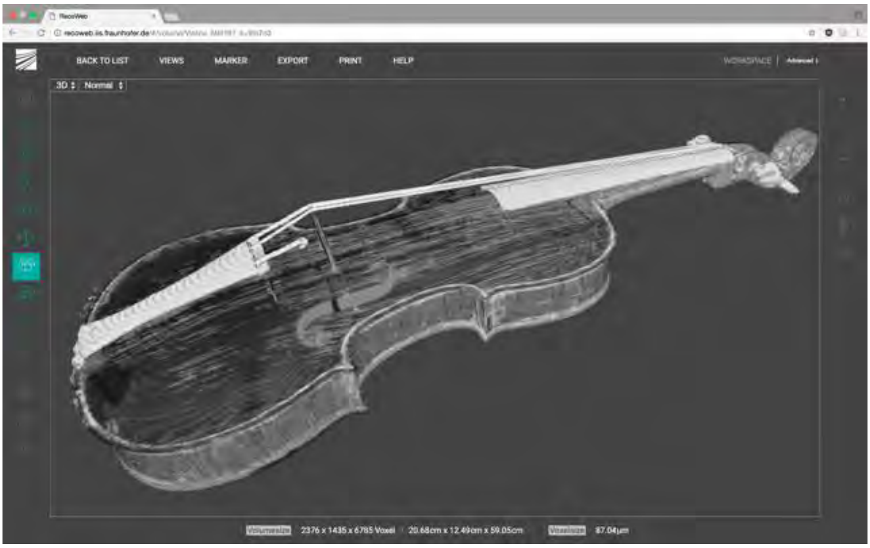

Figure 2: Shows the violin MI419 (GNM) displayed within the RecoWebViewer software.

2. Web Based Viewer - Motivation

Despite detailed information of the geometrical and physical structure is wanted and needed, this creates challenges which have to be handled. In this case: a huge amount of disk space is necessary (see Table 1), a powerful computer for the visualisation and investigation purpose is needed, a cost intensive visualisation software and training for the operator is indispensable. Therefor an open access to the data and information cannot easily be provided in-house or to external customers.

Instrument	***Resolution***	***File Size***
Violine MI419	*87.04um*	*43,09 GB*

Table 1: File size depending on the resolution

3. Approach and Realization

In order to counteract this, we have set ourselves the goal of realizing a viewer software for representation of large X-CT volumes over the internet, reducing the hardware requirements for visualization computer and network, optimized operator workflow as well as reducing cost for visualization software and multi user licensing. By using RecoWebViewer, it is possible to provide an open access to the data and information for different users, in-house and even external.

The approach and realization is based on the slogan “What you see is what is transferred”. This incremental transfer of the volume data presupposes only one server side pre-processing step performed directly after the acquisition and reconstruction process (see Figure 3).

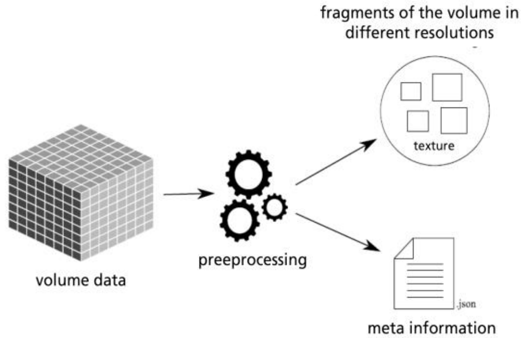

Figure 3: Server side pre-processing of the volume into fragments and meta information

Within the pre-processing step, the volume will be fragmented in partial volumes with different resolutions (see Figure 4).

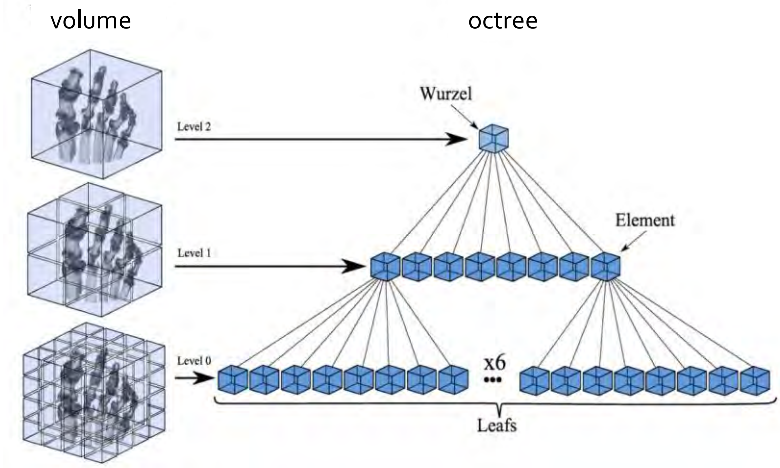

Figure 4: Partial volumes fragmentation

This pre-processing allows an incremental transfer and therefore a presentation in a typical web browser with no special and expensive software installed on the local computer. In addition, no local copy or file transfer to local computer is necessary and a server side multi user access is possible.

4. Result and Conclusion

Within this paper we present a realization of a novel web based visualization software for 3-D x-ray computed tomography (X-CT) data – RecoWebViewer. Realized based on the slogan "What you see is what is transferred" we developed a server side pre-processing tool chain and a web browser application. The main and special features of the RecoWebViewer are:

- The RecoWebViewer software allows representation of large X-CT volumes over the internet on state of the art devices like Personal Computers, mobiles or tablets.
- The RecoWebViewer reduces the hardware requirements for visualization computer and network.
- The RecoWebViewer offers optimized operator workflow as well as reducing cost for visualization software and multi user licensing.
- By using RecoWebViewer, it is possible to provide an open access to the data and information for different users, in-house and even external.

Acknowledgement

Within the MUSICES project, the GNM (Germanisches Nationalmuseum) and the EZRT (Development Center for X-ray Technology) of the Fraunhofer Institute for Integrated Circuits (IIS) are jointly developing a guideline for the three-dimensional x-ray computed tomography (3D-CT) of musical instruments, [1] first use-cases could be discussed and determined as well as a successful demonstration run to experts are realized.

References

[1] MUSICES: Musical Instrument Computed Tomography Examination Standard –procject homepage http://www.gnm.de/en/research/research-projects/musices/

Assessing Musical Instruments Conditions Before and After Restoration Using Industrial X-Ray Ct (iCT)

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2. TEC Eurolab, Italy

Abstract

Assessing the conditions of a musical instrument is the first step in any conservation and restoration activity. Being a delicate artefact made of wood, various factors can compromise their conservation and their functionality: from improper use and handling, woodworm's attacks, abrupt variations in the material moisture content, to non orthodox restorations and repairs. Evaluating the effects of these factors is a crucial point when making a condition report of an instrument. Industrial Computed Tomography (iCT) has proven to be an effective tool in documenting evidences of damages and modifications. In this work we present an example of the flexibility of the iCT. A portion of a violin was scanned at various resolution (112, 224 and 447 mm) and a comparison among these results was performed. An example of decision-making in violin restoration supported by the use of iCT is also reported.

1. Multi-resolution iCT and Diagnostics

TEC Eurolab is a leading company in NDT, since 2014 is working on the application of iCT to cultural heritage. Diagnostics of Bowed Stringed Instruments can be performed with two different iCT systems: NSI X5000 and NSI X7000. A typical scenario is the full-scan at 112 microns of a complete violin. For a given Multi-resolution system, a smaller voxel size means also longer acquisition time and bigger dataset to deal with. The average dataset dimension for a whole violin scanned at 110 microns is 20 Gb. The voxel size can be tailored to the requested application, either focusing the analysis with a small voxel in a certain region of the instrument or using a bigger voxel for a quick analysis of the whole instrument. Further flexibility is given by the possibility of using the so-called "binning" mode. In this approach the x-ray detector area is divided into 2x2 (or 4x4) pixel groups, each of them acquiring data as a single pixel. The acquisition time is respectively 4 (or 16) time faster, at the cost of a voxel size increased by a factor of 2 (or 4). A region of a violin body (measuring approx. 100x230x170 mm) was scanned using different resolutions. Data are summarized in table I.

mode	Voxel size [mm]	Dataset dimension [GB]	Scan time [min]
4x	447	0.08	3
2x	224	0.77	6
1x	112	5.8	24

Table I: *effect of voxel size on dataset dimension and scan time*

At 447 mm the wood structure is not resolved, but the biggest defects are clearly visible. This resolution is useful for a fast identification of defects starting from 0,5-1.0 mm and with a strong radiographic contrast, such as for holes or very dense filler materials.

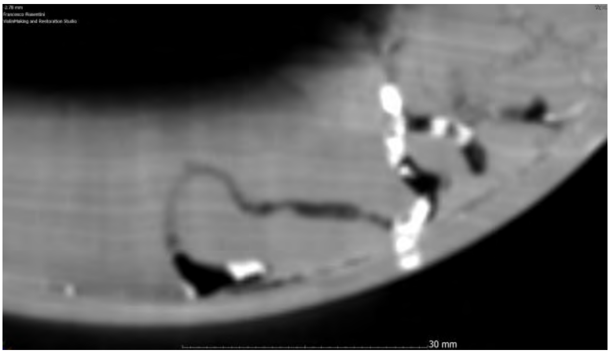

Figure 1: *Coronal section of a violin back. Voxel size: 447 mm (4x mode)*

The intermediate resolution allows the wood growth ring identification. Features such as the residual of the woodworm attack are now visible. Filler material morphology (areas with the higher grey value) turns out to be porous. Finally, the standard voxel size gives the best representation of both the wood structure and the defects, as reported in figure 2.

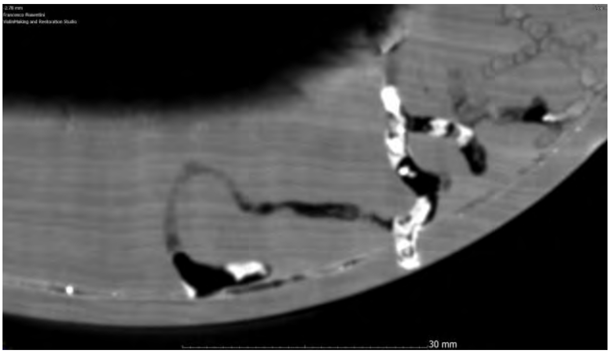

Figure 2: *Coronal section of a violin back. Voxel size: 224 mm (2x mode, or "binning")*

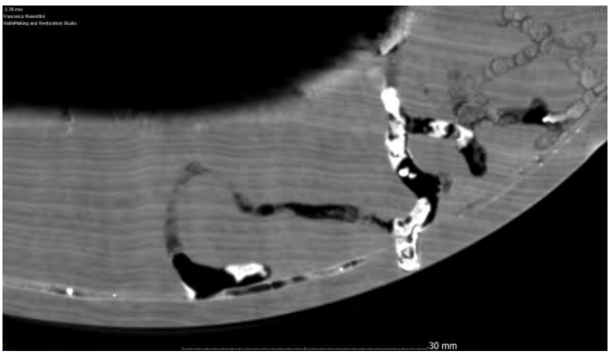

Figure 3: *Coronal section of a violin back. Voxel size: 112 mm*

2. iCT and decision-making in violin appraisals and restorations

Old and valuable violins present various degree of damage and presence of previous restorations. The intrusiveness of these interventions is not always assessed from an external investigation, even when the instrument is disassembled. When planning a restoration activity, the process of decision-making is often between leaving the old restorations or replacing them. In this process iCT plays an important rule, because it allows to determine the extensions and depth of both damages and previous restorations.

Another example is reported in Figure 5. A suspected woodworm damage on an Andrea Guarneri violin turns out to be a re-composed fracture, with missing fragments lost during the previous restoration.
The iCT analysis, performed at 68 mm, showed that no woodworms damage is present.

Figure 5-6: *Suspected wood-worms damage on an Andrea Guarneri violin (Courtesy Franco Simeoni)*

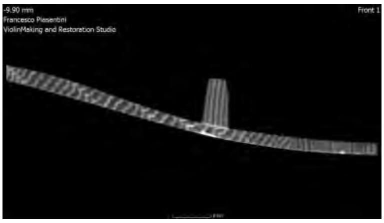

Figure 7: *axial slice of the corresponding area, voxel size 68 mm*

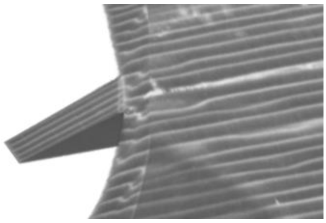

Figure 8: *3D volume rendering showing sections of the region of interest.*

3. Assessing the quality of restoration activities

Another explored application of iCT is the assessment of the quality of restoration activities. CAM milled wood patches are becoming an interesting alternative to traditional techniques.
A portion of a violin was scanned at 70 mm, and the quality of the restoration performed using CNC milled patches was investigated in terms of porosity and glue layer thickness. Original wood is denser (see bottom of Figure 9: higher gray values stand for more x-ray absorbing material). Glue lines are visible in the original wood.

Figure 9: *Coronal section of violin back plate, voxel size 70 microns*

Finally, a Giuseppe Guarneri “del Gesù” violin top plate was scanned in order to evaluate the thickness of the original material under a patch. Results guided the restorer in the subsequent restoration activities.

