Making wooden musical instruments
An integration of different forms of knowledge

Proceedings

Editors: Marco A. Pérez & Sandie Le Conte

3rd Annual Conference
COST FP1302 WoodMusICK

Museu de la Música de Barcelona
September 7-9, 2016

COST
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

COST is supported by the
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Organized by:

MUSEU DE LA MÚSICA

WoodMusICK
FPS COST Action FP1302

In Collaboration with:

L'AUDITORI BARCELONA

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IQS
PERSONA CIENCIA EMPRESA
UNIVERSITAT RAMON LLULL

ISBN: 978-84-945603-3-0
DOI: http://dx.doi.org/10.3926/wm2016

Printing and Binding: OmniaScience (Omnia Publisher SL) · www.omniascience.com
Cover Design: M.A. Pérez. Antonio Torres guitar fretboard

Printed in Barcelona

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A sincere thank you to all the Museu de la Música, L'Auditori and ESMUC staff who have been involved in the organisation of the conference, particularly, L'Auditori: Spaces & Promoters Department, Technical Department, Maintenance-Cleaning-Informatics, Communication & Marketing, Finance; Museu de la Música: Museum Projects & Programs and Collections; ESMUC: Sonology Department, Communication.

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Useful Information

Conference venue

MUSEU DE LA MÚSICA - L'AUDITORI

Lepant 150, 08013 Barcelona
Tel. +34 93 256 36 50
GPS: X: 2.185421, Y: 41.397844
www.museumusica.bcn.cat

The Conference will be held at Sala 4 – Alicia de Larrocha. The entrance is located at the Padilla side of the building.

How to get there:

Tramway: Auditori/Teatre Nacional (T4)
Metro: Marina, Glòries (L1); Monumental (L2)
Bus: Lines 6, 7, 10, 56, 62, 92, V21, H12 – Night bus: N0, N2, N3, N7, N11
Train: RENFE Arc de Triomf – Lines R1, R3, R4, R7 / RENFE Clot-Aragó – Line R2
Bicing (public bike service): Station at Padilla, 151

Delegate pack

Your delegate pack contains the following:

- Name badge
- Conference booklet
- Notebook
- Pen and pencil
- Tube map
- Wifi log-in details

Lunch and refreshments

Refreshments (tea/coffee break) will be available in the Espai 5 (accessible directly from Sala 4) during breaks in the scheduled programme, see the conference timetable for details. Lunch will be served in *Llanterna* restaurant located at the entrance.

Dinner

Wednesday 7th night dinner will be served at Ayre Hotel Rosellon Carrer del Rosselló, 390, 08025 Barcelona.
Nearest station: Sagrada Familia 200 m

Assistants

Auditori attendants are kindly assistant the event. They are able to provide general assistance and orientation. Hostesses are in charge of registration, cloak-room and event assistance.

Emergencies

In the event of an emergency, please notify an attendant, hostess or member of the Auditori staff. In case of a fire, an alarm will sound and all delegates and members of staff will be asked to leave the building through designated emergency exits. Please follow the instructions given by Auditori staff.

Instructions for presenters

Due to the busy conference schedule, it is vital that sessions keep to 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

Accessible restrooms are located on the -1 floor (Sala 4) and on the first floor (Espai 5), next to the elevator.

Concert

Thursday 8th night the concert will be held in Parròquia de Santa Anna
Carrer Santa Anna, 29, 08002 Barcelona
Nearest station: Urquinaona 500 m
www.parroquiasantaanna.org

What is the Museu de la Música about

In March 2007, the Museu de la Música opened its doors to the public in the Auditori with a brand-new display of its instrument collections and musical documents.

The new permanent exhibition gathers nearly five-hundred instruments from various periods and cultures, a collection that is considered one of the most important in Spain. Structured into various fields and with audiovisual materials –music, images and text– the Museu de la Música invites visitors to acquaint themselves with the world of music in a direct and experiential way and to discover how throughout history, humankind has used music as a vehicle for communication and expression. The main tour path called Orpheus, begins with an introduction to the elements that constitute music and then continues with its evolution over time and space: it begins with ancient civilisation and covers the birth and diffusion of polyphony, Baroque, classicism, romanticism, new colours and the industry of sound in the 19th century as well as new styles and technologies from the 20th century. Key instruments and the guitar collection occupy a prominent place in the Museum as does the Catalan Musicians' Gallery. Running parallel to the collections is the exhibition «The Permanence of Sound», which explains societies' need to capture music using different supports that have changed over time – from the writing of music to the technological advances that have allowed for the recording and reproduction of sound. Finally, there is the Interactive Gallery, where visitors can handle objects, model instruments and real instruments to answer the question: "why does it make a sound?"».

The Museum offers visitors the chance to tour the permanent exhibition in a flexible manner guided by its various thematic itineraries. Orpheus is the name of the main itinerary and is designed for the general public. Little Orpheus is for school groups, families and other groups. Other monographs can be adapted to suit the specific requirements of different groups. These alternative audiovisual itineraries must be booked in advance and are offered in Catalan, Spanish and English.

WoodMusICK – 3rd Annual Conference 2016

Making Wooden Musical Instruments: An Integration of Different Forms of Knowledge

Museu de la Música, Barcelona (Spain), 7-9 September 2016

The craft of building wooden musical instruments requires a wide variety of both empirical and theoretical skills -embodied in pragmatic processes- that aim at the same primary goal: to play music.

The process of building a musical instrument implies different types of knowledge -i.e., types and quality of wood, working and processing technologies, varnishes and glues, mechanics and acoustics- as well as with musical knowledge these skills are acquired in a large measure by oral transmission and apprenticeship even in the most modern schools.

This Conference proposes to discuss the following questions:

- What is the relationship between sound aesthetics and making, historically and currently?
- What are the criteria of choosing, assessing and processing the wood used by the different makers?
- What kind of relationship exists between scholars and makers through societies and times?
- This Conference aims to enhance the cooperation among makers, museums, scholars, and scientists to increase the basic and general knowledge of how wooden musical instruments work, and also how working together can improve this knowledge.

The main topics selected for the Conference are the followings:

- Approaches, solutions and designs developed by makers and which could be investigated by advanced technologies.
- Relationships between music and cultural aesthetics and technical innovations.
- Musical instrument making in different times and regions.
- Wood selection and treatment.

Barcelona, 2016

Conference Agenda

Wednesday 7th September 2016

9:00	Registration begins · Sala 4 Alicia de Larrocha
9:45	Welcome address, Jaume Ayats · Director of MDMB
	Session I - Chair: Christina Young
10:00	Keynote · White Mulberry and Walnut for Iranian Musical Instruments *Aida Se Golpayegoni*
10:45	Historical and Contemporary Non-Occidental Long-Neck Lutes: Relationships between Making Strategies and Musical Aesthetic *Henri Boutin, Farrokh Vahabzadeh, Sandie Le Conte, Philippe Bruguière*
11:10	Traditional and Physico-Acoustical Grading of African Padouk (Pterocarpus Soyauxii) Wood for Xylophones *Straže A., Mitkovski B., Tippner J., Čufar K., Gorišek Ž.*
11:35	Coffee Break
	Session II - Poster pop up talks - Chair: Enric Guaus
12:05	On the Effect of Material in the Acoustics of Flutes *Lamberto Tronchin, Alberto Amendola*
	Identification Issues of Wood in Music Instruments *Piotr Borysiuk, Lesława Ciach, Agnieszka Jankowska, Paweł Kozakiewicz, Agnieszka Kurowska*
	Collaborating with Acousticians, Musicologist & Flute Makers: Towards the Conception of a 19th Century Flute *Camille Vauthrin, Cassandre Balosso-Bardin, Patricio de la Cuadra, Roosen Flute, Benoît Fabre*
	Reverse Engineering and a Reconstruction of the 'Van Eyck' Organ *Andrzej Perz, Jan Boon, Patrick De Baets, Francis Ponseele*
	Using Acoustic Impedance to Propose the Best Restoration Material for Woodwind Instruments *Efstathios Doganis, Sandie Le Conte, Anastasia Pournou*
	Acoustic Wood Properties of Norway Spruce Growing in the Ukrainian Carpathians *Ivan Sopushynskyy, Charles David Ray, Serhiy Zhmurko, Viktor Borisov, Ivan Kharyton, Mykola Sopushynskyy*
	Documenting the Construction Technology of a Portable Wooden Pump Organ *Christina Sperantza, Anastasia Pournou*

	A Window on the World of Guitars of Granada, the city of Guitar-Makers *Daniel Gil de Avalle, Enca González*
	Relationships between Quantitative Anatomy, Microstructure, and Vibrational Properties of Wavy Maple Wood *Ahmad Alkadri, Capucine Carlier, Patrick Langbour, Iris Brémaud*
	Assessment of Volatile Organic Compounds (VOCs) Emission from Wood Applied to the Conservation of Wooden Musical Instruments *Martina Sassoli, Marco Fioravanti*
	Methodical Center of Documentation, Conservation and Restoration of Musical Instruments (MCMI) *Adam Bitljan, Tereza Žůrková*
	Changes in Vibrational Properties of Coated Wood through Time from Application of Varnish, with Recipes Used in European or Iranian String Instruments Making *Iris Brémaud, Elham Karami, Sandrine Bardet, Nicolas Gilles, François Perego, Samad Zare, Joseph Gril*
13:00	Lunch
	Session III - Chair: Anastasia Pournou
14:00	Tonewood Selection: Physical Properties and Perception as Viewed by Violin Makers *Capucine Carlier, Iris Brémaud, Joseph Gril*
14:25	Self-Destructive Elements in the Construction of Guitars in the Nineteenth Century *Jonathan Santa Maria Bouquet*
14:50	Influence of Different Bridge Timbers on the Resonance Behavior of Acoustic Guitars in the Traditional Maccaferri Design - Preview *Volker Haag, Niko Plath*
15:15	Driving Point Mobilities of a Concert Grand Piano Soundboard in Different Stages of Production *Niko Plath, Florian Pfeifle, Christian Koehn, Rolf Bader*
15:45	Coffee Break
16:30	Session IV - Chair: Sandie Le Conte Activity reports: Short Term Scientific Missions, FM and Training Schools
19:30	Dinner

Thursday 8th September 2016

	Session V - Chair: Paul Poletti
9:00	Keynote · Wood, Gut and Compass. Strategies for Making String Instruments in the Iberian World (XVI- XVIII Centuries) *Cristina Bordas Ibáñez*

9:45	Wood-Wind Craftwork and Numerical World: An Experience *Pierre Ribo, Fritz Heller, Roberto Bando, Frank Kamper*
10:10	A Study of the Life, Instruments and Working Methods of the 18th Century Violin Maker Benoit Joseph Boussu - A Presentation of the Project *Geerten Verberkmoes*
10:35	Evaluating the Use of Industrial X-Ray CT to the Reverse Engineering of Bowed Stringed Instruments *Francesco Piasentini, Andrea Scanavini, Simone Carmignato, Valentina Aloisi, Manuel Rigodanza*
11:00	Coffee Break
	Session VI - Chair: Carmen-Mihaela Popescu
11:30	Reconstruction of Oboes Made by Christophe Delusse: from the Material Sources to the Sounding Instrument *Stéphane Vaiedelich, Bruno Salenson, Sandie Le Conte, Lola Soulier, Thierry Maniguet*
11:55	Rethinking the Possibilities of a Notched Flute: The Case of Quena *Cassandre Balosso-Bardin, Patricio de la Cuadra, Camille Vauthrin, Benoit Fabre*
12:20	The Contribution of Archival Research in the Field of Organology. A Focus on Musical Instrument Makers *Maria da Gloria Leitao Venceslau*
13:00	Lunch
14:00	Visit to the Museu de la Música de Barcelona
15:00	Session VII - Chair: Prof. Marco Fioravanti Round-Table Discussion
16:30	Coffee Break
21:00	**Concert - Parròquia de Santa Anna**