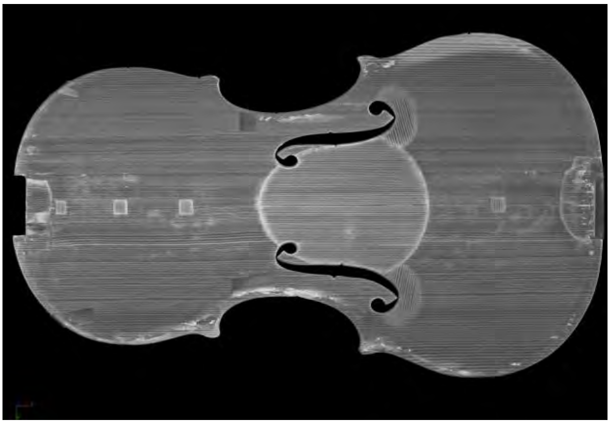

Figure 10: 3D volume rendering of a Guarneri “del Gesù” violin belly (Courtesy Eric Blot)

4. Conclusions

Industrial Computed Tomography is becoming a standard in the evaluation of string instruments condition.

It is actually the only non-invasive method that allows to assess damages and previous restoration invasiveness. Information from iCT can be used to minimize further restoration impacts.

Acknowledgements

Authors wants to thanks violin maker Franco Simeoni and Eric Blot for kindly allowing the use of ICT volumes and renderings.

The Varnish Barrier Effect on the Sorption Properties of Wood Based on Neutron Imaging Measurements

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Abstract

One aspect of preserving wooden musical instruments is the influence of different environmental conditions (i.e. relative humidity and temperature) on the object's materials. As wood is a hygroscopic material, changes in relative humidity induce wood moisture content gradients resulting in internal stresses which can harm the instruments dimensional stability. Hence, wooden instruments are commonly varnished for protection against relative humidity changes. The induced sorption barrier is normally perceived in form of board cupping of varnished plates, but the investigation of the actual diffusion process respectively moisture content distribution is more difficult. Neutron imaging enables investigations of the wood sorption dynamics and allows for the localization and quantification of the moisture content distribution over the wood-cross-section. As demonstrated in this study, neutron imaging clearly visualizes the varnish barrier effect on the sorption properties of wood and could further be applied to determine the protection effectiveness of different coatings or surface treatments.

1. Introduction

The hygroscopicity of wood influences wooden musical instruments in various ways. On the one hand, the moisture content (MC) affects mechanical and acoustical properties via density, stiffness and damping. On the other hand, changes in MC result in swelling and shrinkage of wood and affect the dimensional stability of the instrument. MC variations can lead to high internal stresses even resulting in cracks and ultimately fracture [1]. Consequently, the MC has an important influence - on playing and preservation.

In order to optimize the conservation of wooden musical instruments, it is important to understand how the instrument reacts to changes in ambient conditions (i.e. temperature and relative humidity (RH)). Neutron imaging is a suitable technique to investigate moisture transport in wood [2, 3]. As neutrons are very sensitive to hydrogen, it is possible to determine and localise changes in MC based on transmission images. In addition, the technique can also be used to inspect the instrument's internal and external shape and to reveal hidden internal features [4] that are of great interest for restoration tasks.

Varnishes act as a barrier for changes in RH respectively MC, resulting in an asymmetric MC distribution across the wood cross-section causing internal stresses [5]. Most commonly, the influence has been noticed in form of board cupping to the dry (varnished) surface [5-7], but so far, the influence has only been measured in terms of structural deformation or total mass changes.

2. Materials and methods

The time dependent MC distribution over the wood cross section was studied using neutron imaging.

Figure (a) shows the measurement principle. With the objective to reproduce the diffusion characteristics of violins, spruce samples as shown in Figure (b) were used for the investigations. The four lateral sides were sealed with an aluminium tape, limiting the sorption to the upper and lower L-R surfaces. The samples were placed in a climate chamber [8] allowing to control RH and temperature of the surroundings. As a result, diffusion occurred in tangential direction (in common with violins). All measurement series commenced at standard reference atmosphere conditions, i.e. 20°C and 65 % RH. Eight preconditioned samples (MC≈13.5 %) could be measured within one measurement series, allowing direct comparison of the moisture diffusion for varnished (top surface) and unvarnished samples. To exclude any temperature influence, the temperature was kept constant while the humidity was changed over time (e.g. 30 min at reference conditions → 5h at 95% RH → 5h at 30 % RH).

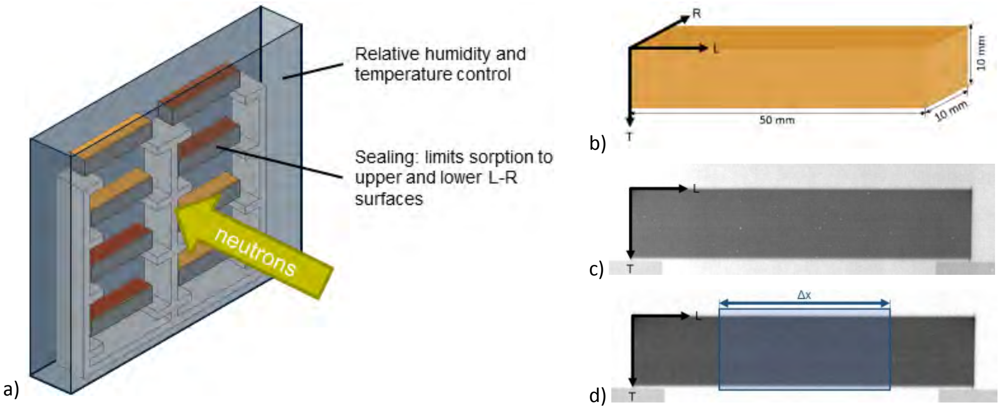

Figure 1: (a) Experimental setup in the climate chamber, (b) wood sample dimensions, (c) example of one intensity image, (d) example of resulting transmission image based on intensity image (c)

The neutrons passed the samples in radial direction, resulting in radiographic intensity images as shown in 1 (c). Images were taken at regular time steps and the transmitted intensity follows the Beer-Lambert's law:

$$I = I_0 \cdot e^{-\Sigma \cdot d} \quad (1)$$

Where I_0 is the intensity of the incident radiation, S the attenuation coefficient and d the material thickness in beam direction (here radial wood direction).

To account for artefacts generated by the experimental setup, the intensity images were post-processed before quantitative analysis. This post-processing included: removing of outliers, dark current correction compensating for background noise of the CCD camera, black body correction to correct for backscattered neutrons from the experimental setup and an open beam normalization to adjust fluctuations of the incident beam finally resulting in transmission images as shown in 1 (d).

Based on the transmission values ($T=I/I_0$, see equation (1)), the difference in water layer thickness $\Delta d_h = -\ln\left(\frac{T_t}{T_0}\right)\frac{1}{\Sigma_h}$ [9] and neglecting swelling, the change in wood MC can be calculated by:

$$\Delta MC = \frac{\rho_h \Delta d_h}{\rho_w d_w} = -\frac{\rho_h \ln\left(\frac{T_t}{T_0}\right)}{\rho_w d_w \Sigma_h} \quad (2)$$

Where ρ_h and ρ_w are the densities of water and wood (oven dry), T_0 and T_t are the transmission values at reference conditions respectively at time t, d_w is the wood thickness (oven dry) and S_h the attenuation coefficient of water.

For further evaluation the transmission values of one image were averaged over a distance Δx resulting in a 1D-neutron transmission profile from top to bottom surface. The change in MC was calculated according to equation (2) with the initial state (65 % RH and 20 °C) as reference condition. Therefore the final 2D results show the change in MC compared to the reference conditions from top to bottom surface studied over time.

4. Results

Neutron measurements on varnished wood confirmed that the varnish counteracts moisture sorption. 2 shows the resulting changes in wood MC for an unvarnished sample (a) and a sample with a varnished top surface (b). The uptake of moisture and the barrier function of the varnish can easily be seen as moisture (blue colour) diffuses only via the unvarnished surfaces into the wood. Furthermore, an uptake of water by the varnish layer is apparent even though the actual value of ΔMC is not correct as the higher density of the varnish is not taken into account (see equation (2)). Additionally, in case of desorption, the varnish acts as a barrier, preventing the diffusion of moisture through the varnished surface to the environment.

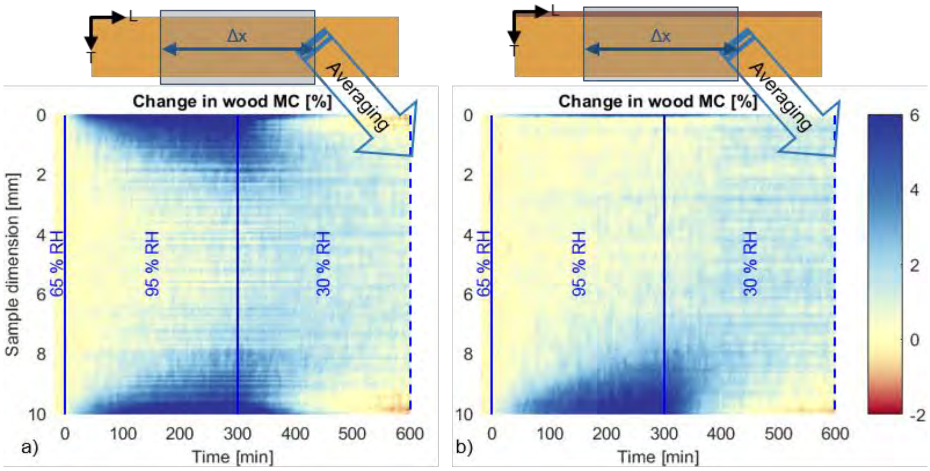

Figure 2: Change in wood MC [%] compared to reference state at 65 % RH for (a) an unvarnished and (b) a varnished sample

In general it was observed that diffusion is a rather slow process resulting in longer lasting MC gradients after changes in the ambient conditions. The same measurement principle can be applied to damaged (e.g. including cracks) or different coating systems to evaluate their "effectiveness" based on the resulting spatial MC distribution. Bearing in mind possible consequences of MC changes, these measurements reveal a great potential related to instrument playing and preservation considerations.

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Post-Processing of Musical Instrument 3D-Computed Tomography Data for Conservational Applications

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Abstract

Industrial 3D-computed tomography (CT) has been established as a powerful method for non-destructive examination of objects of cultural heritage in restoration and conservation science. The produced data not only provide views into internal parts of objects, but also hold a lot of information accessible through subsequent applications. This work presents utilizations of 3D-CT data and demonstrates possible workflows based on the use of non-specialized personal computers and open source software.

1. Introduction

High resolution industrial CT can achieve X-ray data with a spatial resolution of around 100 µm which opens the method for many fields of research, but also presents challenges regarding post-processing. One of these is the required high-performance computational resources to process the achieved amount of data: Scanning of an entire violin with a spatial resolution of 100 µm yields a reconstruction consisting of up to 8000 single images with 2.5 Megapixels resolution which can have an overall cumulative size of more than 60GB. Another challenge is the need of expertise to be capable of handling the data in order to extract available information. Last but not least, common solutions are based on proprietary, mostly very expensive, software.

The research project MUSICES is developing a standard for computed tomography of musical instruments [1]. It mainly includes the technical settings, important steps for the storage of metadata and advices for mounting and transport to ensure a high quality in imaging and data handling. In addition to this fundamental research, the current work presents approaches to post-processing the recorded CT data in order to make the obtained information easily accessible for further research.

2. Hardware requirements

All described processes are intended to run on a current personal computer, only a few hardware requirements have to be considered. Due to the mentioned size of the datasets, working memory is most crucial; at least 16GB of memory is needed, 32GB is preferred. Since several processes challenge the graphics card, a standalone GPU leads to smoother image navigation and decreased rendering time. All given information is considering the technical disposability in 2017. All suggested programs are open source / freeware and work on Windows and Linux.

3. Description of workflow

All following examples refer to the open medical standard DICOM (Digital Imaging and Communications in Medicine) as a starting point. The file format is widely accepted, and compared to proprietary formats a lot of free viewing and processing software is available.

3.1 Preprocessing of DICOM files

To minimize the needed computational resources, the cross-sectional images are rotated and cropped in a way that they show only the proposed region of interest (ROI). This can be batch-processed with script languages like *Python* which support handling of DICOM files. To preserve dimensional units, note to carry the pixel spacing information from the imported header when exporting the edited slices. For a first approach, the images can also be downsampled by a factor of 2 (reduces the needed memory to $1/ 2^3$).

3.2 Segmentation and classification of sub-volumes

Segmentation allows to distinguish and extract sub-structures with homogeneous properties from a heterogeneous object. It is widely used in medical applications to discriminate tissues or to generate content-related regions in machine vision. Open-source medical image analysis software is available to a great extent and can be utilized for the examination of musical instruments. Although there are comprehensive and powerful programs like *3DSlicer* or *ImageJ* the authors suggest using *ITK-Snap* for the segmentation process, which has a more limited range of functions but is specialized on semi-automatic segmentation (based on region growing) and performs well even with large-scale data sets [2]. Each voxel is allocated to exactly one of the defined sub-volumes, therefore different sub-volumes cannot overlap, which is crucial for subsequent applications like physical modelling or rapid prototyping. Note that filtering or re-meshing the individual sub-volumes can destroy this ratio.

3.3 Extraction of surface data

Since sub-volumes are generated according to their homogeneous properties, the respective surface data adequately describes a body. This leads to a massive reduction of data. Handling, therefore, is simplified (3D meshes of instrument parts can easily be sent per email) and individual sections can be stored in databases for specific research tasks. For the exact determination of the surface, a scan with as less noise and other image errors (e.g. metal artefacts) as possible is necessary. However, even for an excellent scan the exported surface meshes (most commonly stored as .stl files) may have diverse defects, e.g. self-intersecting faces, non-manifold edges or unreferenced vertices. The software *MeshLab* is recommended for this purpose, which provides various automated mesh cleaning filters. A reliable way to obtain a clean and watertight mesh is a Poisson Surface Reconstruction (the algorithm is implemented in *MeshLab*) but note that since this is actually a re-meshing, individual sub-volumes could overlap afterwards [3].

3.4 Processing of Sub-Volumes

Sub-volume data can be utilized for physical modelling (e.g. Finite Element Method), thus allowing for evaluation of the vibroacoustic behaviour of instruments, even in non-playable condition. With regard to conservation issues physical modelling can also provide insights into the structural behaviour of displayed instruments under long term mechanical loading [4]. The 3D modelling software *FreeCAD* provides a module to perform simple finite element analysis (FEA), *OpenFOAM* is mainly a tool for computational fluid dynamics but also includes FEA. Certainly, to get scanned complex geometries with heterogeneous material properties working well in physics simulation software is still a challenging task [5].

Since historical instruments are in many cases not in playable condition, exact copies are a big desire. Using extracted surface data of CT scans, whole instruments can be reproduced with high geometric precision as well as missing parts for restoration purposes [6]. Manufacture may be obtained by additive (3D printing) or subtractive methods (CNC milling). Several consumer 3D printers based on fused deposit modelling (FDM) can achieve a vertical spatial resolution of 200 µm, printers based on stereolithography (SLA) realise comparable resolutions in all axes.

Fig. 1: Exemplary results of the proposed workflow (clockwise): photo of the kit violin, cross-sectional CT image (inverted grey values), rendering of segmented sub-structures, finite element model from surface data of the bridge.

From a vibroacoustic viewpoint the substitution of complex materials like wood is difficult. Although it is possible by now to print composites of wood and polyester, the exact orthotropic material properties are not yet reproducible. Nevertheless, rapid prototyping can be utilized e.g. during pre-planning of restoration projects or to aid the understanding of complex mechanical details, in workshop and exhibition.

3.5 Measurements and technical drawings

The software *ImageJ* is proposed for performing high precision measurements on the scans at any location i.e. on otherwise inaccessible parts. Also thickness mapping is possible which can be a useful tool to illustrate the distribution of wall thicknesses or material densities. The results can provide useful information for further research or technical drawings. The latter can also be produced using the 3D data itself, since CAD software like *FreeCAD* can produce technical drawings directly from the achieved surface data.

3.6 Dendrochronological dating

Cross sections of CT data can be utilized for dendrochronological dating [7]. The required resolution depends on the smallest distance between the annual rings, but usually a spatial resolution of 80 µm to 100 µm is sufficient. Using cross sections as a basis has a lot of advantages in cases that certain wooden parts are covered with dark varnish or the part to be analysed is implemented in the instrument like in the case of a patch under the soundboard of a violin.

4. Case study: Kit violin

The proposed methods are exemplarily applied to one object scanned during the MUSICES project: a so-called kit violin (pochette), a small violin built in the 17th century in Italy, mainly used during dance lessons (see Fig.1). For X-ray CT methods this is a challenging object, because like most musical instruments, it consists of various materials with highly differing densities (in this case including conifer wood, ivory, ebony and mother of pearl). The cross section illustrates the curved shape of the body and the top plate. A slight buckling in the top plate is observable, caused by the sustained pressure of the sound post. It is possible to conduct measurements at any point of the top plate or body as well as distances between the annual rings. The segmentation image visualizes spatial disposal of the different instrument parts (e.g. positioning of the sound post) and allows further applications like e.g. rapid prototyping. Using physical modelling the vibrational behaviour of parts like the ivory bridge could be analysed and virtually compared to e.g. a bridge made out of maple. The presented results show straightforward and inexpensive ways to handle and process CT data of musical instruments, which are easily transferable to a wide range of objects of cultural heritage with various requirements in conservation, restoration or technological issues.

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Monitoring Changes in Wood Properties Using Very Near Field Sound Pressure Scanning

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Abstract

The experimental setup, described in this paper, was used for wood characterization and observation of changes in vibroacoustic properties due to exposure to prolonged vibrations and controlled humidity changes. A large number of conducted measurements require a fast and easy method with satisfactory reproducibility and measurement precision. Different approaches were tested and analysed in order to meet these goals. Wood samples were measured using the Very Near Field sound pressure scanning technique with different excitations and boundary conditions to achieve best possible results using simple measurement instrumentation. One of the important characteristics of wood, from the standpoint of musical acoustics, is Young's modulus of elasticity, which can be determined by observing the wooden test sample's response to an excitation. Visualization of vibrational modes helps identify which frequencies match which mode, and thereby allow numerical calculation of desired parameters.

1. Introduction

The most important characteristics of wood as material, from standing point of music acoustics, are Young's modulus of elasticity (Modulus of Elasticity, MOE), loss factor and specific mass. MOE is related to a piece's rigidity, while the loss factor describes how long the piece will continue to oscillate after the excitation. This parameter is directly related to what is called sustain. When it is necessary to monitor or quantify the changes occurring for a sample of wood, it is customary to measure these parameters.

Wood is hydroscopic and these properties are sensitive to changes in atmospheric conditions. Changes in wood moisture content has influence primarily on its mass, but also on dimensions, MOE and loss factor. For this reason, it is desirable to keep the samples in a chamber with controlled atmospheric conditions before and during the test. If samples are taken from the chamber to measure their characteristics, it is necessary to minimize the time required for measurement, and to follow the same procedures so that the conditions are always the same.

One standard procedure for measuring MOE uses impulse excitation for obtaining resonances of a prismatic rectangular sample [1,2]. For a piece of known dimensions l_x, l_y, l_z, MOE can be calculated. The signal can be recorded with the microphone placed near the sample. In this case, the first mode of flexural vibration is identified in the frequency spectrum of the recorded signal and used to calculate MOE. The decreasing sound energy after a transient impulse is frequency dependent, and by analysis it is possible to determine also the loss factor.

2. Oscillation modes

The correct identification of the first flexural mode in the signal spectrum can sometimes be a problem if the MOE cannot be estimated, or if, due to the geometry and properties of the sample, there are other mode with similar frequency with which it may be mixed. Visualization of oscillation modes of the tested sample can be helpful with this process, and sample scanning in the Very Near Field (VNF) is one method that allows this using simple instrumentation. The sample is excited with vibrations that are usually generated by an electrodynamic exciter driven by some test signal. The scanning process is basically point-to-point microphone recording of a vibrating surface's sound response, measured directly above it. The microphone should be kept only few millimeters above the analyzed sample to make sure that it is in a VNF. If distance from vibrating surface d satisfies equation (1) where a is the width of the antinode, or the distance between the two adjacent nodes, it could be considered as VNF[3].

$$d < 0.11\ a \qquad (1)$$

The sound pressure recorded with the microphone kept within this limit does not vary more than 1 dB, and it is proportional to vibration velocity of observed surface.

The experimental setup in this paper was primarily designed for examining the influence of long-term vibration exposure of wood in combination with different wood treatments. Observing the vibration modes of the samples can provide additional information on the possible spatial change in (non-homogeneous) wood properties, and for this reason, those measurements were applied. During experiment preparation, various modifications of the apparatus, excitation signal, and type, location and mounting of electrodynamic exciter were examined in order to meet the required criteria of simplicity, precision, repeatability, speed and compatibility with the measurements prescribed by standards.

3. Measurement using the electrodynamic exciter

The experimental setup shown in Figure 1 left shows apparatus for recording the response of a wood specimen in a VNF. The specimen, with its characteristics shown in Figure 1 right, is pseudo-rigidly fixed at one end to an electrodynamic exciter which excites the wood sample. During all performed measurements sound samples were recorded (2 mm above the surface) with a electret lapel microphone that was attached to a digital caliper. The calipers slider, and microphone, could be freely moved across the entire sample and position changes read from the caliper's digital display. This allowed fast and precise point-to-point moving of microphone in order to record sample's response to a given excitation.

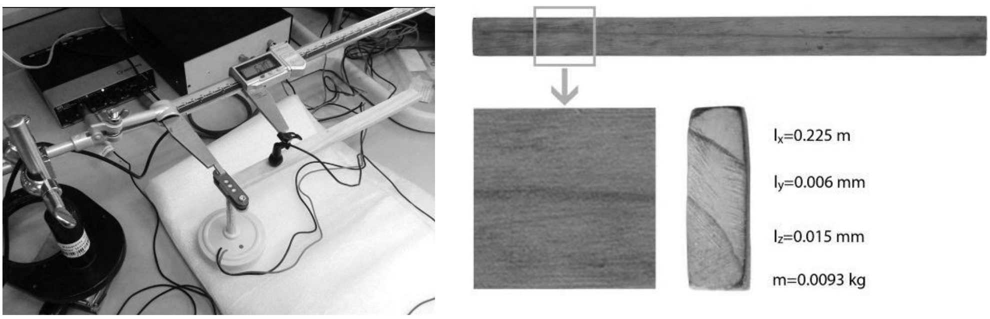
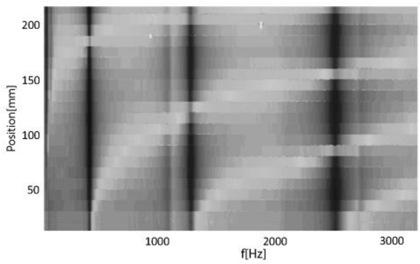


Figure 1: left: Experimental setup for VNF wood analyses using the electrodynamic exciter; right: Specimen characteristics

The sine sweep signal was found to be the best test signal for measurement. It was important to have same level of excitation from electrodynamic exciter as some non-linearities in the system response were recorded; in addition to the expected difference in response intensities, changes in resonant frequency of modes occurred. For higher levels, it was noticed that the resonance moves slightly to lower frequencies.

For N number measurement points along the length of the sample signals were recorded with the microphone in a VNF. For a signal at each recorded point, a spectrum with a frequency resolution of 1 Hz in the frequency range from 1 to 3200 Hz was calculated and the results stored in a 3200 x N matrix.



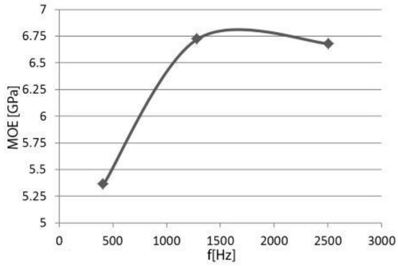


Figure 2: left: Visualization of vibration modes for clamped-free beam; right: Young's modulus of elasticity depending on the observed frequency for clamped-free beam

Graphic representation of this matrix, shown in Figure 2 left, visualizes the sample's oscillation modes. The graph represents the sound pressure level that appears on the surface of the beam depending on the position of the observed point and frequency. Modes, drawn on graph with black, are natural frequencies of the observed system. Their frequencies are expressed with the approximation formula (2)

$$f_n = \frac{C_n^2}{2\pi\sqrt{12}} \frac{l_y}{l_x^2} \sqrt{\frac{E}{\rho}}$$

where E is MOE, ρ the density of wood, l_x the length of the sample and l_y the thickness of the sample [4]. C_n is a coefficient that depends on the boundary conditions of the analyzed beam. The coefficients in the case of a free-free boundary conditions are C_1 = 4.7300; C_2 = 7.8532; C_3 = 10.9956; C_4 = 14.1372; C_5 = 17.2788; C_6 = 20.4204, etc. which allows estimation of resonant frequencies f1, f2, f3, etc. In the case of cantilever beam anchored at only one end (clamped-free), these coefficients are C_1 = 1.8751; C_2 = 4.6941; C_3 = 7.8548; C_4 = 10.9955; C_5 = 14.1372; C_6 = 17.2788; C_7 = 20.4204, etc. Comparing these coefficients for those two cases it can be noticed that the samples will have all resonances at almost same frequencies in both cases, except for the lowest resonance that occurs only in the case of a cantilever. For this reason, cantilever beam measurements are comparable with analyzes prescribed by the standard which uses free-free boundary conditions.

The values of the resonant frequencies, that can be identified from the graph, match the theoretical expectations. Second vibration mode can be identified at f2=415 Hz, third at f3=1286 Hz and fourth at f4=2512 Hz. Frequencies above 3500 Hz have not been analyzed. The lowest mode for this setup which is expected at a frequency below 100 Hz, according to the position of other modes, is not identified on this graph.