Friday 9th September 2016

	Session VIII - Chair: Pascale VANDERVELLEN
9:00	Keynote · Wood as a Window: Keyboard Instruments in Their Global Context *John Koster*
9:45	A New Approach to the Design of Cremonese Violins, Using the Roman Oncia *Simone R. Zopf*
10:10	Modal Analysis Illuminates the History of the Soundpost *George Stoppani*

10:35	Methodologies and Tools for Characterising Stringed Musical Instruments in the Maker's Workshop *Francois Gautier, Frederic. Ablitzer, Guilherme. Paiva, Bertrand David, Marthe Curtit, Mathieu Sécail, Emmanuel Brasseur, Gautier. Michelin*
11:00	Coffee Break
	Session IX - Chair: Simone Zopf
11:30	The Industrialisation of the Early Pedal Harp: Detecting Evidence on Wood and Metal *Panagiotis Poulopoulos, Marisa Pamplona, Luise Richter*
11:55	Ruckers Harpsichords: Specific Acoustic Silhouette? *Sandie Le Conte, Pascale Vandervellen*
12:20	The Impact of the Second World War on Piano Manufacturing in Britain *Sarah K Deters*
12:45	Closing
13:00	Lunch
14:30	Management Committee Meeting

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White Mulberry and Walnut for Iranian Musical Instruments

Aida Se Golpayegani

PhD in wood and Tree Mechanics · Independent researcher · Tehran, Iran

Abstract

Musical instruments of Asia and specially Middle East have rarely been scientifically acknowledged despite their rich history and cultural influence. The artisanal criteria for choosing particular wooden species as well as their traditional rituals for preparing the material for fabrication make for interesting scientific challenges. White mulberry (*Morus alba* L.) and walnut (*Juglans regia* L.) are both used in making Iranian lutes and string instruments for several centuries. Two separate studies were carried out to enlighten different aspects of these species. For white mulberry, various test methods were used to determine its basic acoustical features, its reaction to some prominent traditional pretreatments, the nature and localization of extractives, its natural resistance to degrading microorganisms, and identification of one allergy-inducing component. For walnut, through a series of interviews and material collection from artisans, a comparative study was done aiming at finding a relationship between traditional grading and real mechano-vibrational characteristics of the material.

1. Introduction

Musical instruments of every region are the lead indicators of sound history, culture, artifacts developments, and people musical tastes. They are ambassadors of history carrying evidences of myths and legends, experiences and mistakes, challenges and conquers, and most of all emotions. Investigating this hidden knowledge, will not only help in comprehending the past, but will also be consequential in paving a smooth road into the futuristic musical culture.

Iran has an old and considerable musical treasury. From the old Persia, consisting parts of the modern India, Turkey and Iraq, emerged a variety of instruments that ultimately each nestled inside a separate place and took its own local form.

Tar, Setar, Kamancheh and Santoor are amongst the most well-known Iranian musical instruments (Fig 1). The first three are lutes made mainly from white mulberry (*Morus alba* L.), and the last is a string instrument fabricated out of walnut (*Juglans regia*).

Fabrication of Tar, a bowl-shaped lute is specially a curious process. The wood is handpicked by the artisan, trimmed to a rough shape and then is left to be dried naturally for the period of 4 to 7 years. During this time, the artisan works on and off on the actual bowl and simultaneously applies some traditional heat/water pretreatments to enhance the workability and vibrational properties. As the instrument is hand carved with a hammer and gouge, inhalation of the resulting wood powder was reported to cause some severe allergic problems on the craftsmen, rendering some incapable of continuing to work on the species.

The case of Santoor is rather different. Artisans normally purchase the cut, dried wood plate, and rarely do any kind of pretreatment before starting to work on the wood. They however have very specific ideas about the quality of the perfect wood for instrument making. This is a combination of cutting, direction of fibers, aesthetic features and internal criteria based on experience.

Figure 1: Photos of Tar, Setar, Kamancheh (up, from left to right respectively), and Santoor (Down). The bowl part of all three lutes is fabricated out of white mulberry, while the necks and Santoor is made of walnut.

To study further into these points, various approaches were tested and presented. White mulberry specimens were examined for their damping and specific modulus (two main indicators of acoustical characteristics) and were tested for the effect of some most common pretreatments. Biological tests, resulting in toxicology speculations were also carried on. Walnut samples were gathered from professional ateliers, rated and evaluated based both on artisanal and scientific criteria.

2. Material collection and preparation

2.1. White Mulberry (*Morus alba* L.)

Samples were provided by a professional lute maker, who handpicked two trees and made sure all the artisanal criteria for making an exceptional lute were met. Different specimens in various shapes and conditions were prepared to be used in various mechanical/chemical/biological tests in order to give us a comprehensive picture of this species characteristic [1].

2.2. Walnut (*Juglans regia* L.)

Several top plates made out of walnut for Santoor were collected from ateliers of two professional Santoor makers. The plates were already cut and in final shapes to be added to the instruments. Both artisans evaluated and graded their plates based on their internal criteria ranging from the best to the worst. Plates were then cut to appropriate dimensions for mechanical tests (Fig 2) [2].

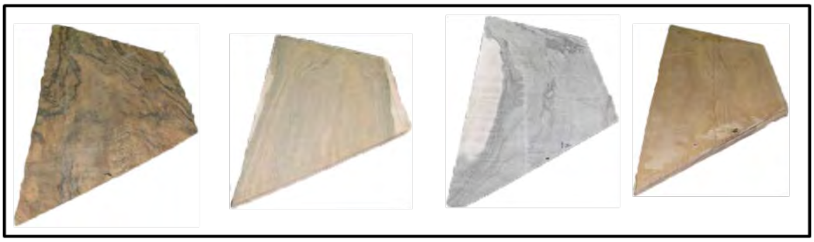

Figure 2: Examples of the Santoor top plates collected from ateliers.

3. Methods

Chief method used for evaluating mechano-vibrational properties of samples was "free-free bar vibration method", which resulted in calculating damping (tanδ) and specific modulus (E/ρ).

Extractions along with GC-mass helped with identification of white mulberry's extractives types and quantity. DMA (Dynamic mechanical analysis) was used to clarify the anisotropic properties of the specimens. *Morus alba* natural resistance and possible toxicology of some extractives were evaluated using various standard biological tests against termites and fungi. Furthermore, three of commonly traditional pretreatments on white mulberry were closely recreated in laboratory scales and their potential efficiencies were studied [1, 3, 4].

4. Results and discussions

4.1. White mulberry

4.1.1. Untreated vibrational characteristics

Musical white mulberry exhibited a medium density (0.45 to 0.60 gr/cm^3), a specific modulus varying between 11-18 GPa (but still firmly in the lower level comparing to standard trend), and a lower than expected tanδ (≈0.008). Damping and specific modulus anisotropy stayed in the lower range compared to the most well-known musically important instruments (i.e. spruce). With a low longitudinal specific modulus and a reduced anisotropy, white mulberry stands closer to maple (used for back and sides of western string instruments) rather than resonance spruce (Fig 3) [1,4].

4.1.2. Extractives and Damping

Two types of extractions, one independent (using 5 different solvents on 5 different sets of samples) and one successive (using all five solvents successively on one set of samples) resulted in identifying two types of extractives. Depending on their polarity (chemical type), locations (cell wall or cavity) and quantity, extractives can be increasing or decreasing to ultimate damping of the wood [1].

4.1.3. Tradition pre –treatments

Three commonly used pretreatment were recreated and evaluated:

a. one to 4 months in ambient water: resulted in no significant change in tanδ, while decreasing specific modulus.

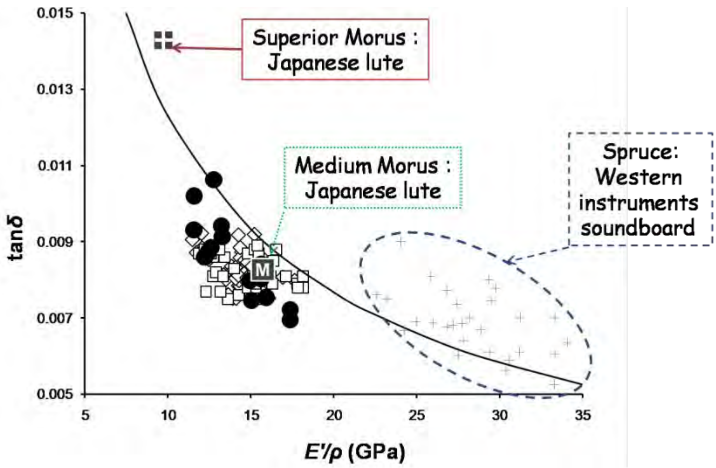

Figure 3: Relationship between tanδ and (*E/ρ*) for mulberry wood used for simulated traditional treatment, compared to lute making mulberry wood from Japan and to *Picea* tone wood [5].

b. two to 12 hours in 70°C water: possibly caused degradation in cell wall polymers, increasing tanδ and negatively effecting specific modulus.
c. Cycling mild drying and re-humidification to simulate the natural life course of the instrument: was able to decrease damping (tanδ) without negatively affecting specific modulus (*E/ρ*), which may be a reason why makers generally prefer seasoned wood (Fig 4) [4].

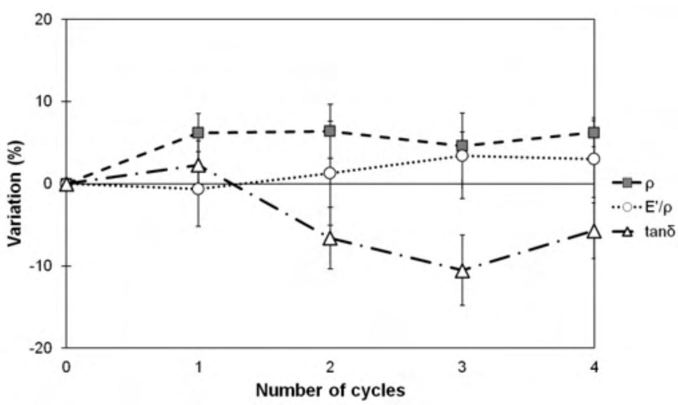

Figure 4: Variations in properties after submitting specimens to hygroscopic cycles. Changes in all cases are relative to the first measurement.

4.1.4. Biological investigation and toxicology

Morus alba L. proved to be highly resistible to fungi, even the most aggressive tropical ones, both in leached and un-leached states. Towards termites, white mulberry specimens exhibited a moderately resistible status when out of the water, but became sensitive once they were leached.

Combining GC-mass identification of chemical extractives with their toxic effect on termites, the probable component causing the allergic reaction in artisans was introduced as Resorcinol ($C_6H_4(OH)_2$), a phenol which its usage is already limited in the European working environments [3].

4.2. Walnut (Juglans regia L.)

After obtaining samples mechano-vibrational key factors, it became obvious that in most cases, the results were in complete sync with artisanal traditional grading. As specimens came from different plates which had various musical qualities, expectedly their damping and specific modulus spread along a wide range. However, as a rule, the samples with better grading showed lower tan*δ* and higher *E/ρ*, while those lacking desirable qualities exhibited low specific modulus and a high damping. It was also become clear that aesthetical criteria along with cutting plans could also disqualify a perfectly acoustically good plate in the eyes of an artisan (Fig 5) [2].