For identified frequencies, and rearranged equation 2, the MOE for the wooden specimen can be calculated for all these frequencies. The change in the calculated MOE depending on the observed frequency is shown in Figure 2 right. The value of modulus of elasticity calculated using the resonance of the second mode f_2 is lower than the modulus that are calculated using the resonance of the third f_3 and fourth f_4 mode. This is likely a result of the imperfect support conditions and differences between the real behavior and the simple theoretical model.

4. Measurement using the impulse excitation

Using of electrodynamic exciter changes the boundary conditions, and the behavior of such complex mechanical system that consist of an isotropic specimen and transducer is not easy to predict. Fortunately, visualization of vibration modes also can be achieved by scanning in a

VNF while the sample remains in free-free boundary conditions, and where sample is excited with impulse (hammer). Experimental setup shown in Figure 3 left includes two microphones to record the specimen response, whose characteristics are shown in Figure 3 right. The M_1 microphone is used, as in the experiment above, to record the response at the N points along the specimen, while the reference M_2 microphone does not move from one point. Its role is to register variations in different levels of sound pressure due to a nonuniform hammer impact, so the signals recorded with the M_1 microphone are increased or decreased according to variations of signal recorded with the M_2 microphone.

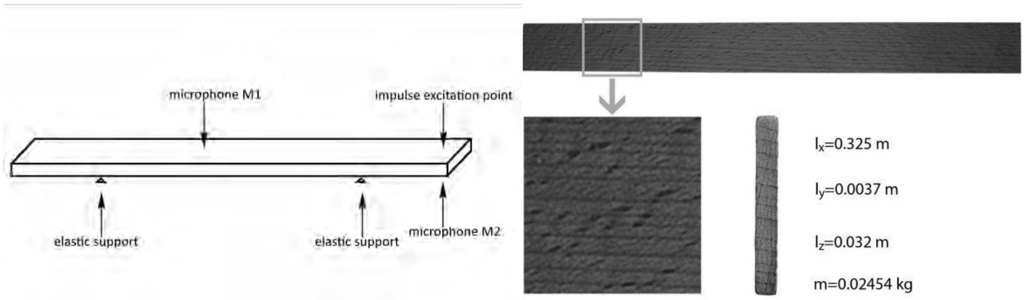


Figure 3: left: Experimental setup for VNF wood analyses using the impact hammer; right: Specimen characteristics

Experimental results for this setup are shown In Figure 4 left. Good visualization has been achieved for all modes up to 2500 Hz. Based on five identified modes (182 Hz, 508 Hz, 991 Hz,1633 Hz,2438 Hz), according to equation 2, MOE can be calculated, by using the C_n parameters for free-free boundary conditions. The Figure 4 right shows a change in the value of the modulus of elasticity depending on the observed frequency. At all analyzed frequencies, the modulus of elasticity has approximately the same value.

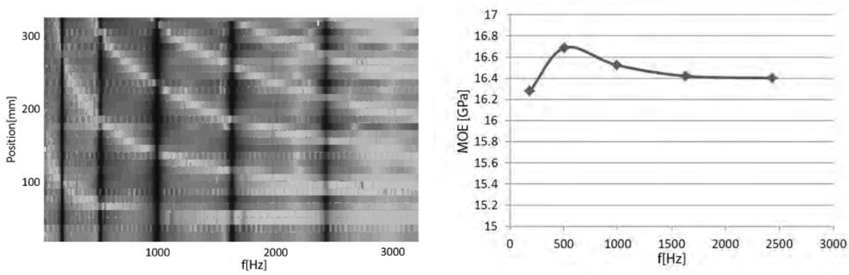


Figure 4: left: Visualization of vibration modes for free-free beam; right: Young's modulus of elasticity depending on the observed frequency for free-free beam

5. Conclusions

The VNF method is a simple way of measuring resonant frequencies while also visualizing the vibration modes to which they belong. The proper estimation of mechanical properties, such as MOE, from these results requires good theoretical formulas (ranging from simplified formulas as here, or complex numerical models), but also good knowledge of boundary conditions. Use of VNF in free-free vibration is therefore a useful for simplifying the system.

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An Innovative Monitoring Plan: the Case of Museo del Violino (Cremona, Italy)

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Abstract

Preventive actions have increasingly been playing an important role over time in the Cultural Heritage Conservation. The aim of this practice is to reduce the risk of artworks' deterioration and to slow down the natural ageing of materials. The case of musical instruments is generally more complex since it deals with both the material preservation needs and the original function of the object to produce sounds. The Arvedi Laboratory of Non-Invasive Diagnostics has outlined an innovative monitoring plan to check the instruments' preservation status through the time in order to suggest better conservation practices and to ensure the material durability. Microclimatic conditions and some analytical parameters have been monitored through non-invasive methods during the period of a year. Three violins of the collection held in the Museo del Violino were selected, both less and frequently played, to understand the influence of sound performances on the material preservation.

1. Introduction

In the wide field of Cultural Heritage Conservation, preventive actions have assumed an increasing relevance. According to the main institutions' specific recommendation, the aim of the Preventive Conservation is to reduce the risk of artworks' deterioration and to slow down the natural material ageing, avoiding the invasive restoration practices [1-4]. On musical instruments, the issue is more complex since their material preservation sometime cannot ignore the original purpose of the object that is to produce sounds [5].

Generally, a violin is mainly made of wood treated with inorganic compounds and organic binder, over which some varnish layers (variable mixtures of oils, resins, inorganic pigments or organic dyes) are laid to give it protection and aesthetic properties [6]. Such a composite object constitutes a whole system complex to study: materials interacts among themselves and with the environment while mechanical stresses occur due to the tuning and the playing strains. It follows that the chief decaying causes are the non-suitable environmental conditions (air temperature, relative humidity and pollutant), the photo-degradation caused by ultraviolet components of light, the biological degradation and hours-long use in concerts as well as bad handling. The resulting effects are cracks, changes in chromatic and compositional characteristics, likewise delamination and thinning of the surface varnish layers [5].

The Arvedi Laboratory proposed a monitoring plan applied on selected violins as a diagnostic tool to evaluate the validity/efficiency of the existing practices in the museum and the potential transformations originated from the "Violin-Environment" system. To this purpose, three historic violins held in the Museo del Violino in Cremona were chosen depending on their frequency of use over a year. This plan allowed to study the influence of the performances on the material preservation. Microclimatic parameters and other markers able to reveal an ongoing material transformation were also considered. Non-invasive analytical techniques carried out on periodic inspections allowed to document and gather information about the state of conservation of the violins.

2. Materials and methods

In January 2017, we started the monitoring of three historical violins (from the least to the most played): Andrea Amati "Carlo IX" (1566), Antonio Stradivari "Clisbee" (1699) and Antonio Stradivari "Vesuvio" (1727c.). The whole monitoring period will last one year, at least.

The definition of the monitoring plan was preceded by a careful experimental phase that allowed the identification of the most suitable parameters, timing, mode of acquisition and data processing. Two regions of interest were selected on the violins' back plate, respectively on the top and on the bottom (Fig.1), through the use of image processing techniques that allowed to identify the areas more subjected to wear, namely those in contact with the musician [7]. The plan also included a continuous monitoring control of the microclimatic parameters of rooms and showcases (air temperature and relative humidity) using mini data loggers (Testo 174H) as well as an illuminance checking by means of a digital light meter (Velleman DEM 300).

The analytical investigations were performed every two months and consisted in: weight measurements; analysis of UV-Induced Fluorescence (UVIFL) images acquired with a Nikon D4 full-frame digital camera equipped with a 50mm f.1.4 Nikkor objective, using two Wood lamps Philips TL-D 36 W BBL IPP low-pressure Hg tubes (emission peak at 360 nm) as UV sources; colorimetric measurements, performed by means of a portable Konica Minolta (CM-2600d) spectrophotometer; X-ray Fluorescence analysis, carried out by a portable energy-XRF spectrometer ELIO produced by XGLab srl; Fourier Transform Infrared (FTIR) analyses, performed using the Alpha portable spectrometer (Bruker) equipped with the R-Alpha module. The monitored parameters chosen as alteration markers are shown in Table 1.

To ensure the repeatability of the measurements and the comparability of the data, the environmental conditions were kept under control during each session, and the instrumental parameters were kept constant. In addition, a software was developed to optimize the handling of the final great amount of data.

Table 1: Overview of the parameters involved in the monitoring plan. Linked material transformations, decaying processes and analytical techniques are also listed.

MONITORED PARAMETER	OBSERVED CHANGE	ANALYTICAL TECHNIQUE	ALTERATION CAUSE	KIND OF ALTERATION
Weight	Increase/ decrease values	Weight measurement	Sorption/desorption of humidity from the air (change of thermo-hygrometric conditions - concert)	Mechanical deformations/cracks
Chromatic characteristics	Changes in tone and/or in brightness of the surface	Colorimetry	Yellowing varnish Wood darkening due to soiling, oxidation and/or hydrolysis	Photochemical/chemical decay Biodegradation
UV fluorescence properties	Fluorescence colour, intensity, area and distribution	Analysis of UVIFL images by histogram	Fluorescent matter alteration New surface restoration substance Surface layer wear	Photochemical/chemical decay Mechanical wear

Chemical composition	Changes in the spectrum	XRF spectroscopy FTIR reflection spectroscopy	Chemical transformations Mechanical wear	Chemical/ Photochemical decay Mechanical wear

3. Results and discussion

The results reported in this paper refer to the data collected in the first five months of the year 2017, namely those of the first and the second sessions. A further update will come out from the next sessions. Here, only the violins "Carlo IX" and "Vesuvio" were presented as limit cases of a low and a high usage frequency, respectively. As regards the microclimatic parameters, significant variations were recorded in the room environment, while smaller fluctuations occurred inside the showcase.

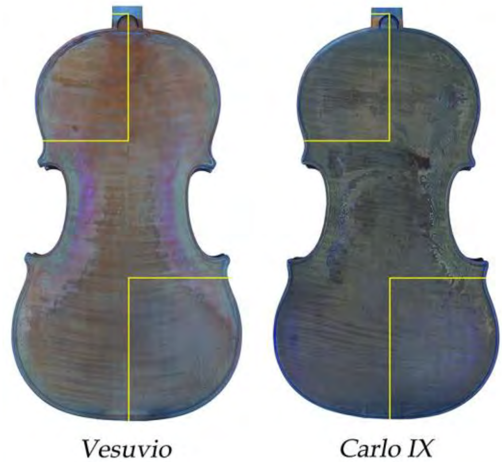

Figure 1: UVIFL images of the two violins' backplates ("Vesuvio" on the left and "Carlo IX" on the right): yellow open squares mark the regions of interest (worn areas).

About the "Vesuvio", the area of the backplate that seemed to be affected by variations over time is the inferior one. By the histograms' comparison of UVIFL images, performed using χ^2 test, this area showed values greater than 0.1, up to 0.25; small values in an absolute sense, but remarkably different from those in the top area, where χ^2 was always lower than 0.04. Likewise, colorimetric differences (ΔE values around 2), XRF and IR spectra variations occurred within some sub-areas. XRF spectra related to the second session, in particular, showed a greater intensity for the peaks of some elements (Ca, K, Cu and Zn) compared to the first session, as shown in figure 2a. Within the same areas, an increase in the intensity of proteinaceous bands was observed in the IR spectra. The rise in intensity of these signals (in particular Ca, K and protein compound), which are probably related to the wood treatment, suggested the thinning of the overlying paint layers as a consequence of wear. Among the detected elements, Cu and Zn are often associated to the musicians' sweat residues due to the sound performances as reported by Echard [8].

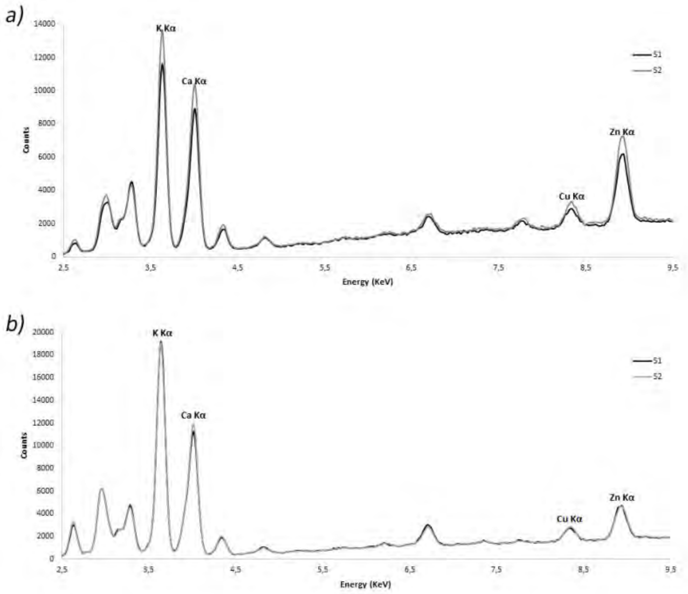

Figure 2: Comparison of XRF spectra acquired in the same measure point in two consecutive sessions (the first one S1 and the second one S2) on the Vesuvio (a) and Carlo IX (b) back plate.