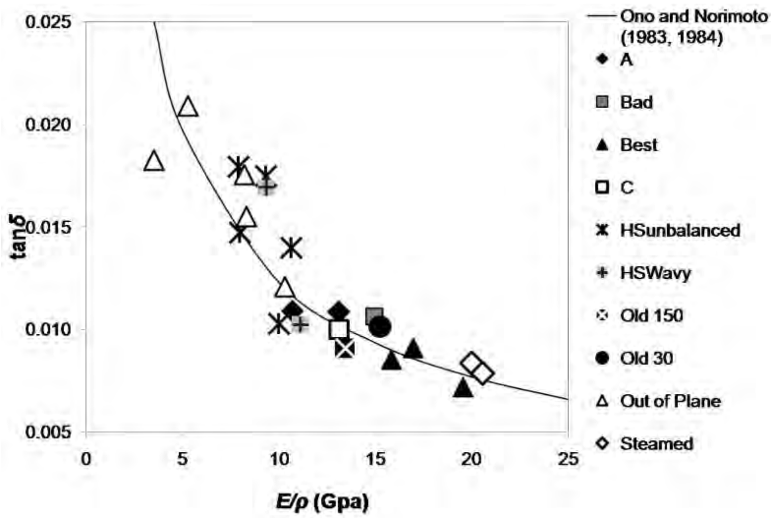

Figure 5: The relationship between specific modulus (*E/ρ* (GPa)) and damping coefficient (tanδ) based on artisanal grading for *juglans regia* samples. The curve was added from [6].

5. Conclusion

Even though Middle East has a rich musical culture, wooden species used for fabrication of instruments were left rather unnoticed. *Morus alba* L., and *Juglans regia* L., are both used in body and neck of Iranian Lutes and Santoor. Studying for their basic characteristics is indispensable for a better understanding and qualification. That being said, the results acquired so far is raising the question that whether Asian instruments could be regarded with the same "standard" and criteria as western ones. Widely different cultures and geographical environments resulted in dissimilar music tastes and distinct features in wooden species. What may sound "sharp" for some audience could have a calming effect on the trained ears of an audience from another region. Notwithstanding the importance of classification of musically important woods of each region, a more extensive knowledge and comprehension of all cultural, historical and anthropological factors is needed when attempting an international comparison.

Acknowledgments

The author is grateful to Samad Zare, Amirmasood Falah, and Hasan Ghafoori, the professional instrument makers who provided the wooden samples. The white mulberry project was carried out thanks to Service de Coopération et d'Action Culturelle (SCAC) of the French embassy in Tehran and Center for International Scientific Studies and Collaboration (CISSC) (Gundishapur project, Egide nb 20714UJ).

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Historical and Contemporary Non-Occidental Long-Neck Lutes: Relationships between Making Strategies and Musical Aesthetic

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Abstract

The Musée du Quai Branly in Paris keeps a large collection of non-occidental long-neck lutes, showing a variety of geometry and wood species, due to different making strategies. Some of them have been scarcely documented and present missing parts or pieces. Most of them are not in playing conditions. 14 instruments of this collection have been selected as well as 5 contemporary instruments. Their dimensions and their vibration are compared and analysed. This study reveals that longer instruments have larger soundboards. However, their first resonance frequency, due to the coupling between body and air vibration in the sound box, is not necessarily lower. In addition, specific making techniques may have been adapted to longer lutes, so that they can support higher string tension.

1. Introduction

The different musical traditions in Asia, especially those concerning long-neck lute family in Iran and Central Asia differentiate themselves by their repertoire, playing techniques, musical systematics, but also and very strongly by the choice that they make in manufacturing of instruments. The article presents the results of an interdisciplinary collaboration between acousticians on the one hand and ethnomusicologists on the other hand. This study focuses on the organology of this family of instruments and its relation with a traditional aesthetics. While investigating simultaneously historical and contemporary instruments, this study provides both a diachronic perspective and a synchronic perspective, which are complementary.

The corpus of musical instruments shows a large variety of dimensions as shown in Fig.1. In order to establish relationships between their making characteristics and their vibration, two sets of measurements are introduced: one concerns the dimensions of the body, the other focuses on the instruments vibrations.

2. Materials and methods

This experimental study concerns a corpus of 19 non-occidental long-neck lutes originating from an area that extends from Turkey in the West, Uzbekistan in the North to Kashmir and Jammu in the East. The 14 instruments, that are part of the collection of Musée du Quai Branly in Paris, date back from the last century, and are called "historical instruments". They are all provided with metal strings, except two made of silk and gut. Most of these lutes are not in playing conditions because the bridge is missing, the soundboard, the sound box or the neck is cracked.

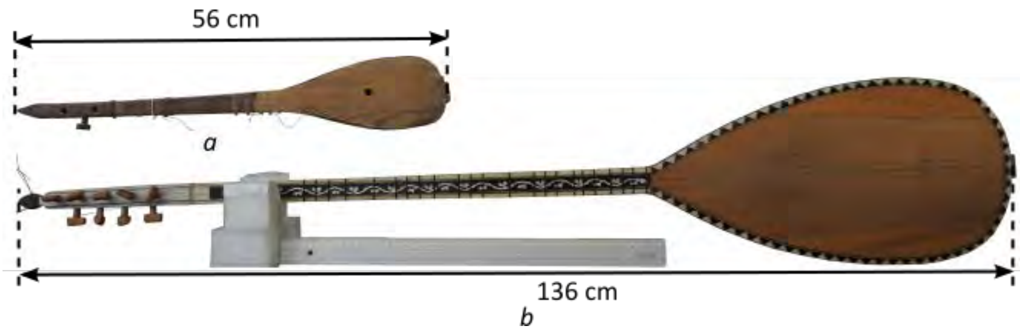

Figure 1: Shortest and longest lutes of the corpus, from collection of Musée du Quai Branly: a- non documented (ref. 71.1937.0.417) b-Turkish Saz (ref. 71.1975.104).

Among the five contemporary instruments, four have two strings, made of metal (one dotār from East Khorāssān and one Turkmen tamdera), silk (one Tajik-Uzbek dotār) and nylon (one Tajik dombra). The last one is a setār from Iran, with four metal strings. They are all regularly played. In order to group the lutes into categories, their dimensions and vibrations are investigated.

For each instrument, the distance from nut to bridge, equal to the maximum string vibrating length and called $\boldsymbol{L_{vib}}$, is measured, as well as the length $\boldsymbol{l_{sb}}$, width $\boldsymbol{w_{sb}}$ of the soundboard and depth of the body: $\boldsymbol{d_{sb}}$.

In order to investigate the vibration of the instruments, three impacts are applied to the back of the sound box, at the furthest point from the soundboard using an impact hammer (Dytran, CA, USA) and their force is recorded via an acquisition card. A sensor located near the treble foot of the bridge measures the acceleration normal to the soundboard. For each impact, the ratio between the acceleration and force Fourier transforms, subsequently called inertance spectrum, is calculated with a frequency resolution of 0.6 Hz. Then, for each instrument, the three inertance spectra, corresponding to the three impacts, are averaged. In addition, the sound radiated from the instrument body is recorded by a microphone, placed 3 cm away from the bridge, perpendicularly to the soundboard plan. Figure 2 shows the average inertance and sound spectra recorded on an Azerbaijani lute from collection of Musée du Quai Branly (ref. 70.2008.28.2).

3. Results

3.1 Geometry analysis

For each instrument, the dimensions of the sound box are compared to the maximum string vibrating length. Because the shapes of instruments' bodies have complex geometries, as shown in Fig.1, the sound box volume is not readily calculated. For reasons of simplification, it is estimated by an effective volume, subsequently called V_{eff}, equal to the product $l_{sb} \times w_{sb} \times d_{sb}$, cf. Fig.3.

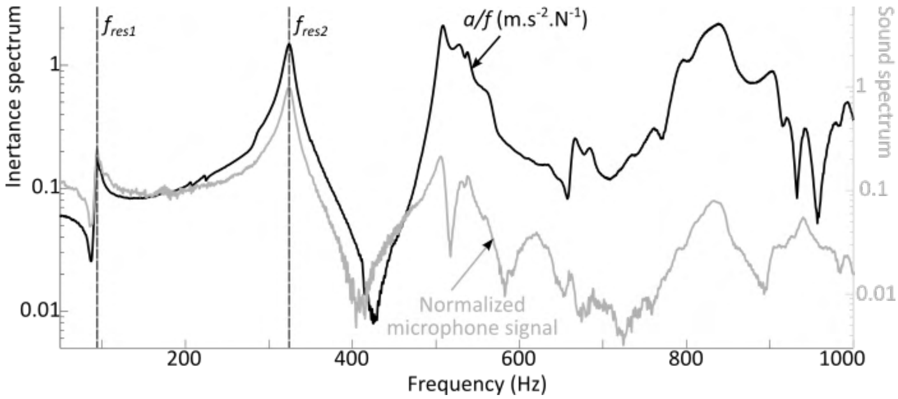

Figure 2: Inertance spectrum (black) and sound spectrum (grey) measured on an Azerbaijani Lute from collection of Musée du Quai Branly. The vertical dashed lines show that the frequencies of the first two peaks in the sound spectrum coincide with peak frequencies in the inertance spectrum.

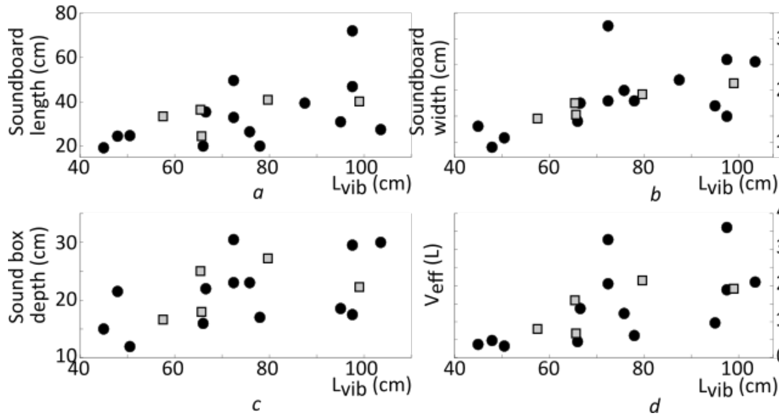

Figure 3: Soundboard length (a), width (b) and depth (c), and effective volume of the sound box (d) versus maximum vibrating length of the strings. The black circles correspond to the historical instruments and the grey squares show the five contemporary instruments.

First, Fig.3 shows that the dimensions of the contemporary instruments, identified with grey symbols, are compatible with those of historical instruments. In addition, Fig.3d reveals that the effective volume of the instruments ranges over a wide interval of values, from 3.2 L to 36.1 L.

As shown in Figs. 3a and 3b, the soundboard width and length increase with the vibrating length L_{vib}, and consequently the total length of the instruments. This trend is less obvious in Fig.3c, between the sound box depth andL_{vib}.

3.2 Vibration analysis

In string instruments, some body resonances, resulting from the coupling between structure and air vibration in the sound box, amplify the radiated sound. Indeed, in the measurement shown in Fig. 2, the frequencies of the two largest inertance peaks match those of the sound spectrum.

Thus, in order to investigate the acoustics of the lutes, the lowest resonance frequency, called Helmholtz frequency, was measured on the historical instruments as well as the contemporary dotār from East Khorāssān and the setār from Iran, available for the experiment. It corresponds to the lowest frequency where both inertance and sound spectra reach a maximum value. Fig. 4 shows this frequency in function of the vibrating length L_{vib}.