In the “Carlo IX” violin no significant variations were observed. The histograms’ comparison of UVIFL images did not present significant variations between the two sessions, with values of χ^2 near to zero (that is a mark of very high similarity). The colorimetric variations are not significative, as well as the XRF elemental data (Fig. 2b). Similarly, the IR analysis showed a uniformity in the intensity of the spectral signals thus confirming the unchanged and constant presence of compounds such as benzoin resin, shellac or oleo/resinous varnish and proteinaceous material.

4. Conclusion

In this work, still in progress, some preliminary results allowed to outline a detailed framework of the current conservation state of some historical violins and to gather further information about the Preventive Conservation in the musical instruments field.

The most significant variations were observed in the lower area of the back plate, confirming that this is the region most susceptible to stress, and therefore to wear, during the playing of the violin. Reasonably, it suffers for the greatest interactions with the musicians, despite the presence of the shoulder rest that should be used during auditions and concerts.

Considering two violins as representatives of two extreme cases (the “Vesuvio” played a lot whereas the “Carlo IX” did not play at all), preliminary data showed that significative variations occurred only in the case of the “Vesuvio”. This suggested that the preservation of an instrument seems to be mostly influenced by its frequency of use, although further analyses will allow us to confirm or deny it.

The data acquired during all the year will be used to improve the existing conservative procedures aimed at ensuring the material durability. Variations will be discussed and contextualized in more detail once the next sessions are over: increasing the data set will make it possible to treat them statistically, thus enhancing the results’ reliability.

Acknowledgement

The authors gratefully acknowledge acknowledge the Museum of Violin of Cremona and Cultural District of Violin Makers of Cremona. Special thanks to Fondazione Arvedi Buschini for funding the researches of Arvedi Laboratory of Non Invasive Diagnostics.

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Correlation of Mechanical Behaviour with Advanced Chemical Analysis of Varnished Wood

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Abstract

The aim in the current work is to use non-invasive and minimally invasive techniques at the nano-level; atomic force microscopy (AFM) for imaging together with nano-mechanical analysis to characterise varnished surfaces on model violin samples, naturally aged and accelerated aged. These samples were prepared according to traditional recipes.The information from nano-mechanical analysis will be complemented with chemical analysis using micro-Fourier Transform Infra-red analysis.

1. Introduction

Within the framework of two COST IE0601 short term scientific missions attention was directed to the physicochemical state of varnish and how this affects the mechanical response of wood [1][2]. It was observed that the stiffness of the wood measured in tension in the radial direction increased in the presence of the dammar varnish layer and these results were consistent with what was reported previously using a theoretical approach on spruce plates with natural resins [3].There was a difference in the mechanical properties and response to RH of panels stored within protected enclosures such as micro-climate frames and showcases and outside these enclosures together with a difference in the topography of varnished surfaces. Chemical analysis at the molecular level using gas chromatography and mass spectrometry (GC/MS) showed differences in the chemical composition of varnished panels maintained within and outside the enclosures [4]. On the basis of these studies the aim in the current work is to use non-invasive AFM for imaging together with nano-mechanical studies to characterise varnished surfaces at the nano-level. Force spectroscopy with AFM has emerged as powerful technique able to provide information on the nanomechanical properties of a wide variety of materials at the nanometre/ nanonewton scale [5]. This information will be complemented with chemical analysis using micro-Fourier Transform Infra-red analysis.

2. Methods

The portable Nanosurf Easyscan 2 AFM operating in intermittent contact mode was used for *in situ* imaging of the surface of a violin. The violin was made by Boosey&Co and was bought in 1946, so is likely to be no more than 70 years old. It has never been re-varnished but has been polished with Hidersine 3V violin wax and varnish cleaner. The AFM (JPK) was used to measure the nanomechanical properties via force distance curves of the model violin samples. The cantilever used for the measurements had a spring stiffness k= 38 N/m. Once the cantilever makes contact with the surface it is then used to measure Young's modulus or stiffness. When the cantilever retracts adhesion forces can be measured. The Bruker ICON Dimension 3000 with Peak Force QNM was also used for nanomechanical measurements on both the model varnish samples and on collagen-based samples such as leather used within historical organs. The probe used for the measurements had a spring stiffness k= 5.008 N/m.

Micro- Fourier Transform Infra-Red Analysis (Micro-FTIR) was used in order to establish the differential ageing of the varnish components within the sample, from the surface to the wood support. Experiments were performed at the IRIS beamline (BESSY II, HZB, Berlin, Germany) on a Thermo Nicolet Continuum™ microscope equipped with a mercury–cadmium–telluride

(MCT) detector. The sample was mounted on a diamond cell on a motorized microscope stage and raster scanned through the synchrotron beam with a diameter of 15 µm collecting a grid-like pattern of IR spectra spaced in 10-µm increments. Measurements were performed in transmission mode at a magnification ×32 using confocal objectives. Infrared spectra were registered between 4,000 and 650 cm^{-1} with a spectral resolution of 4 cm^{-1}. An accumulation of 128 scans per point was used. Background spectra were collected under identical conditions with only the BaF_2 window on which the sections were placed. The spectrum and mapping acquisition was performed by using the OMNIC Atlµs™ software] [6]. The sample preparation protocol consisted in the microtoming of the samples without embedding at 10 µm.

3. Samples

Model samples were prepared with traditional violin varnish recipes by Gabriele Carletti (2012). These model systems consist of several layers on top of maple wood (6cm x1.2cmx2cm). Initially two samples were studied. These have the following layer types: (1) an aqueous based preparation layer type, and (2) an ethanol based preparation layer type. The composition of the preparation layer was (1) potassium dichromate and for the other (2) Sandalwood and aloe. The varnish layers were (1) oil-based containing stand oil, spirit of turpentine, Venice turpentine, Mastic and Sandarac and (2) spirit-based containing ethyl alcohol, Venice of turpentine, Mastic, Elemi, and Shellac. Naturally aged samples (10 months) and accelerated aged samples were measured. Accelerated aging was performed for two to four weeks after 10 months' natural ageing in a Solarbox 1500e RH (Erichsen, Milan, Italy) purchased from Erichsen (Germany). Ageing conditions were as follows: 20C, RH 50%, excitation with Xenon lamp (wavelength 280-400nm) power 400W. A soda-lime glass uv filter was used to simulate indoor exposure. Irradiation uniformity was guaranteed by a parabolic reflector chamber with the Xenon lamp in focus.

4. Results

Figure 1 shows in situ imaging of the surface of a violin using the portable Nanosurf Easyscan 2 AFM operating in intermittent contact mode. The ability to visualise the surface at the nanoscale level can provide information on the types of preparation used.

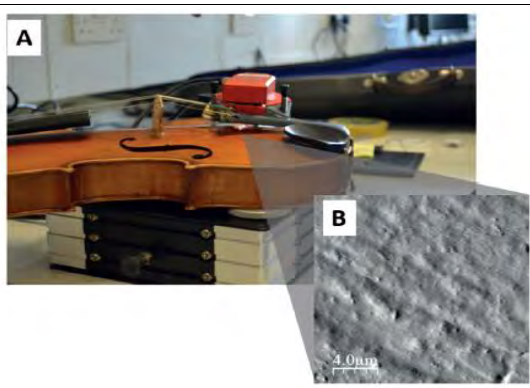

Figure 1. Nanosurf Easyscan 2 AFM head on a violin placed on an anti-vibration table (A) and AFM image of the surface of the violin (B) [7]

AFM images (10umx10um) of the two model samples oil-based and spirit based are shown in Figure 2(a) and 2(b) respectively. The surfaces of the spirit based varnishes were in general smoother than the oil-based sample. Several locations were tested.

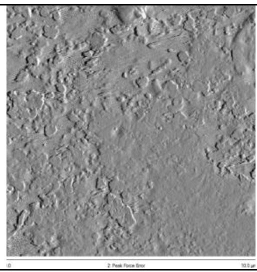

Figure 2(a) AFM image of oil-based varnish

Figure 2(b) AFM image of spirit-based varnish

FTIR spectra of the varnish layers of the two systems analysed showed strong and broad carbonyl stretching absorption and alkyl stretching bands. Differences could be observed in agreement with their composition. Oil-based varnish shows a characteristic C=O stretching vibrations centred at 1735 cm-1 with a shoulder at 1708 cm-1 characteristic of the ester linkages of the triglycerides from the drying oil and the free fatty acids formed during its ageing as shown in Figure 3(a).

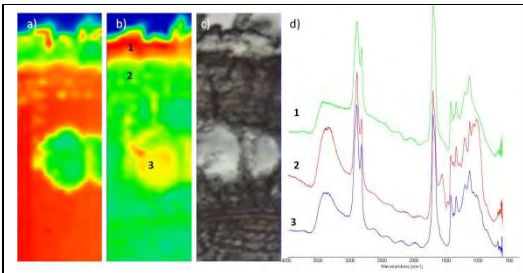

Figure 3 (a) SR-microFTIR mapping of oil-based varnish (sample 1). (a) and (b) Chemical image at 1000 and 1735 cm^{-1}, respectively (c) Photomicrograph of the microtomed cross-section of model system 1 (width: 10 µm). **(**d) FTIR spectra representative of the varnish layer (1), the penetration areas (2,3). Oil-based varnish shows a high penetration into the wood porous structure (around 200 µm).

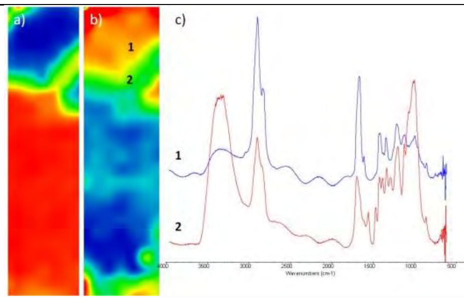

Figure 3(b) SR-microFTIR mapping of spirit-based (sample 6). (a) and (b) Chemical image of 1000 and 1700 cm^{-1}, respectively.c) FTIR spectra representative of the varnish layer (1), the wood penetrated area (2). The spirit based varnish remains on the surface with a neat separation from the wood.

Spectra of spirit-based varnish show a C=O stretching band centred at 1696 cm-1 in agreement with the presence of a terpenoid resin in its composition. Medium intensity absorption bands at 1,452, 1,373 cm^{-1} are in agreement with the presence of a terpenoid resin in both samples [8]. Interestingly, from the FTIR maps, it is easy to notice the different penetration of the vanish layer into the wood support. The oil based varnish based varnish shows a high penetration into the wood porous structure (around 200 µm) while the spirit based one remains on the surface with a neat separation with the wood. That could be related to the preparation characteristics. Analysis of differently made paint model systems should follow to establish the reason for this different behaviour.

With regard to the mechanical properties of these samples measured at the nanoscale level results from the force distance curves obtained from AFM are shown in Figure 4(a)(b) (below). Measurements were made in areas of $50\mu m^2$ on three different locations.

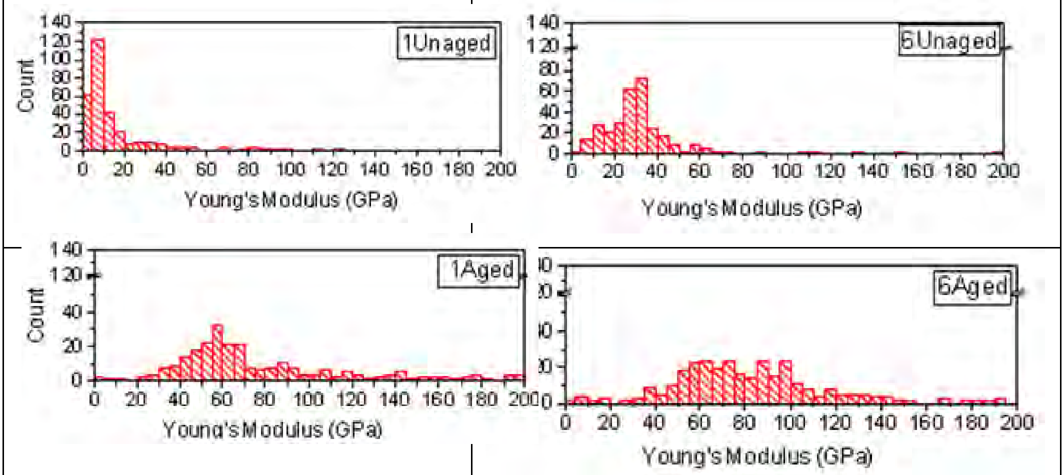

Figure 4 (a) Oil- based varnish layer showing distribution of Young's modulus values in (top) unaged naturally aged 10months (top) and (lower) accelerated aged samples..

Figure 4(b) Spirit - based varnish layer showing distribution of Young's modulus values in (top) unaged naturally aged 10months (top) and (lower) accelerated aged samples.

Young's modulus values in (top) unaged naturally aged 10months (top) and (lower) accelerated aged samples samples. In Figure 4(a) the maximum in the distribution is in the order of 5-10GPa. In the accelerated aged sample there is a clear shift in the maximum of the distribution of Young's modulus to higher values i.e 60GPa. Also there is a broader distribution in the aged sample. These measurements are non-destructive but are limited at this stage as samples are required to fit under the AFM. In future it may be possible to obtain values directly on surfaces of instruments. Values for the distribution of Young's modulus (as calculated from the force distance curves) values are shown for the oil based varnish layer. In the spirit-based sample distributions of Young's modulus were obtained as shown in Figure 4 (b). In the unaged sample the maximum value for the modulus is higher than in the oil based sample and is in the region 30-40GPa. In the accelerated aged spirit-based sample there is also a shift in the maximum of the distribution of Young's modulus to higher values but the distribution of the aged sample (60-100GPa) is broader than in the oil-based sample. Further measurements are in progress to evaluate the difference in mechanical properties of additional model varnish samples. Recent work in the context of another project NANOFORART enabled some preliminary work to be performed on collagen-based materials using nanonechanical analysis. As there are leather materials associated with wooden parts of musical instruments such as historical organs this could be a useful procedure for monitoring the physicochemical state of collagen, the main component of leather. The rationale for evaluation at the nanoscale is to determine whether localised areas of gelatinisation are present. These are known to have a different response to fluctuations in RH and this can lead to cracking.

5. Conclusions

Force spectroscopy with AFM has provided information on the nano-mechanics of oil-based and spirit-based varnishes and the changes that occur on accelerated ageing. Micro-FTIR shows differences in chemical composition between the two varnishes and examination of the layer structure reveals that the stiffer spirit-based varnish shows less penetration into the wood than the oil-based varnish. In situ imaging on a surface of a violin has also been demonstrated.

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A Comparative Study on Adhesives Used in Wooden Musical Instruments Conservation

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Abstract

The aim of this work was to study comparatively the suitability of commonly used adhesives for conserving wooden musical instruments. Natural and synthetic adhesives were selected and their performance was tested on maple (*Acer pseudoplatanus* L.) mock ups, a common wood species in musical instrument construction. The adhesives were evaluated, before and after ageing based on a) the bond strength under shear stress b) the damage of wood after bond failure, c) colour stability under UV exposure and d) their reversibility. Results obtained demonstrated that Paraloid B72 and fish glue had the best overall performance.

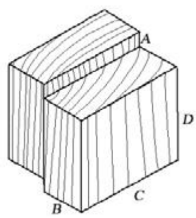
1. Introduction

The selection of the appropriate adhesive in wooden artifacts' conservation is one of the most important decisions a conservator should make. A poor adhesive can cause further and sometimes irreversible damage, both aesthetically and mechanically, to an already deteriorated item. Furthermore, for musical instruments is often demanded to be functional and playable again and thus the role of adhesion becomes more crucial. Hence, the conservator has to be aware of the properties of the adhesive to be used such as their mechanical strength and aging behaviour over time. This work studied comparatively some commonly used in conservation of wooden musical instruments natural and synthetic adhesives in order to examine their performance.

2. Methods

Three natural glues, casein, fish glue and rabbit glue and two synthetic, a methacrylate (Paraloid B-72) and a polyvinyl acetate adhesive (Ravemul M18 Vinavil).) were investigated. Twelve pairs of maple wood, Acer pseudoplatanus L., were used for each glue. The samples were free from imperfections, such as knots and cracks. In total 60 samples were prepared based on the ASTM D 905 (Fig. 1).

Single spreading was applied with different spreading rate for each glue on conditioned samples at 10-12% moisture content. Pressure was then applied onto assembled samples for 4 days. Post-cure conditioning was undertaken in a climate chamber (Binder BKF P720) for 7 days, where temperature (T) and relative humidity (RH) were kept constant at 23± 2 oC and 55% ± 2 respectively.



Dimensions	*A*	*B*	*C*	*D*
mm	*6.3*	*19*	*44.4*	*50.8*

Figure 1: ***Specimens dimensions.***

One group of 20 samples (4 for each glue) was then aged under a XENON Arc lamp with window glass filter in an Atlas Suntest XLS+ chamber at irradiance level 350 W/m2. The samples remained in the chamber according to ASTM G151, until a distinct change in colour was produced. This change was observed in 98 hours when samples have been exposed at a total of 120960 kJ/m2.

A second group of 20 samples was subjected to ageing under two different cycles of RH and temperature, in a climate chamber Binder KBF P 720, based on the ASTM 1183. The duration of the first (T: 23± 2 oC and RH: 78% ± 2) and the second cycle (T: 48.5± 2 oC and RH : 23 ± 2) was initially 24 hours. Then the first cycle was repeated for 72 hours and upon completion was followed by the 2nd cycle conditions for 48 hours and this was repeated for one more week. The last group of 20 samples was kept as control.

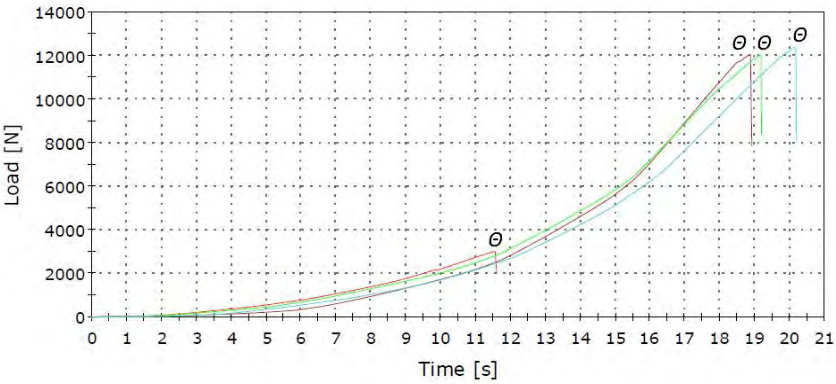
The bond strength was assessed on both aged samples and controls, by shear stress on an Instron 3300 machine with continuous motion of the movable head, at a rate of 5mm/min to failure of bond, based on the ASTM D 905. All measurements reordered have been elaborated through the Blue Hill software.

Colour stability under UV exposure in the Atlas chamber, was evaluated by a Lovibond RT Series SP60 colorimeter, according to the European Standard EN 15886.

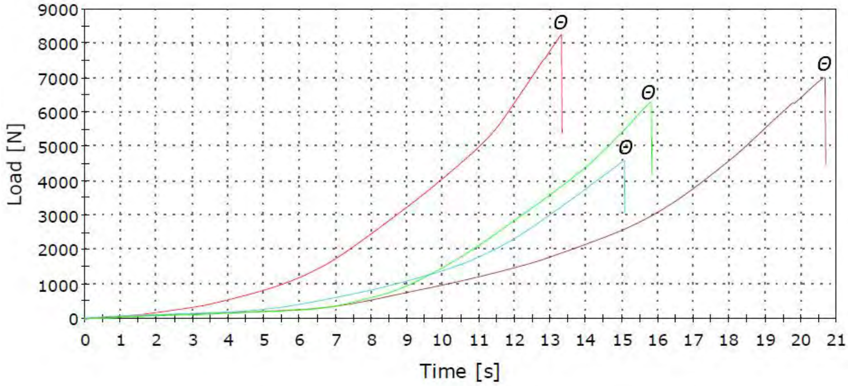
Performance of glues was also was evaluated based on the extent of wood damaged produced during bond failure and based on by their reversibility before and after aging with the use of solvents.

3. Results

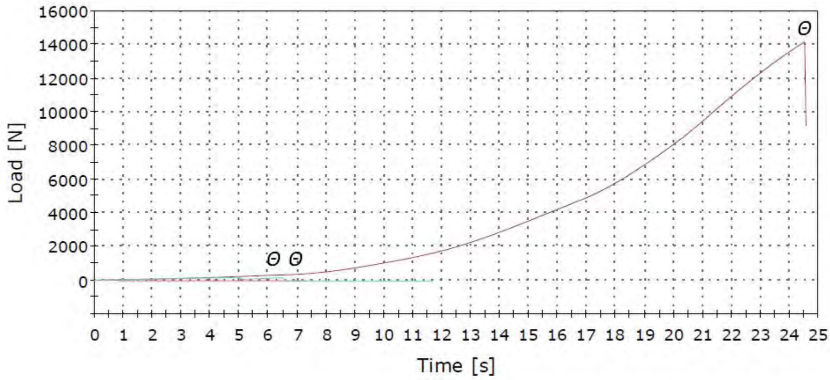
Fish glue demonstrated the highest bond strength followed by Paraloid B72, rabbit glue, Vinavil and lastly casein. No wood failures were observed. Graphs (1-3) present measurements obtained when testing of fish glue samples.



Graph 1: Bond failure of fish glue when applied on four pairs of controls (un-aged samples)



Graph 2: Bond failure of fish glue when applied on four pairs of samples exposed to ageing under XENON arc lamp



Graph 3: Bond failure of fish glue when applied on four pairs of samples exposed to ageing under cycles of RH and temperature.

Concerning reversibility, Paraloid B72 was the easiest to remove from wood surface, before and after accelerated ageing, followed by casein, fish glue, rabbit glue and Vinavil. Accelerated ageing under the XENON arc lamp made Vinavil harder to remove. Changes in the solubility of rabbit glue were also observed in the samples subjected to temperature and RH cycles.

Vinavil was found to be the most colour stable adhesive followed by fish glue, rabbit glue, Paraloid B72 and lastly casein.

4. Conclusion

Results obtained illustrate the following conclusions:

- Fish glue demonstrated the highest bond strength followed by Paraloid B72
- Ageing under cycles of RH and temperature had a higher impact on adhesives' performance than XENON arc lamp ageing.
- Based on the overall performance of the adhesives tested, Paraloid B72 and fish glue demonstrated the best results.

Acknowledgement

The authors gratefully acknowledge and thank for their help and support throughout the course of their work Mr . Athanasios Karabotsos and Mr. Antonis Milidonis for their help with the Instron machine.

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Structure Modification of Polymeric Components of Wood Cell Wall Due to Aging Processes

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Abstract

The idea of this paper is to present the use of both nuclear magnetic resonance spectroscopy method and the analysis of volatile organic compounds to characterize the aging processes of *Picea abies* samples. For the study, historical and modern wood specimens have been compared.

1. Introduction

Wood is subject inevitably to oxidation, hydrolysis, depolymerisation and others chemical processes which, over time, modify its polymeric components, changing its chemical, physical and mechanical characteristics.

The aim of the research is studying the aging of Norway spruce (*Picea abies* (L.) Karst.) wood by means of spectroscopic analysis and understanding the possibility to follow aging and degradation processes that affected the material by means of the collection and the characterization of organic compounds emission as well.

Carbon-13 Cross polarization/ Magic Angle Spinning Nuclear Magnetic Resonance (^{13}C CPMAS NMR) spectroscopy has been used to analyse ancient wood samples and modern wood, used as control. In fact, NMR spectroscopy is a very powerful technique for studying structural changes in wood [1]. Furthermore, volatile organic compound (VOC) emissions from ancient and modern Norway spruce samples were collected and compared. Monitoring and studying the emissions from the raw material, we could have the possibility to analyse wood structure in a non-invasive way, in order to understand also the conservation state of the material [2, 3].

2. Material and Method

2.1. Material

The spruce samples analysed in this study are listened in the Table below.

Historical wood samples were taken from three ancient beam sections, purchased in Ancient palace in northern Italy, aged respectively 174, 302 and 620 years old. The two modern control were obtained by different spruce log, seasoned in the department of Wood Science and Technologies of the University of Florence respectively for 2 and 30 years.

From each samples, a thin powder of wood has been obtained (224 μm <d < 300 μm).

	Name of the specimen	**Period**	**Age of the sample (years)**
Modern wood	MOD_2y	1935-2015	2
	MOD_30y	n.a.- (1987)	30
Historical wood	HIS_COR (1843)	1731-1843	174
	HIS_ROS (1715)	1657-1715	302
	HIS_VIG (1397)	1312-1397	620

2.2. NMR spectroscopy

^{13}C CP/MAS NMR measurements were done using a spectrometer operating at 700 MHz WB equipped with commercial 4-mm probe CPMAS in double-channel C-H. For each sample (~60 mg of powder wood), the spectrum was acquired at a contact time of 1ms.

2.3. VOCs analysis

Proton Transfer Reaction - Time of flight - Mass Spectrometry (PTR-ToF-MS) has been used to rapidly determine VOCs emitted by wood samples. The volatile compounds of modern and historical wood samples (1$\pm$0.15 g of powder wood with MC 12%) were analysed with PTR-ToF-MS by direct injection headspace analysis of the powder wood. Three replicates were prepared for each sample.

The real-time detection of VOCs emitted by different wood samples was achieved using 8000 PTR-ToF system (Ionicon Analytik Innsbruck, Austria).

3. Results and discussion

The polymeric structure of both historical and modern Norway spruce samples were analysed by means of ^{13}C CP/MAS NMR spectroscopy. The weak signal at 21.5 ppm is due to the CH_3 carbon of the acetyl group in hemicelluloses. The signal at 55.6 ppm is assigned to methoxyl groups of aromatic units of lignin. The region between 60 and 105 ppm is dominated by signals mostly assigned to cellulose, whereas the region between 105 and 160 ppm is specific to the aromatic carbons of lignin. The signal at 172 ppm arises from carbonyls in acetoxy groups of hemicelluloses and to acid groups possibly present in wood. The resonances at 148 ppm and at 153 ppm are assigned to different carbon atoms of lignin structure [1]. Figure 1 shows ^{13}C CP/MAS NMR spectra of different samples. Historical spruce exhibited reduced intensities at hemicellulose-related peaks (21.5 and 62 ppm) compared with modern spruce, clearly indicating the occurrence of hemicelluloses degradation (moistly deacetylation of hemicellulose). By contrast the relative amount of carbohydrates and lignin (evaluated from the ratio between the integral of signal at 105 ppm of the C-1 carbon of cellulose and the integral at 55.6 ppm of the methoxyl groups of lignin) did not show a significant decrease in the amount of carbohydrates that had eventually permitted a further discrimination between modern and historical wood. As well as, lignin did not present any depletion of the β–O-4 linkages in its structure.