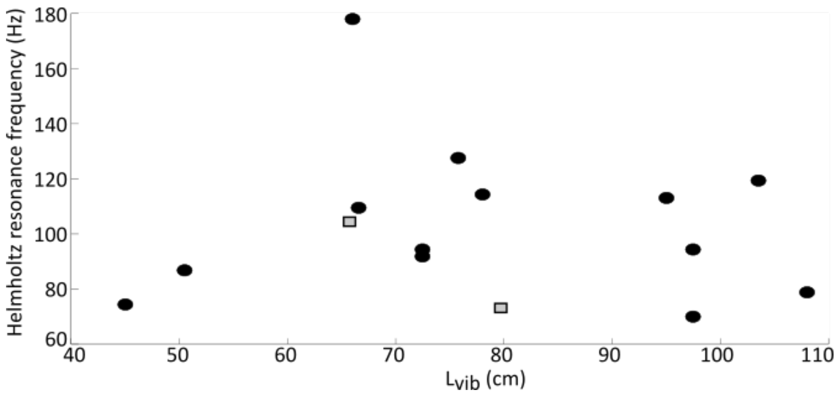

Figure 4: Helmholtz frequency of the instruments in function of the vibrating length L_{vib}. Black and grey symbols correspond to historical and contemporary instruments respectively.

As a result, Fig. 4 shows no clear relationship between the Helmholtz frequency and the maximum string vibrating length, in contrast with other families of string instruments, like violins and guitars [1]. Such diversity in the Helmholtz frequencies can be due to a large variability in the sound holes area from one instrument to another.

4. Discussion

The study of the instrument geometry shows that the soundboard dimensions increase as the instrument length grows, in contrast to the sound box depth. This feature tends to enhance the acoustic radiation of larger instruments, without necessarily changing the sound box volume. Such an adjustment may be sought by makers in order to control both the acoustic power of the instrument and the Helmholtz frequency, due to coupled vibrations of the body and air in the sound box.

Further, vibrating analysis shows that the Helmholtz frequency, is not tuned on a fixed frequency and does not decrease for lutes with larger sound box volume. This result raises the question whether makers adjust the Helmholtz resonance, while modifying the surface area of the sound holes, in order to give a specific timbre to the instrument.

Although strings of large instruments are longer, their musical register (range of notes that can be played) is similar to that of smaller instruments [2-3]. In consequence, the string tension must be higher on bigger instruments, in order to compensate for the increased vibrating length. For this reason, makers may have developed techniques to reinforce the body.

In particular, among the 11 longer lutes, only four have a back made of ribs joined with glue. For one of them, from Turkey (ref. 71.1973.77.662), some ribs are cracked and disassembled, as shown in Fig. 5. The sound box of the other long instruments is made of one or two pieces of wood. The latter technique may allow the instrument to support a larger string tension. For purposes of comparison, among the six shorter instruments, three have a back made of ribs.

Figure 5: Sound box of a long-neck lute from Turkey made of glued ribs. Some of them are cracked and disassembled.

The tension applied to the instrument bodies also depends on the string linear density. Thus, for longer lutes, the string material may be chosen such that the tension is lower. Further investigations on historical and contemporary instruments will aim at identifying other making characteristics specific to musical traditions.

Acknowledgement

This research is supported by the Chaire thématique "GeAcMus" through the "Idex Sorbonne Universités".

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Traditional and Physico-Acoustical Grading of African Padouk (Pterocarpus Soyauxii) Wood for Xylophones

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Abstract

The feasibility of combining the subjective traditional assessment of wood quality for percussion instruments by acoustic measurements was studied. Sawn boards of African padouk (*Pterocarpus soyauxii* Taub.), having various structural properties, were classified into 5 grades by using the dynamic combined specific modulus of elasticity. They were sawn afterwards into raw xylophone bars, which were traditionally graded by listening to the sound damping at flexural bending excitation and additionally by acoustic measurements. A high quality grade matching of xylophone bars and sawn boards was confirmed. The audial grading quality of raw xylophone bars was highly correlated with sound damping (tan δ), specific modulus of elasticity and with acoustic conversion efficiency.

1. Introduction

Extra quality wood for xylophone bars is usually characterized by high density, stiffness, hardness, durability and dimensional stability, as well as low internal friction and tendency to split, crack and twist [1, 2]. Wood species with such properties can mainly be found among tropical hardwoods [3]. Xylophone makers still primarily select wood based on sensory evaluation, while acoustic measurements are scarcely used. A few studies have been conducted in order to establish the relationship between the timber quality and the viscoelastic properties obtained on large pieces of wood and on small specimens, sampled from them. The present study was therefore designed to gain insight into the relationship between physical and acoustical properties, structural characteristics and perceptual grading of African padouk (*Pterocarpus soyauxii*) raw boards, which is frequently used to produce bars of xylophones and marimbas.

2. Material and methods

2.1 Vibration analysis of boards

Vibrational properties were first evaluated on the measured and weighed boards (27 mm × 180 mm × 2150 mm), which were supported by loose thin silk threads located at the nodes of the 1st mode of the flexural vibrations; they were exposed to free longitudinal and free flexural vibrations, using a steel ball impact. Displacement was measured at the belly of the vibration (Fig. 1).

The first resonant frequency was used, from which the dynamic specific moduli of elasticity in bending $(E'/\rho)_B$ were calculated according to the Euler-Bernoulli equation (E' – modulus of elasticity [GPa], ρ – wood density [kg/m^3]). In longitudinal vibrations, the first vibration mode (f_1) was used in order to estimate its dynamic specific modulus

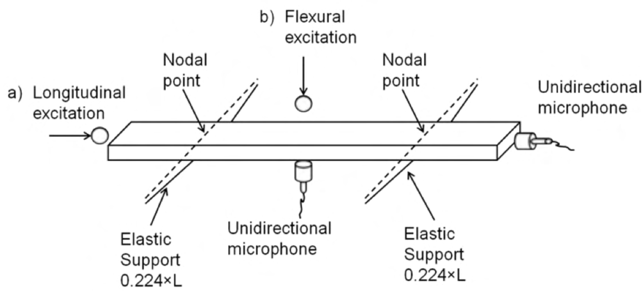

Figure 1: Experimental setup up of acoustic radiation measurements with longitudinal (a) and flexural excitation of samples (b)

of elasticity $(E'/\rho)_L$. The $(E'/\rho)_L$ and $(E'/\rho)_B$ were coupled whereby a new dynamic combined specific modulus of elasticity $(E'/\rho)_C$ was introduced (Eq. 1).

$$\left(\frac{E'}{\rho}\right)_C = \sqrt{\left(\frac{E'}{\rho}\right)_L \times \left(\frac{E'}{\rho}\right)_B} \quad (1)$$

The coupled modulus was introduced due to expected differences in stress distributions in the boards for the different vibration modes, longitudinal and bending, caused by the wood heterogeneity. It was further used to grade the boards according to a 5-grade scale, representing a wide range of normally distributed quality, whereby 1 was the lowest and 5 the highest quality grade. This classification helped us to select 5 representative boards, one for each of the 5 grades, which were then cut into 15 specimens - raw xylophone bars (3 per width (W) and 5 per length (L) of the board).

2.2 Classification of raw xylophone bars

A xylophone maker afterwards graded the raw xylophone bars conventionally. He assessed the wood by hearing. For this purpose, he stroked each of the bars with a woollen mallet in order to excite it maximally in the 1st bending mode, at half of the length, and in the 2nd bending mode at one third of the length. The specimens were in each case held at the position of the vibrational node, at 0.224 and 0.5 of the specimen length, respectively. The xylophone maker evaluated the sound damping by listening to each of the bars in both vibration modes, according to the traditional 5-class grading (1 lowest…5 highest grade) method used in manufacturing practice [4]. Bars with extremely low sound damping were graded 5 and those with the highest were graded 1.

2.3 Vibration analysis of raw xylophone bars

Flexural bending vibration tests (Fig. 1) were in addition carried out on xylophone bars, to determine the dynamic specific modulus of elasticity in bending $(E'/\rho)_B$ and vibration damping (tan δ). In supplement, some other acoustic criteria, i.e. acoustic coefficient (*K*), acoustic conversion efficiency (*ACE*) and relative acoustic conversion efficiency (*RACE*), known for efficiently selecting timber for wooden musical instruments were tested [5].

3. Results

3.1 Vibration analysis of boards

The dynamic combined specific modulus of elasticity $(E'/\rho)_C$, varied in the sawn boards from 17.6 to 25.4 GPa and enabled us to grade the initial set of 15 boards into five quality classes, with a 2.0 GPa range (Fig. 2).

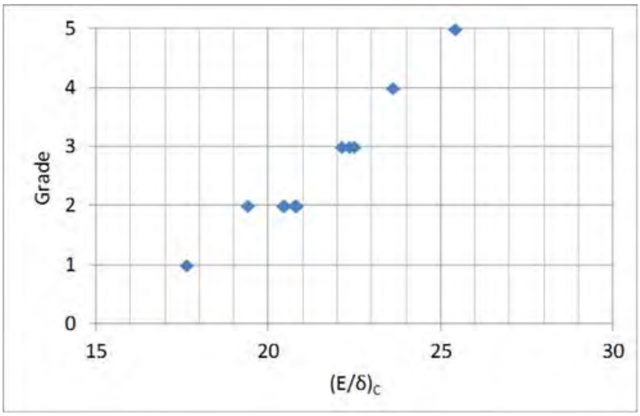

Figure 2: Grading of 15 African padouk boards (dimensions 27 mm × 180 mm × 2150 mm) based on combined dynamic specific modulus of elasticity $(E/\rho)_C$

The grading of xylophone bars by hearing and the previous grading of the sawn boards (based on $(E'/\rho)_C$) did not completely match (Fig. 3). In the case of highly graded xylophone bars, over 50% of them were produced from boards classified to the same grade. There was good agreement for bars and boards graded extremely low (grade 1) or high (grades 4 and 5).

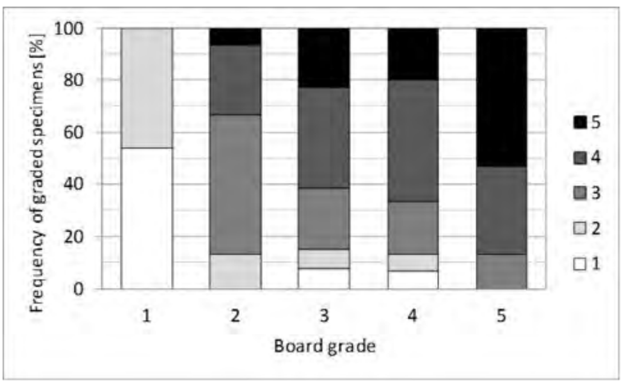

Figure 3: Frequency distribution of raw xylophone bars (=specimens) made of African padouk graded by hearing (□-grade 1, lowest quality to ■-grade 5, highest quality) in sawn boards classified by dynamic combined specific modulus of elasticity

3.2 Physical and acoustical characterisation of raw xylophone bars

Firstly, the wood density did not have a significant effect on perceptual grading (Fig. 4a). This can be explained by the fact that grading by hearing records the viscous rather than elastic properties of wood [6]. The specific modulus of elasticity proportionally increased with increasing quality grade (Fig. 4b), although the differences between the classes were not statistically significant (Duncan test; $p \leq 0.05$). The increased specific modulus of elasticity of higher grades is probably due to better grain orientation, the

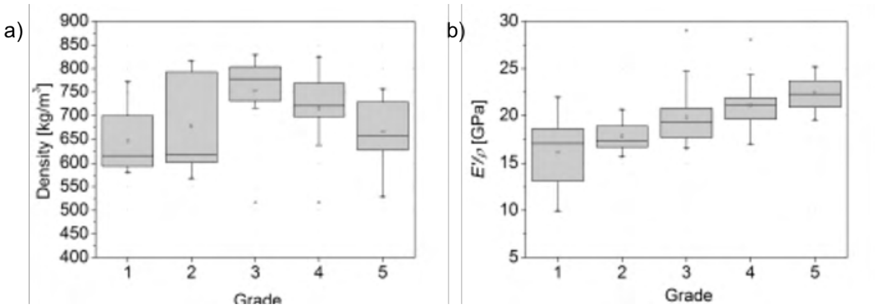

Figure 4: Distribution of wood density (a) and specific modulus of elasticity (E'/ρ) (b) at various perceptually based specimen grades

absence of wavy grain and a higher share of quarter-sawn specimens.

The damping coefficient, in contrast to the E'/ρ, had an effect on quality grade and the mean values between classes were significantly different (Duncan test, $p \leq 0.05$) (Fig. 5a). The damping coefficient is thought to depend on wood structure, although the effect of cellular organization is not clear.

The relative acoustic conversion efficiency RACE (Fig. 5b) proved to be the most promising of all descriptors. It showed a linear positive trend, with a narrow distribution within grade classes and statistically significant differences between classes ($p \leq 0.05$). The agreement of the RACE classification with that defined by hearing was 73%.

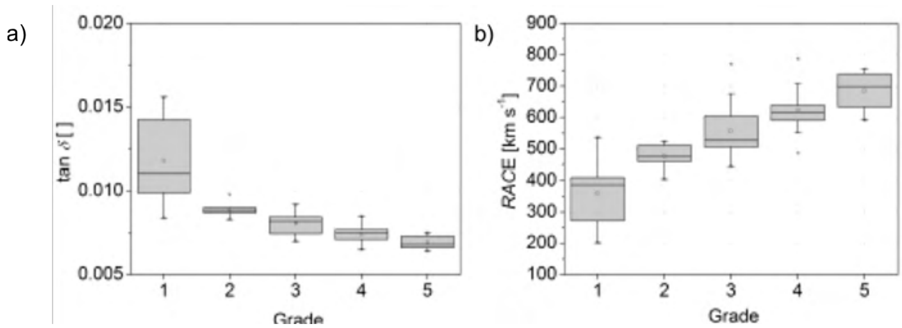

Figure 5: Distribution of damping coefficient (tan δ) (a) and relative acoustic conversion efficiency (RACE) (b) at various perceptually based specimen grades

4. Concluding remarks

The research confirmed the possibility of improving the subjective traditional quality assessment of African padouk for percussion wood instruments by non-destructive physico-acoustical characterisation. The initial classification based on dynamic combined specific modulus of elasticity reliably distinguished the five quality grades of raw sawn boards. Visual inspection of the boards confirmed the importance of structural criteria.

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On the Effect of Material in the Acoustics of Flutes

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Abstract

The influence of the material in the flute construction represents an important argument among flutist community. The main question is whether the material in which the flute is made, could really effect the global acoustic behaviour and sound perception for the performers and listeners. Nevertheless, only a very few studies of this phenomenon were presented so far.

In this paper, the effects of the material in flute construction have been considered from different perspectives. Three equal flutes, which differed only in the material, were analysed. The first one in nickel silver and copper alloy, the second one in silver metal, and the last one in gold alloy (12 karats). For all the flutes, the impulse responses were measured for each key position, exciting the bore with an exponential sine sweep on the mouthpiece and positioning a special probe, which included a microphone at the end of it. Moreover, one reference microphone was used in near field in a semi-anechoic room, together with one accelerometer, to capture also the vibration of the bore, in order to measure and calculate the IAR of the three flutes. Finally, some recordings were obtained on the gold alloy flute, and used in psycho-acoustic experiments. In a further step, the original recordings were utilised to obtain anechoic music by means of convolution of the signal with the inverse filter obtained with the inversion of the impulse response of the flute. Afterwards, one of these anechoic signals was utilised to emulate the original musical performance. The original and emulated signals, which included the harmonic distortions of the flutes, were finally utilised during subjective tests with some students in flute performance at the Music Department of the University of Bologna. The results of the acoustic measurements underlined differences among the three flutes. The results from the measurements are here presented.

1. Introduction

In order to determine the relation between sound emission and material or obsolescence, the measurements were conducted considering both acoustic and vibrational characterisation of the bore.

The relation between sound emission and vibration on the bore is expressed by the Intensity of Acoustic Radiation, IAR. It is defined as the space-averaged amplitude of cross spectrum between sound pressure caused by the movement of the vibrating surface and the velocity of the vibration of the surface itself:

$$IAR(\omega) = \langle P(\omega) * V(\omega) \rangle \tag{1}$$

Where $P(\omega)$ represents while $V(\omega)$ represents. The IAR is able to relate sound emission with mechanical vibration, i.e. to how the vibration of the body of the instruments with the sound production. Moreover, in addition of modal analysis, IAR is able to link the modal shapes of musical instruments with its sound emission, and therefore to underline which modal shape is most important if compared with the overall sound generation of the musical instruments.

2. The experiments

The experiments have interested 3 different flutes, made in different material but tuned at the same tone (frequency), namely Jupiter flute, Sankyio flute, and a Mateki flute. The three flutes are made in alloy, silver and gold.

Figure 1: The three flutes

The experiments have been conducted by using a miniaturized sound source located at the reed of the flute, and measuring the sound emission in the near free field in a semi anechoic room. Furthermore, a miniaturized accelerometer has been fixed in the bore of the flute, in order to capture the vibrational emission.

For the measurements, the sound signal was an exponential sine sweep, which is able to measure both linear and nonlinear components (i.e. harmonic distortions) of the audio system.

After the measurements, a flutist has performed some pieces of music, which was recorded by means of the same microphone. Figure 1 represents the three flute here considered, whilst figure 2 represents the performance of the flutist.

Figure 2: The performance of the flutist

3. Results

The measurements have been utilised to virtualise the sound emission by means of Volterra series. Following a very recent method [7-8], the measurements were post-processed both to obtain information about sound/vibrational behaviour (i.e., Frequency Response Functions and Intensity of Acoustic Radiation), and to emulate the linear and nonlinear emission of the flutes.

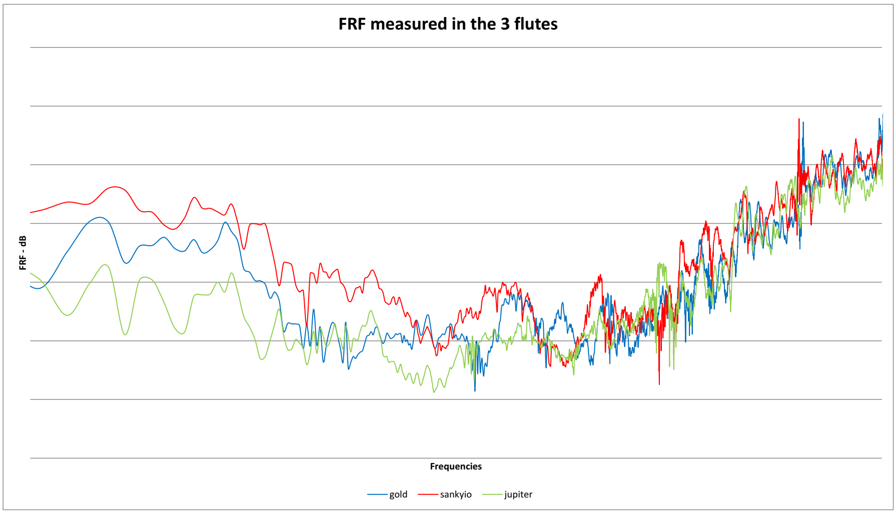

Figure 3: IAR measured in the three flutes

By inverting the experimental Impulse response, an "anechoic" signal was retrieved, and afterwards convolved with different impulse responses to "virtualise" the sound. In other words, the measurements allowed to virtually reconstruct the sound of the flutes, making possible to perform listening tests that are able to clarify the differences in timbre among the three flutes.

The "standard" measurement allowed to graphically find the difference in sound timbre due to the material of the flutes. On the other hand, the virtual reconstruction of the sound allowed appreciating the differences among flutes by mean of listening the sound emission, and by comparing the linear (or nonlinear) emission, with the original performance. In order to allow the nonlinear convolution, a proper script (VST plugin) was realised and utilised in a MIDI host (Reaper).

Figure 4: The "Volterra" convolver

4. Conclusions

The experiments here presented allowed to find differences among three similar flutes which differed only in the material. The differences were found both considering IAR and FRF, and both by listening tests realised by means of nonlinear convolution.

Acknowledgement

The authors gratefully acknowledge Angelo Farina and Andrea Venturi for their precious help. Alberto Amendola, who worked considerably for this work, passed away before ending this paper.

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Identification Issues of Wood in Music Instruments

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Abstract

Identification of wood in musical instruments is a necessary element of the proper design of restoration works and often resolves or constitutes a premise for authenticity and origin of instruments. The most important factors determining a way of wood identification are: (1) condition of musical instruments as well as its value, (2) type of surface finishing - folk instruments are more available for identifying wood than professional instruments. Non-destructive methods are preferred but when they fail using of destructive methods and intervention in historical matter should be considered. The use of computed tomography seems to be a future solution to a wide group of instruments.

1. Introduction

Because of musical instruments combine acoustical and cultural functions, wood used for their building has been studied from two distinct viewpoints: structure analyses and evaluation vibrational properties [1,3,7, 11]. Analysis of wood structure is main part of botanical identification of various species. Identification of wood in musical instruments is a necessary element of the proper design of restoration works and often resolves or constitutes a premise for authenticity and origin of instruments [8]. Special features of such analyses are soundboards of string instrument.

The aim of the study was to recognize an overview of techniques and methods used to identification of wood in musical instruments. The purpose of this work was to indicate the optimal procedures for the identification of wood.

2. Methods

During the studies, macroscopic and microscopic observations were undertaken using an Olympus BX40 light microscope. Wood structure was examined by X-ray computed tomography. Furthermore, a wide literature review was done in order to get knowledge regarding to wood identification using non-destructive methods.

3. Results

The first stage of an identification process involves thorough macroscopic observations of a musical instrument, consisting in locating spots where wood structure elements are visible and, as far as possible, in reaching all anatomical cross-sections (identifying the size of wooden elements, woodwork and joints, the arrangement of annual growth rings and fibres and other characteristics of the wood figure, e.g. the presence and size of rays, vessels, parenchyma bands or resin canals) and defining the colour of wood. The last of these features is often changed due to natural weathering and aging processes [4]. It is best to compare visible sections of wood with standard samples from a xylotheque collection and with descriptions of the characteristics of wood structure which can be found in a number of wood atlases [e.g. 9, 10].

The above mentioned macroscopic observations must often be supported by a microscopic analysis, especially in the case of diffuse-porous hardwood species which do not have many characteristic features. Microscopic observations of singled out sections of the wood surface (taking a reflected-light photography) are often problematic: it is difficult to reach spots where wood is exposed and to illuminate them properly, as they are often located inside the sound box. Paradoxically, the more worn out the instrument, the easier it is to the expose the wood surface and obtain sections for microscopic examination.