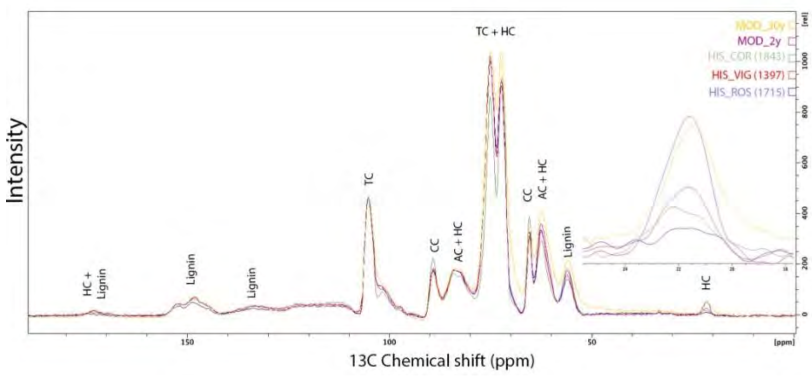

Figure 1: ^{13}C CP/MAS NMR spectra of spruce derived from modern control (MOD_2y and MOD_30y) and the three historical specimens. The contact time was set to 1ms. The peaks were assigned to total cellulose (TC), crystalline cellulose (CC), amorphous cellulose (AC), hemicellulose (HC) and lignin.

Dealing with VOC emissions, several mass peaks in the range of measured masses (m/z= 20-205) were detected from modern and historical *Picea abies* specimens with a MC=12%. Among these, the main compounds detected by PTR-ToF-MS were m/z= 31.018 Tentative Identification: formaldehyde, m/z = 33.033 TI: methanol, m/z = 45.033 TI: acetaldehyde, m/z = 47.049 TI: ethanol, m/z = 59.049 TI: acetone, m/z = 61.028 TI: acetic acid, m/z = 69.036 TI: furan, m/z = 69.069 TI: isoprene, m/z = 93.070 TI: toluene or p-cymene fragment, m/z = 97.028 TI: furfural, and m/z = 137.132 TI: monoterpenes. The masses emitted in the headspace of modern and historical wood were shown in Figure 2.

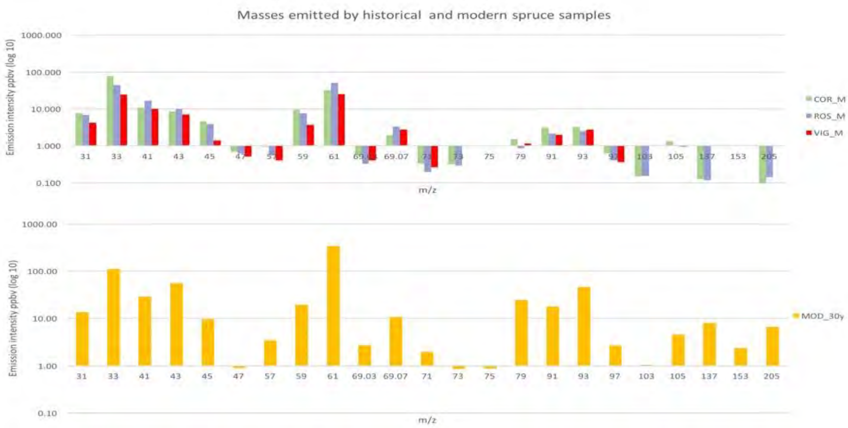

Figure 2: Emission rate of the main VOCs detected by historical and modern wood samples.

The source of acetic acid is due to acetyl group hydrolysis in the hemicellulose [4]. Formaldehyde, acetaldehyde, 2–propenal, butanal, and butanone, could be attributed to the breakdown of the polysaccharide fraction of the wood, while the emission of furfural is still due to hydrolysis of carbohydrates [5]. Furan and furan derivatives are usually associated to thermal degradation products of cellulose and other polysaccharides [2].

4. Conclusion

The nature of VOCs emitted by modern and historical wood did not show significant differences, only the amount of some of them allowed the identification of different clusters of age.

The depletion of hemicellulose in the historical samples evaluated by NMR, is associated to the emission of acetic acid and furfural. But these compounds were emitted by modern wood samples as well. This behaviour seems to indicate that the native polymeric structure of wood (*i.e.* cellulose, hemicellulose, lignin, and their reciprocal bonding) starts its modification immediately after the cut of the tree, initiating a process of aging, whose practical importance is recognizable over a very long period, and that can affect the physical, mechanical, and acoustical properties of wood.

For the other type of emissions there is not a spectroscopic evidence.

Being able to correlate degradation processes to specific organic compound emissions could contribute to understand how the wood of the artefacts modifies in consequences of the inevitable decay processes. This knowledge could contribute to propose the most appropriate preventative maintenance procedures as well.

VOCs emission characterization might have important implication for conservation of wooden musical instruments too, providing information about material aging, its state of preservation and conservation, and the microclimate in conservation cases [6].

Acknowledgement

The authors gratefully acknowledge the CERM team who has permitted NMR analysis.

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Conservation and Restoration of Two Harpsichords at *San Colombano*, Bologna (Italy): Acoustic Analysis

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Abstract

Located in the city centre of Bologna, the Museo of San Colombano is an important collection of keyboard Musical Instruments in Bologna, that was opened in 2010. It hosts the Private Collection of Luigi Ferdinando Tagliavini, a world-named organist and harpsichordist that collected several harpsichords for almost 50 years. This paper deals with the acoustic analysis undertaken in two important musical instruments after their preservation, belonging to the Collection, namely the "Giusti" and the "De Gand" harpsichords.

1. Introduction

The preservation and conservation of ancient string instruments is a complex matter, for a number of different reasons. When the instruments we have today were made, their masters knew all the secrets of wood, of metal and of all the materials, and especially of a good construction. They didn't leave many books, what they knew was (sometimes) handed on to their disciples through work and not through writings.

Today our situation is quite different: we have masterworks that survived through the centuries and from these objects we try to get the secrets of their construction, to improve our knowledge about their conservation and restoration. This matter is often devoted to Organologists, who search for information, especially in the last years, with the aid of other sciences. A relevant role is played by acoustics, which, with its great improvements in technology, can today give a lot of information about the behaviour of soundboards, of strings and their interaction in sound production.

During this work, the soundboard behaviour of two Italian harpsichords of XVII century was analysed, together with sound analysis of strings. Three types of vibrational analysis have been pointed out: modal analysis, intensity of acoustic radiation and loss factor measurements, in order to get a complete vision through their comparisons.

2. The Luigi Ferdinando Tagliavini Collection

Located in the very city centre of Bologna, the Museo of San Colombano is an important collection of keyboard Musical Instruments in Italy, that was opened in 2010. It hosts the Private Collection of Luigi Ferdinando Tagliavini, a world-named organist and harpsichordist that collected several harpsichords for more than 40 years. He died the 11th July 2017.

The San Colombano collection includes three pianos (one of them was built in 1799), a portative organ (17th Century), 7 spinets, and 5 harpsichords, all in efficient conditions.

3. The two harpsichords

The harpsichord craft reached its best period in Italy from XVI to XVIII century. In Europe, there was a great demand for Italian harpsichords, which had different characteristics compared with their cousins of other national schools. Their sound was sharper and ideal for accompaniment, due to their light structure. The strings doubled their length for each octave, with exception of the last strings in the low register, so that their tail is long and slender ("just scale"). They usually had only one keyboard and two registers, the two of 8'.

The first harpsichord here analysed was made by Giovanni Battista Giusti in 1679 in Ferrara (fig.1). Giovanni Battista Giusti was born between 1624 and 1635 in Lucca. He worked in Rome as builder of harpsichords and lutes. He appeared as a workman in Giuseppe Boni da Cortona's shop from 1648 to 1656, and from 1657 in Girolamo Zenti's one. We have no more information on him since 1659. He probably died in or after 1693. There are a lot of instruments which are improperly attributed to him.

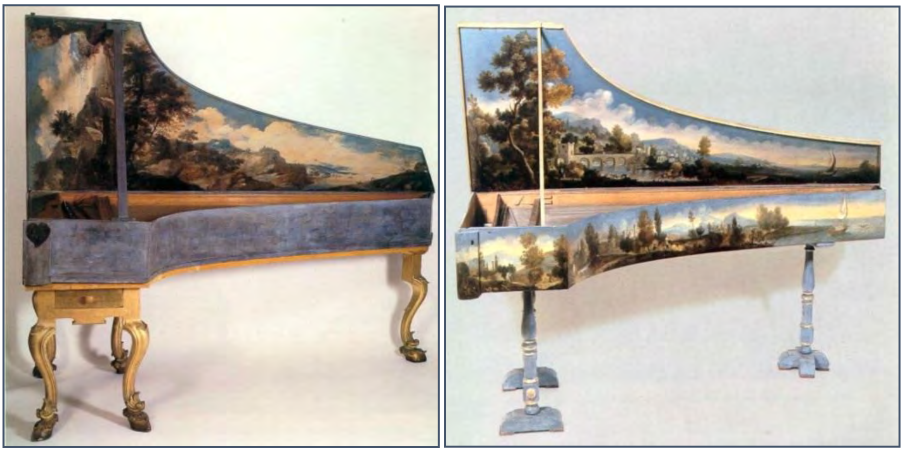

Figure 1: The Giusti (left) and the De Gand (right) harpsichords

This instrument can be considered the "Prince" of Tagliavini's collection, for its high sound quality and its external beauty. It has the original feature of having three registers, the two of 8', as usual, and one of 4'. The date and the place of construction can be read on the ink inscription on the panel behind the keyboard: «IO: BAPTA: IVSTVS: LVCEN: FERRAR: MDCLXXIX».

We have proofs in some letters, that he tried to get the best materials (cypress wood, ebony, ivory) with the help of Giovanni Legrenzi, who lived in Venice in that period. The instrument then belonged to Lodovico Bolognini, marquis of Bologna (1705–1767), as we can read on a label under the instrument support «MARCHIO LVDOVICVS DE BOLOGNINIS». It was probably himself who ordered that support to be made. It's composed of five bent golden legs which end with hooves, referring to the symbol in the armorial-bearings of Bolognini's family: a steinbock. Its style is also typical of wooden art of Bologna in those years. The case is made of spruce, its spine is 235 cm long, and it's simply coloured in turquoise. The soundboard is made of cypress, with no rose on it. It has six ribs: two are between the belly rail and the spine, and don't cross the bridges; other two go parallelly from the bentside to the spine in the back side of the instrument; another one, always parallel to these, is between the bentside and the hitch pin rail of the 4', in the front side (these three ribs cross the 8' bridge); the last one, always parallel, goes from the bentside to one of the first two ribs in the central part of the instrument, and crosses the two bridges and the 4' hitch pin rail. The keyboard has 53 keys, from G-1 A-1 to C5.

The second instrument analysed (fig.1) was made by Mattia di Gand in 1685. Mattia di Gand, born between 1663 and 1667, in despite of its provenience, always worked in Italy, becoming a great constructor of Italian harpsichords. We have information on him as assistant of Giuseppe Boni da Cortona in Rome from 1695, and then he continued to work there from 1703 to 1740.

The paternity of this harpsichord has been discovered only in 1997, during a restoration in which the soundboard has been removed. Two inscriptions have been found on a wooden square between the bottom and the spine, which report the name of «Monsu Matt <…>

Gand». It was probably built in the occasion of a marriage of a noble family, due to the presence of two armorial-bearings surmounted by a crown. It was submitted to an important restoration in 1913 by Giovanni Botteri in Venice, whose label is glued on the hitch pin rail of the front register. The case is 244.7 cm long, it has a very rich painted decoration. The soundboard is made of spruce, with no rose. The traces of a cut-off bar between the lower belly-rail and the spine, and of a littler rib between the bigger one and the spine remain under it. They were probably removed during the restoration of 1913. This instrument was subject of different variations during its life, the most important of which was the enlargement of the keyboard from 53 (the usual extension of that period, which is also the Giusti's harpsichord one) to 60 keys, from F-1 G1-F5, with the consequent rearrangement of various parts. The first enlargement has been probably made by the builder himself, who took the range to 55 keys.

These two instruments, two masterpieces within the San Colombano collection in Bologna, have been chosen for their similarity in dimensions, for the absence of the rose on the soundboard, and for the very near construction time.

4. Acoustic analysis

In this paper, the analysis here presented refers to the first measurement campaign, that was conducted in 1999-2000, and reports only partial results of acoustic radiation and modal analysis.