Cash on the material to perform microscopic preparations and execution of surface outcrops (removing layers of paint, dirt) requires intervention in material structure (destructive testing). Depending on the type of wood structure, often analysis just one of the anatomical sections lets to make wood identification (Figure 1).

a) b) c)

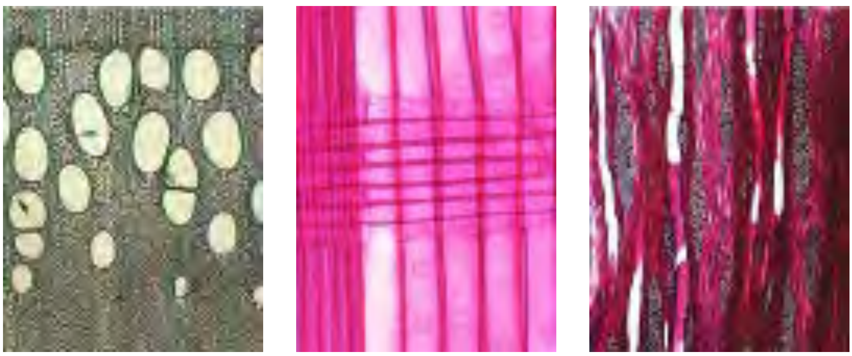

Figure 1: Microscopic images of wood: a - transverse section of European ash, b - radial section of Norway spruce, c - tangential section of field maple

A method of the future, enabling non-invasive wood identification, is X-ray computed tomography (CT). With the resolution of medical CT imaging (voxel size) being at present at the level of 0.1 mm, the arrangement of annual rings, extended rays and large vessels can be observed on reconstructed images of the wood structure. A density analysis based on the Hounsfield scale, after the apparatus has been calibrated, enables the reading of the cyclic variation in density of the width of annual growths, characteristic of particular types of structures (softwood, ring-porous or diffuse-porous hardwood) - Figure 2.

In the case of softwood species, a typical late wood density to early wood density ratio is from ca. 2.4 to 3.2, in the case of ring-porous hardwood species it is from ca. 1.5 to 2.8, and in the case of diffuse-porous hardwood species from ca. 1.2 to 1.7 [5]. Tomographic examinations fully confirm these results (Table 1).

Smaller-size instruments, such as guitars, violins, cellos or even double basses, are especially suitable for this type of study. Their shapes and sizes are similar to the human body, so they can be easily fitted into the gantries of medical CT scan machines.

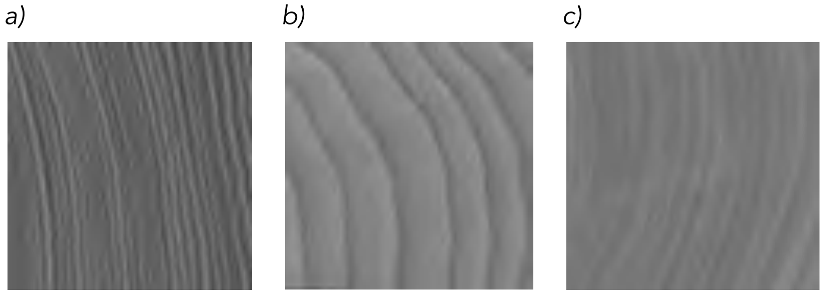

Figure 2: X-ray computed tomography image reconstruction of cross-section of wood: a) Norway spruce, b) European ash, c) field maple

Table 1: Results of density of selected kind of woods (with X-ray computer tomography)

Trade name of wood according to EN 13556:2003 [2]	Average density of early wood ς_{ew} [kg·m^{-3}]	Average density of late wood ς_{lw} [kg·m^{-3}]	ς_{lw} / ς_{ew} [-]
Norway spruce	233	726	3,1
European ash	482	881	1,8
field maple	523	667	1,3

It should be noted that metal elements pose a certain problem in tomographic observation. Due to strong interference with X-rays they nearly totally distort images obtained in the course of the examination [6].

4. Conclusion

The most important factors determining a way of wood identification is condition of musical instruments as well as its value. The second factor is type of surface finishing-folk instruments are more available for identifying wood than professional instruments.

Non-destructive methods are preferred but when they fail using of destructive methods and intervention in historical matter should be considered. The use of computed tomography seems to be a future solution to a wide group of instruments.

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Collaborating with Acousticians, Musicologist & Flute Makers: Towards the Conception of a 19th Century Flute

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Abstract

Professional flute-players recently asked a Parisian flute maker to conceive a period Boehm flute with an open key system, similar to the one inaugurated in 1830. Jointly conducted by acousticians, musicologists and flute makers, the objective of the study is to conceive such a nineteenth century flute. In order to achieve this, our aim is to understand the historical and musical context of flute manufacture, the playing techniques developed by musicians, the acoustic responses of the instrument and the characteristics of the key mechanism. We will be using an interdisciplinary approach, combining musicology and acoustic studies. The former will be using historical documents and academic articles in order to establish a coherent overview of the flute making industry in France in nineteenth century; the latter will be using geometrical surveys, models of admittance and admittance measurements in order to determine the acoustic characteristics of the nineteenth century flute, to identify the elements of flute making specific to each flute maker and to understand the playing techniques developed by the musicians. Furthermore, the understanding of the specific playing techniques developed by the musicians can be improved by the discussion with the professional flute players. Finally, regular discussions with the flute maker are necessary to understand the freedom or the limits of flute manufacture, or by the key mechanism.

1. Introduction

Historic: Until the eighteenth century, transverse flutes are keyless, mainly made of wood and have a cylindrical bore. The first significant changes in flute making appear with Jacques Hotteterre le Romain (ca.1680-ca.1761); the bore becomes cylindrical (for the head) and conical (for the body), various keys are added in order to simplify cross-fingerings and to improve the tuning of the flute [1].

In the history of the flute, the nineteenth century is rife in inventions. Flute makers patent numerous innovations, each trying to offer the best instrument. Without Boehm (1794-1881), the flute was in danger of being abandoned by composers, as it was not compatible with the significant progress of the orchestra. The genius of Boehm was in the implementation of parallel systems to create a new key system, much more convenient and reliable. The Boehm key system allowed the player to access larger holes placed in strategic acoustic positions. The first so-called Boehm flute was built in 1831. It spread in France from 1838 onwards, thanks to a new French version established by Buffet-Crampon and Dorus. Boehm then designed a new flute in 1847, built in metal with a cylindrical bore and a slightly conical head, in order to improve the timbre of the instrument [1].

The technical facility and the acoustics provided by the Boehm mechanism, offering easier intonation and timbre diversity, ensured the future of the flute. Composers became interested and began to compose interesting musical pieces beyond the virtuoso pieces of the nineteenth century, composed mainly to show the skill of the musician without worrying about the timbre of the instrument.

Context: This study was initiated following the request of professional flute-players to conceive a period Boehm flute with an open key system, similar to the one inaugurated in 1832. The research is jointly conducted by acousticians, musicologists and flute makers in order to understand the historical and musical context of flute manufacture, playing techniques developed by musicians, acoustic responses of the instrument, characteristics of the key mechanism, and conceiving a prototype. Furthermore, some comparisons will be established with the modern flute.

2. Methods

We will be using an interdisciplinary approach, combining musicology and acoustic studies. The former will be using historical documents and academic articles in order to establish a coherent overview of the flute making industry in France in nineteenth century; the latter will be using geometrical surveys, models of admittance and admittance measurements in order to determine the acoustic characteristics of the nineteenth century flute, to identify the elements of flute making specific to each flute maker and to understand the playing techniques developed by the musicians.

Furthermore, some interviews have been conducted with professional flute players in order to highlight their expectations about the new flute.

As the preservation of the period sound seems to be a significant characteristic, it would be interesting to study the embouchure of the flute, that most probably plays an important part in the timbre of the instrument. The playing techniques at the embouchure of the instrument can be studied thanks to a specific protocol, described by De la Cuadra, [2].

Finally, regular discussions with the flute maker are necessary to understand the freedom or the limits of flute manufacture, or by the key mechanism. The conception of a first prototype will be conducted with the flute maker, while reflecting on ergonomic problematics.

3. Results

To conduct our study, we worked on 6 flutes from the nineteenth century and one modern flute, each flute is described in the table 1, in terms of date of built, the type of the foot joint and the name of the builder.

Geometry: The first results show geometrical differences between the nineteenth century flutes and a modern flute by Sankyo. The geometrical surveys, Figure 1-left, allow us to confirm that the bore of the nineteenth flute presents a cylindrical head and a conical body varying between 18 and 11mm, while head of the modern flute is parabolic with a cylindrical body varying between 17 and 19mm. Flutes with a D foot

Table 1: Details on the flutes studied

Builder	Date of built	Type of foot joint
Louis Lot	1884	D
Louis Lot	1886	D
Louis Lot	1881	C
Isidore Lot	after 1860	C
Isidore Lot	after 1860	C
Gautrot-Marquet	Between 1875-1883	C
Masspacher		C
Thibouville-Lamy	after 1867	C
Sankyo	2015	C

joint present a variance, in fact the bore of the foot joint is like a divergent cone between 11 and 14 mm; this exception may be a heritage from the baroque flute.

Figure 1-right shows the diameter of the holes and their positions from the top of the flute body for the two flutes.

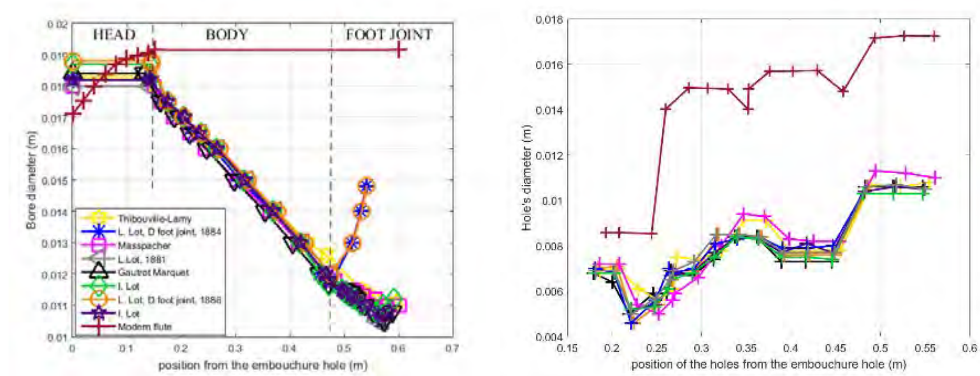

Figure 1: left - bore diameters of the flutes, right – hole's diameter and position from the embouchure hole.

The comparison between the flutes pictured in figure 1-right indicates that the diameter of modern flute finger holes are twice as large as those of the nineteenth century flutes, except for the three first holes which are trill holes or register holes. Consequently, modern flute holes are placed slightly further down the body of the instrument. We also observe differences in the position of the holes for the nineteenth century flutes. However, the diameters of the holes seem to be similar for all measured flutes.

Admittance measurements: The input admittance of the flute can be measured by using an impedance sensor, developed in Le Mans [3]. Thus, the resonance frequencies of the flutes are estimated using the zero crossing of the imaginary part of the admittance. Obviously, the frequencies have to be distinguished from the frequencies played by a musician as our measurements do not take into account the radiation at the embouchure, the influence of the lips, and the influence of the air jet. However, through these measurements we can estimate the musician's control if s/he were to play with an equal temperament. Figure 2 represents the frequency difference between the resonance frequencies and the equal temperament frequencies in cents for the flutes we measured (L. Lot, Sankyo and Thibouville-Lamy) and for the first two registers.

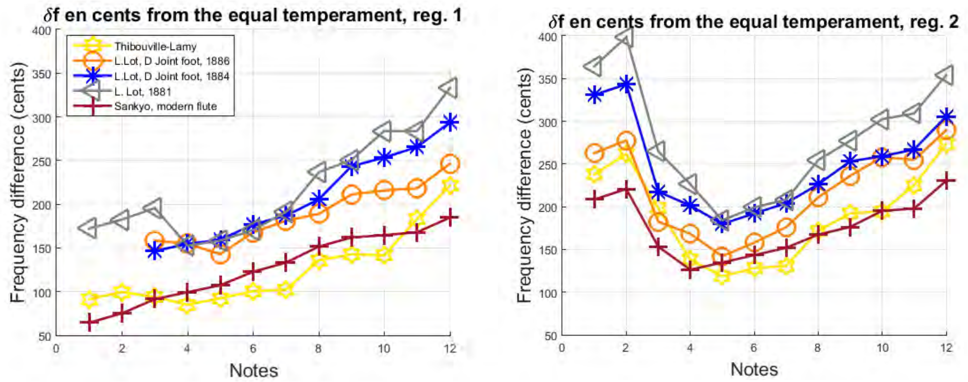

Figure 2: left: Frequency differences between the resonance frequencies and the equal temperament for the register 1. Right: Idem for the register 2.

On figure 2, we can observe that the spaces between two successive notes are more regular for the modern flute than for the nineteenth flutes. Tone control is therefore probably easier for a musician playing the modern flute because it evolves in the same way during the scale. We also note that the flute Thibouville-Lamy seems to have the same pitch as the modern (442 Hz), whereas the others flutes seem to have a lower diapason, around 430 Hz. Finally, we remark that control may be difficult for the flautist between C4 and E4, especially with the grey flute, as the variations fact for this flute are higher. During a scale, the musician will have to adjust his/her control (position of the lips and air jet velocity [2, 4]) in order to compensate around 100 cents for the modern flute and 200 cents for the grey flute. Others acoustical parameters can be studied in the admittance measurements such as the magnitude of the peaks and the spectral composition of the spectrum, in order to estimate the emission facilities or characteristics on the sound.

Admittance model: The admittance of the flute can be modelled using the plane wave theory, described by Pierce [5]. Using the approach of transmission lines, this theory describes the flute as a product of transfer matrices, established by the geometry of the instrument: cylinder, cones, holes, … Each element corresponds to a matrix transfer, as explained by Kergomard in [6], which is multiplied with the others. Thus, we can model the impedance between the head cork and the embouchure, and flute body (as Lefebvre [7], Vauthrin [5]), which we place in parallel with the impedance of the cavity. The impedance obtained is then placed in series with the impedance of the embouchure hole. We then obtain the impedance of the entire flute above the embouchure hole. The admittance of the flute is just the inverse of the impedance. In the same way as previously, we estimate the resonance frequencies and the frequency differences with the equal temperament, figure 3.

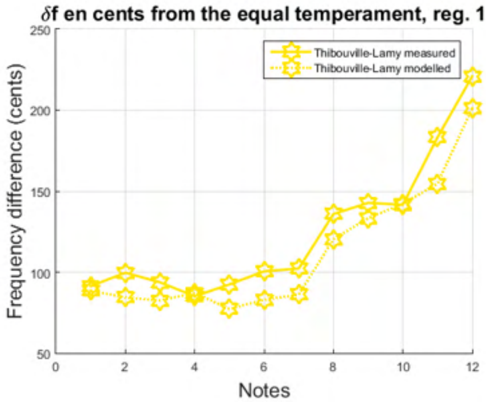

Figure 3: left: Frequency differences between the resonance frequencies and the equal temperament for the register 1, for the Thibouville-Lamy flute measured and modelled.

Figure 3 shows that the resonance frequencies obtained by our model are close to the one obtained by the admittance measurements. However, we note variations of up to 15 cents for some fingerings. These variations may come from the linear acoustics description of the geometry of the holes which does not take into account the undercutting technique [8]. Before using this model to produce a prototype, we need to improve it, to correctly model the measures. We could then use it in order to determine the changes of the flute geometry in order to optimize the prototype in agreement with the musician greetings.

Discussion with the musicians: An important part of the study is to understand the musicians' point of view in order to create an instrument that is attractive to them. To this effect, we interviewed two musicians from different backgrounds, both owners and regular players of period flutes. The first was a historical enthusiast with great interest for period instruments as a collector and amateur musician, the second was a professional musician who was until recently employed by a prestigious period orchestra. The concerns of both musicians, however, were similar in that the main characteristic they wished to see reproduced in a new version of the Boehm conical flute was its distinct sound, before even working on slight tuning adjustments. The amateur flautist was keen for the new flute to retain its sound, "more intimate, softer and less aggressive" than the modern Boehm flute. Similarly, the professional musician expressed his appreciation for the "fine" and "elegant" sound of the French manufactured conical Boehm flutes and was keen for the new flute to retain the slight discrepancies in tuning and timbre as these were musically included in the contemporary repertoire by the composers.

4. Discussion

The first results of the study show the main geometry differences between the nineteenth century and the modern flutes, and their influences on the resonance frequencies of the instrument and on the playing techniques.

The flute can also be modelled with a model based on the linear acoustics, this model needs to be improve in order to use it in order to generate the prototype in agreement with the musicians greetings.

This work will be continued with a study on the sound of the flute, and more particularly on the influence of the embouchure shape, in order to determine the best embouchure geometry to choice in terms of emission facility and sound produced.

Acknowledgement

The authors want to thank the musicians for the loan of their flutes.

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Reverse Engineering and Reconstruction of the "Van Eyck" Organ

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1. Introduction

Organs from the 15th century and earlier are only fragmentarily preserved, and the sources that can lead to a better knowledge and understanding of the organ-making techniques and concepts are not or not sufficiently accessible. As a result, the musicians of today lack the adequate instruments to rediscover the music from that period and to perform it faithfully to the original style. Hence the need for reconstructions. The fragmentarily preserved material has to be supplemented by other sources, one of the most important of which is iconography. The issue with this kind of source, however, is that it usually cannot be fully reliable. That is why reconstructions of musical instruments from the past should be based on the interdisciplinary research that involves, besides pure organological studies, many other domains. An example of this approach is the latest attempt to reconstruct the positive organ depicted in the famous 'Ghent Altarpiece' (or the 'Adoration of the Mystic Lamb') by the Van Eyck brothers from 1432 (see Figure 1) – a project carried out at the School of Arts of the University College Ghent. The project emerges from the iconography but would not be scientifically reliable without a strong support of other sources and modern research techniques. This paper presents a few methods that have been used so far in this ongoing reconstruction of the 'Van Eyck' organ.

Figure 1: 'Musician Angels' from the 'Ghent Altarpiece' by the Van Eyck brothers [4]

2. Methods

The first phase of the project – the visual analysis of the panel with the 'Musician Angels' from the 'Ghent Altarpiece' – was based on the extensive photographical documentation of the painting, made in different techniques by the Belgian Royal Institute for Cultural Heritage on the occasion of the restauration campaign of this masterpiece that began in 2012 and is planned to last until 2019. This high-resolution imagery obtained by macrophotography, infrared macrophotography, reflectography and X-rays [4] allow to examine the organ depicted in the panel on a scale that has not been achievable before. Thanks to this documentation the step of the technical research on the panel could be skipped and one could focus on the interpretation of the design of the organ in different layers of the painting and on the assessment whether the organ from the painting could have existed in reality.

In order to reconstruct the external design of the organ, research was done on the perspective in the painting. The whole process was carried out with the help of CAD software.

At the same time organological research was undertaken, in search for the preserved organs and their elements from the Middle Ages that could share some characteristics with the organ from the 'Ghent Altarpiece', to collect the referential material complementing the main source of information – the painting of the Van Eyck brothers itself.

In the course of the project, different experiments have been and will be performed, including ultimately the construction of the organ, which remains an important empirical study supporting all the other methods and vice versa.

As the project is still underway and the whole variety of the methods used is beyond the confines of this paper, we discuss only a few examples of them.

3. Results

3.1. Value of the iconographical representation of the organ

The depiction of musical instruments in the panel with the 'Musician Angels' seems to be very realistic. Even superficial examination demonstrates how precise and detailed the picture is, and the magnification of the high-resolution pictures [4] confirms this. For example, in the harp we can see not only the difference in thickness of the strings but also such a detail as a small curve on the string that appears also in a real tightened gut string near a tuning pin. In the organ one can see not only a clear representation of the oak that the organ case was made of, but also very specific technical aspects of the pipes: distinctive narrow bulges at the edges of labia, pressed in the metal sheet on the inner side of the pipe; or a soldered joint between the body and the foot of the pipe. But one detail in particular can be noticed only by the insiders of organ making: a very fine bevel at the edge of the upper labium, which is the result of the voicing process. All these peculiarities let us assume that the painters had at their disposal a real instrument as a model and, being an attentive observer, did not omit even minuscule features.

3.2. Peculiarities of the pipes and the keyboard

Already in the late seventies of the 20th century the first infrared photographs revealed that behind the keyboard that is visible in daylight (resembling in general the 'modern' keyboard, with black keys between white keys) there was another keyboard, consisting of two rows, with the black keys above the white keys [1, 2]. The keyboard that was initially depicted in the 'Ghent Altarpiece' was not completely unusual though: such an archaic type of keyboard can be found in the oldest preserved organ fragments in the world – in the Norrlanda positive organ from the end of the 14th century (ca. 1370–1400) [3].

The new imaging techniques seem to resolve also an inconsistency encountered in the analysis of the pipework. Namely, in the painting there are two rows of pipes; the pipes in the back row appear to be shorter than those in the front row, what would suggest a staggered chromatic order of the pipes (see Table 1). On the other hand, the physics of organ pipes dictates that the body length of a pipe that sounds an octave higher be two times shorter. In this case we should expect the pipe an octave higher than the first pipe to be the 7th pipe in the front. It is nevertheless evident that the body length of this pipe is not half that of the first pipe, even if we take a perspective correction into account.

Infrared-photography and reflectography, however, show that pipes in the rear row were originally of the same length as the pipes in the front row. If so, then we are probably dealing with the double chromatic arrangement of the pipe rank (raddoppio, see Table 2). In this case the pipe that sounds an octave higher would be the 13th in the row. The body length of this pipe seems indeed to be half of the height of the first pipe.

Table 1: The staggered chromatic placement (top view of the pipework)

	cis	di	f	g	a	h	
C	d	e	fis	gi	b	c	…
(1)	(2)	(3)	(4)	(5)	(6)	(7)	

Table 2: The double chromatic placement (top view of the pipework)

C	cis	d	di	e	f	fis	g	gi	a	b	h	c	…
C	cis	d	di	e	f	fis	g	gi	a	b	h	c	…
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	

3.3. Perspective

The research on the perspective in the panel with the 'Musician Angels' showed that there are surprisingly many lines in the painting that are converging towards two vanishing points (or rather 'zones') and can be used as reference for drawing of a 3D model of the organ, even if the perspective as such was still not completely developed at that time of the history of art. Still, there are elements that violate the perspective, especially the handle of the organ, the ornament on the side of the organ case and – to much smaller extent – the keyboard. These irregularities can be explained by the compositional priority that the painters tend to give to some objects over the rules of the perspective. Taking into account the predominant perspective lines that meet in the vanishing 'zones', it was possible to draw a preliminary 3D model of the organ with the aid of CAD software.