Accelerometers for Di Gand's			Impulse sources for Di Gand's		
acc n°	*x*	*y*	*point n°*	*x*	*y*
1	*12.1*	*20*	*1*	*13*	*195*
2	*25.7*	*11.5*	*2*	*21*	*138*
3	*18.7*	*41.3*	*3*	*28*	*94*
4	*5.5*	*74*	*4*	*44.5*	*43*
5	*49.3*	*9*	*5*	*61.5*	*19.5*
6	*36.3*	*28.5*	*6*	*79*	*7.5*
7	*22.7*	*66*			
8	*12*	*115*			
9	*7.5*	*161.5*			
10	*55.4*	*32*			
11	*37.3*	*69.5*			
12	*22*	*160*			

Accelerometers for Giusti's			Impulse points for Giusti's		
acc n°	*x*	*y*	***8' bridge***		
1	*11.6*	*13.8*	*point n°*	*x*	*y*
2	*45*	*9.5*	*1*	*13*	*164.3*
3	*9.8*	*39.2*	*2*	*22.5*	*118*
4	*27*	*9.8*	*3*	*29.8*	*88.6*
5	*25.3*	*25.6*	*4*	*45.8*	*39.7*
6	*9.4*	*62.1*	*5*	*61.8*	*15.6*
7	*51.5*	*22.7*	*6*	*78.6*	*6.5*
8	*32.8*	*51*	***4' bridge***		
9	*21.6*	*82.3*	*point n°*	*x*	*y*
10	*12.7*	*116*	*1*	*11.7*	*78*
11	*8.3*	*145.3*	*2*	*21*	*51.8*
12	*38.5*	*73*	*3*	*27.8*	*38*
			4	*44.4*	*17.2*
			5	*60*	*6.3*

Table 1. Measurement points for Di Gand's (left) and Giusti's (right) harpsichords

The instruments haven't been disassembled in any of their parts. The two rooms in which they are conserved, and where the measurements took place haven't any particular acoustic setting. The instruments used were a sound meter level Brüel & Kjær Type 2231, positioned at a distance of about 50 cm from the centre of the soundboard; two accelerometers Brüel & Kjær Type 4398 which were attached to the soundboard with little amounts of wax; an impedance-head hammer Brüel & Kjær Type 8202. The accelerometers and the hammer were connected to three charge amplifiers Brüel & Kjær, one for the hammer Type 2628 and two for the accelerometers Type 2635. The measurements were conducted in the same way for the two instruments. Twelve points where to put the accelerometers have been chosen on the soundboard, and six where to give the impulses with the hammer on the bridge, corresponding to the strings of the C5 key. The measurements were conducted in the same way for the two instruments.

5. The first analysis: acoustic radiation

The acoustic radiation (pressure vs velocity) was studied following the work on pianos made by Giordano [Giordano, 1998], which inspired this kind of research. In this way, we could characterize the sound production features of the soundboard for different frequencies. By calculating the ration between the two channels previously stored in the DAT recorder, the values of the transfer function in the range of frequencies 11-23760 Hz were obtained. A general average of the behaviour of each instrument has also been made, and from these graphs a first difference between the instruments can be pointed out (fig. 2).

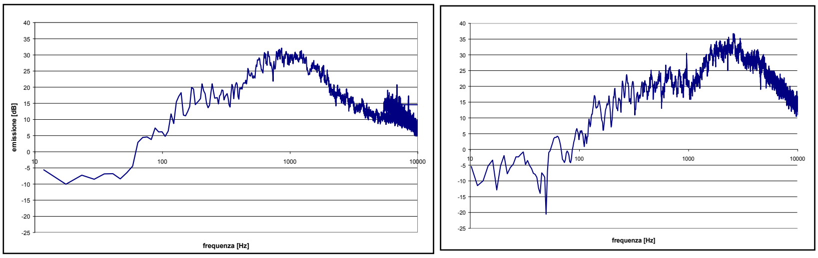

Figure 2: Acoustic radiation for *Giusti's* (left) and *Mattia di Gand's* (right) harpsichords.

6. The second analysis: modal analysis

Starting from the values of acoustic radiation, the frequencies of the proper modes of vibration of the soundboard have been obtained. In Giusti's harpsichord 34 vibration modes have been found up to 800 Hz, whereas in Mattia di Gand's they were 27.

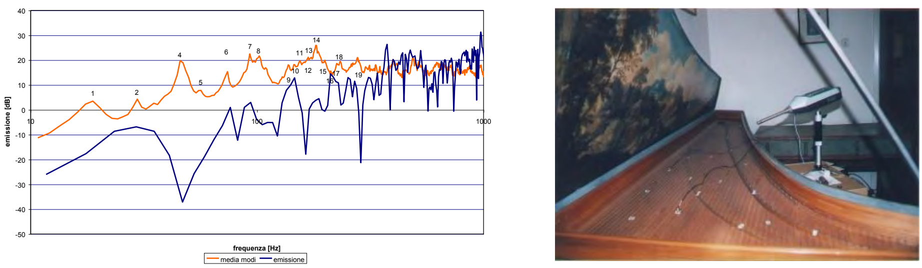

Figure 3 FRF (red) and acoustic radiation (blu) for Di Gand's (left); (right): the measurements

7. Analysis and conclusions

The two ribs in Di Gand's instrument and the bridge on the soundboard seem not to limit the movement. In Giusti's harpsichord, on the contrary, the ribs which extend from the bentside seem to be important in the formation of nodal lines. The two which go from the lower belly-rail to the spine, the same position as Di Gand's cut-off bar, do not influence the movement.

Comparing the graph of the transfer function used for modal analysis, and that of acoustical radiation (fig. 3), the frequencies of maximal radiation often correspond to minima in transfer function, so that the frequencies of better acoustical emission are not the same as those of greater transversal movement of the soundboard. A similar result was found by Suzuki in a work about pianos [Suzuki 1986], where the resonance frequencies didn't coincide with those of acoustical emission, on the contrary they were often in antithesis. He explained this fact in two ways: «(...) (1) the cancellation of sound from different areas of the soundboard surface is the determining factor of radiation efficiency; and (2) the volume velocity of the soundboard vibration becomes large when two modes interfere strongly». Few years later, this lead to the definition of a new parameter, the Intensity of Acoustic Radiation (IAR) [Tronchin 2005].

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Martin's Acoustic Guitar circa 1880: Assessing the Impact of the Former Restorations on the Historical and Acoustic Values

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Abstract

This study associates the conservation-restoration approach with a work on the matter and structure of the instrument made by a physico-chemist, in order to obtain a better description of the object.

The purpose of our research is studying its materials through observations and scientific analysis for being able to describe the material history of this guitar. These results provide an opportunity to understand the restoration interventions that the guitar has gone through, and then to approach the question of the evolution of the restoration concept for the guitars.

We have tried to determine the acoustic modification of this non-playable instrument caused by all the interventions of restoration, and to measure the impact of these former restorations on its historical values.

1. Introduction

The interest of this Martin's acoustic guitar, made in New-York circa 1880 and currently preserved in le Musée de la musique, Paris, lies in its historical testimony. It is one of the first model of acoustic guitar which has inspired the current steel-string guitar. It also contains a major innovation: X-bracing. Furthermore, it symbolizes the technology transfer between Europe and America with the advent of an American lutherie.

As the history significance of this instrument, we made the choice to preserve its role in the development of the steel-string guitar and its print in the American musical landscape. This historic value seems more relevant than the conservation of the sound.

The study of this case has enlightened several restoration processes. The back was removed for stopping the increase of sides cracks, caused by mechanical stress and an unsuitable environment. Thus bindings has been destroyed and replaced. Concerning the surface, the guitar body has been varnished, original shellac and several restoration shellacs are overlaid and a cellulose varnish is present on the top of the neck. The width of the neck has been reduced.

The main damage results from the replacement of the gut strings by steel-strings, a fashion appeared after 1915 with the discover of Hawaiian ukulele and its steel-strings at the Pan-Pacific exhibition in San Francisco. From 1916 to 1930, the entire Martin range is equipped with steel-strings [1]. However, the guitar wasn't able to support the strength of these strings. Consequently, the bridge has been ripped off twice, the soundboard includes convex and concave distortions and the tuning machines are oxidized, incomplete and non-authentic.

Since the creation of this guitar, all the interventions aim at preserving its functionality, its playability, despite the authenticity of the original materials. However, the tuning machine and the bridge seems historically and aesthetically consistent with the date of creation of this Martin's guitar. This kind of pyramid bridge are visible on several Martin's guitar from the 1880s, as the 0-34 Martin's guitar from 1885. Concerning the tuning machine, the same iconography exists in the 19th century but, with the same model, it varies according to the year. The tuning pegs should be in ivory and not in cellulose nitrate, as the example of the 2-24 Martin's guitar from 1888.

2. Methods

In order to assess the composition of varnish, we first studied the guitar under ultraviolet light. This allowed us to make a representation of several areas of varnish, as different fluorescence correspond to different varnishes [5]. However, our perception of fluorescence may be biased by the diffusion of visible light by the object. To refine our results, we measured fluorescence and reflectance spectra of samples. Apparent fluorescence can be corrected using reflectance in visible light [4]. The following formula gives us the correction factor γ

$$\gamma = \left(1 + \sqrt{\frac{A}{A+2}}\right)\left(1 + \sqrt{\frac{A(A+2)}{A_{max}(A_{max}+2)}}\right)$$

with $A = \frac{(1-R^2)}{2R}$, R the relative reflectance of the material (function of wavelength) and A_{max} the value of A at the maximal emission of the lamp (365 nm).

We also measured infrared spectra on each varnish area and compared measured spectra to a data base.

Concerning the acoustical structure, we aim to determine vibration modes of the soundboard before and after the bounding of the bridge, by measuring the displacement of the soundboard with an accelerometer. Thus we will be able to quantify the influence of the bridge on the resonance of the soundboard. We will also measure Helmholtz frequency of the rosace cavity. These results will be compared with an ideal guitar in perfect conservation state.

3. Results

UV photography shows an orange-greenish fluorescence on the soundboard, an orange fluorescence on the headpiece and part of the neck, and a blue fluorescence on sides, back and neck (see picture below). Orange fluorescence is typical of shellac, orange-greenish may be old shellac, and blue fluorescence is typical of cellulose-based varnish [3]. IR spectra confirm the presence of shellac on the soundboard, headpiece and neck. Varnish on top of the neck contains cellulose nitrate. Its goal probably is to conceal fingerprints. IR spectra also reveals that sides and back are also covered with shellac, despite a blue fluorescence.

Figure 1 - UV photography of the guitar

Fluorescence spectra have been measured on two shellac samples. The first (reference) is a traditional shellac displaying an orange fluorescence, the second is a shellac displaying blue fluorescence on its center, where the layer is thick, and orange fluorescence on its edges, where the layer is thin. Spectra reveals that both samples have blue and orange emission under UV light (see figure below). The colour of fluorescence is related to the relative intensity of the two peaks.

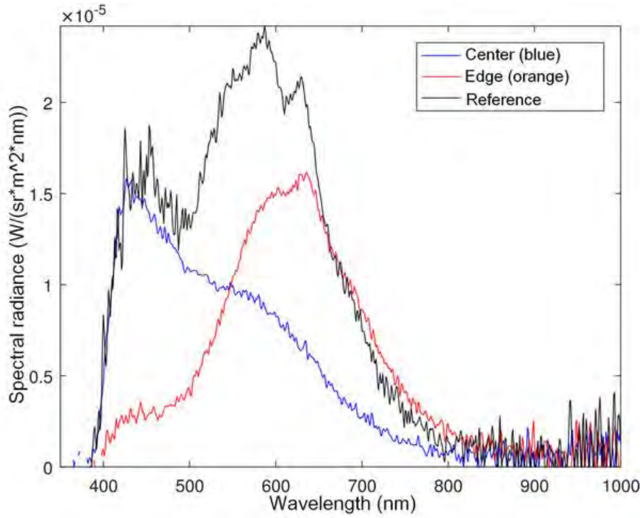

Figure 2 - Corrected fluorescence of the two shellac samples. Peaks are approximately at 420 nm (blue) and 650 nm (orange)

No explanation to this phenomenon has been found yet. Our hypothesis is the presence of two different compounds in shellac with different emission wavelength under UV. Future experience will consist in the study of shellac sample on microscopic scale.

Acoustical experiments have not been performed yet, but we expect that bounding the bridge will muffle some resonance mode of the soundboard and that, despite a poor conservation state, acoustical properties of the guitar are well preserved and similar to an ideal guitar in perfect state.

4. Conclusion

Thanks to the association of our both skills, we traced the material history of this Martin's guitar which brings out the elements that have been changed. This knowledge associated with bibliographic research to define the historic consistent between the new elements and the former, allowed us to make coherent propositions of restoration.

The evolution of the restoration concept is interesting for guitars. Contrary to violins, the guitar has taken a long time to acquire a worldwide recognition [2]. In America, after the growing popularity of banjo, mandolin and ukulele, the guitar succeeds to impose itself around 1930 and becomes the icon of a style of music: the rock'n 'roll. This late reputation explains that this instrument has gone through many interventions only for its playability and not for its "documentary interest". However, we could qualify the impact of these restorations, the instrument lost a certain authenticity but the new elements are historically coherent with the date of creation and this acoustic guitar, transformed in steel-string guitar, embodies the evolution of the current steel-string guitar.

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