4. Discussion

Already at this initial stage, our research raises new questions. Firstly, the interpretation of the alterations in the painting: what might have prompted them? Why have the Van Eycks (or somebody else?) decided to change the appearance of the organ, since the 'original' version under the visible layers seems to be the most consistent? One of hypotheses is that the Van Eyck brothers used as a model an organ that already at that time was outdated and that somebody suggested 'modernizing' the keyboard and shortening the pipes in the second row to create an impression of the staggered chromatic placement that would better correspond to a keyboard layout 'contemporary' with the painting.

The second question concerns the initial 3D drawing of the organ, which uncovered for example the relatively big spacing between the pipes and the sides of the organ, and relatively small diameters of the pipes at the same time. This can be explained by the possible visual enhancements due to artistic licence on the part of the painters, who wanted to emphasize individual pipes by making them thinner; otherwise their contours would overlap in the perspective representation. The actual spacing and the diameter will be corrected and tested in the physical reconstruction of the organ.

The third important issue is the absolute length of the pipes.

To make the reconstruction the closest to the depicted organ from the 15th century, more interdisciplinary research is planned. During the organological study some preserved organs and their elements were selected for further examination in situ, especially the 'Norrlanda' organ (ca. 1370–1400) whose 'archaic' keyboard resembles the original keyboard in the 'Ghent Altarpiece', visible in the underpaintings [3]

The preserved original pipes from the organs form the comparable period, among others in the Valère basilica in Switzerland (ca. 1435) and the organ from the St. Anderas church in Ostönnen (ca. 1430) will be examined by spectroscopy to determine the composition of the alloys that was in use at that time.

In summary, the reconstruction of the 'Van Eyck' organ currently in progress can be perceived not only as the result of an interdisciplinary study but also a part of empirical research, which will allow testing some of the theoretical assumptions experimentally.

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Using Acoustic Impedance to Propose the Best Restoration Material for Woodwind Instruments

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Abstract

This paper, aimed to study whether the repair of cracks in woodwind instruments could alter their amplitude or/and frequency, by measuring four wooden recorders before and after their conservation with acoustic impedance. Four different adhesives/fillers were tested for examine their ability to repair and preserve the acoustic properties of the recorders made of maple wood. Acoustic impedance was used to examine the recorders in three different stages: a) in their undamaged condition, b) after developing an artificial crack and c) after repairing the crack. Results showed that the most appropriate conservation material was "keromasticho", a traditional material used in Greece, a blend of beeswax and mastic, followed by Paraloid B-72. However, keromasticho does not meet some conservation standards and therefore further research is necessary before recommending its use.

1. Introduction

Selecting the appropriate materials for the conservation/restoration of wooden musical instruments, is undoubtedly one of the most important steps for their preservation and safeguarding. This work aimed to underline that not suitable materials can have a damaging effect on both the tone and the volume of an instrument and consequently destroy its musical, artistic and historical value. Furthermore, it aimed to present that acoustic impedance has the potential to evaluate the effectiveness of a conservation restoration method in woodwind instruments

2. Materials and methods

In order to implement the experiment, an impedance sensor was used which was developed and patented by CTTM (Centre de Transfert de Technologie du Mans) and LAUM (Laboratoire d'Acoustique de l'Université du Maine). The sensor was calibrated and tested by the formula F=2n-¼ * C/L. The mouth-piece of the recorder was removed and the diameter of body was measured in order to add this dimension to the software. Then, the instrument's body was placed to the sensor (figure 1) and the acoustic impedance of the instrument was measured. The duration of the signal was 9 seconds. To test the reliability of results, some instruments have been tested more than two times. All recorders were recorded in 8 different fingering positions.

After measuring and documenting all the recorders in their original condition, an artificial crack was developed onto them. The artificial crack was made in the hole at the back (thumb) (figure 2) with a cutting tool (cutter). The crack was near 1mm width and 7,4 mm height in all recorders.

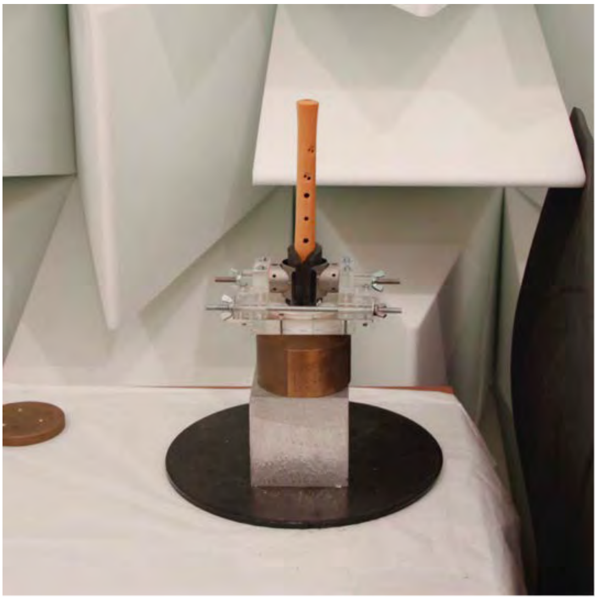


Figure 1: Placement of the instruments to the sensor

Figure 2: The artificial crack

The third phase of the experiment was the restoration of the cracks with different adhesives/fillers for each recorder as it is shown in table 1.

In most cases, instrument manufacturers in Greece repair the musical instruments with natural adhesives with no chemical processing such as natural res-ins or animal glues. For this reason, the adhesives selected for the filling of cracks were fish glue and a blend of beeswax and mastic called "keromasticho". For comparative purposes, two more adhesives were chosen; polyvinyl acetate, commonly used for wood gluing and a methacrylate copolymer for its great durability and reversibility. All fillers were applied on the cracks with a paintbrush. After the restoration the acoustic impedance was recorded again in eight different fingering positions.

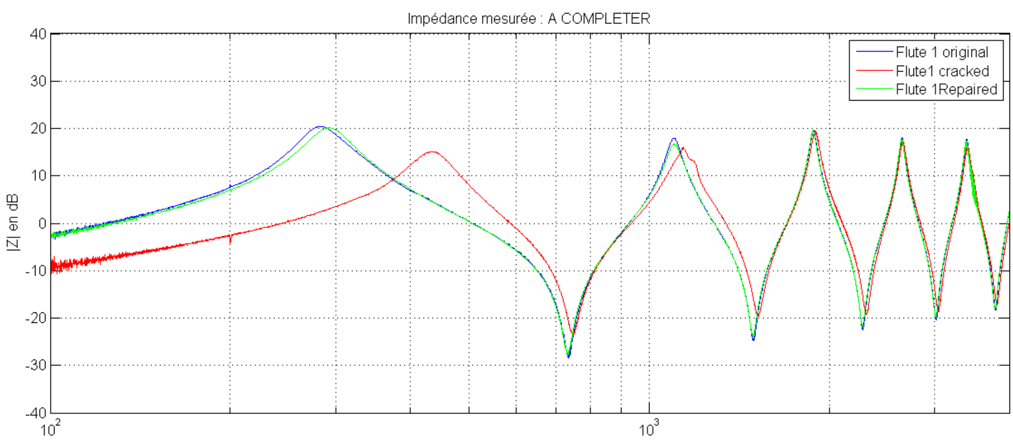
Table 1: Adhesive/Fillers used for the restoration of the recorders

Recorder	***Adhesive/filler***	***Name***
1	*Mastic & Beeswax*	*Keromasticho*
2	*Protein based glue*	*Fish glue*
3	*Ethyl methacrylate copolymer*	*Paraloid B72 40% w/w*
4	*Polyvinyl acetate glue*	*Vinavil*

3. Results and discussion

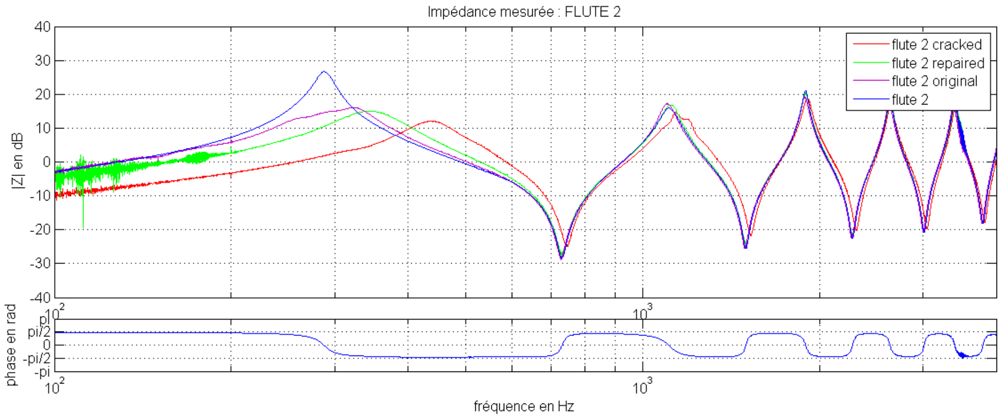
Comparing the spectra before and after the crack restoration, it is observed that in the majority of the recorders the sound spectra have been preserved with various degrees of distortion.

Comparing the initial sound spectrum of each recorder (before the crack) with the final sound spectrum, (after the restoration), the effect of the adhesive to the sound was possible to be evaluated. In spectrum 2 and 4, it is observed that the sound spectrum after the restoration has been shifted right or left to a degree higher than 3 Hz. That indicates that the recorders have eventually lost their tonality. Also, results show that the sound spectra acquired, presented different peaks after the repair, indicating that their volume has been also in-creased or decreased.



Spectrum 1: First recorder restored with the beeswax-mastic blend, (blue: original, red: cracked, green: restored).

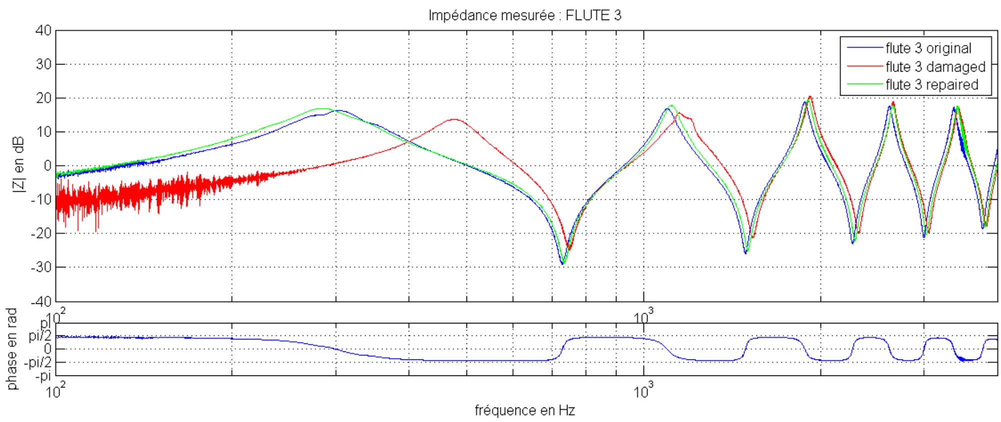
As shown in spectrum 1, the initial spectrum and the spectrum after the resto-ration, have the same picks as well as they follow the same frequency in contrast with the red spectrum (cracked).



Spectrum 2: Second recorder restored with fish glue, (blue: original, red: cracked, green: restored).

In the spectrum 2, it is observed that the flute repaired with the fish glue has approximately the same picks as the original; but its frequency has shifted right. In contrast, figure 3 shows that the spectrum of the repaired recorder with ParaloidB72, has shifted some hertz to the left but its peaks remained the same.

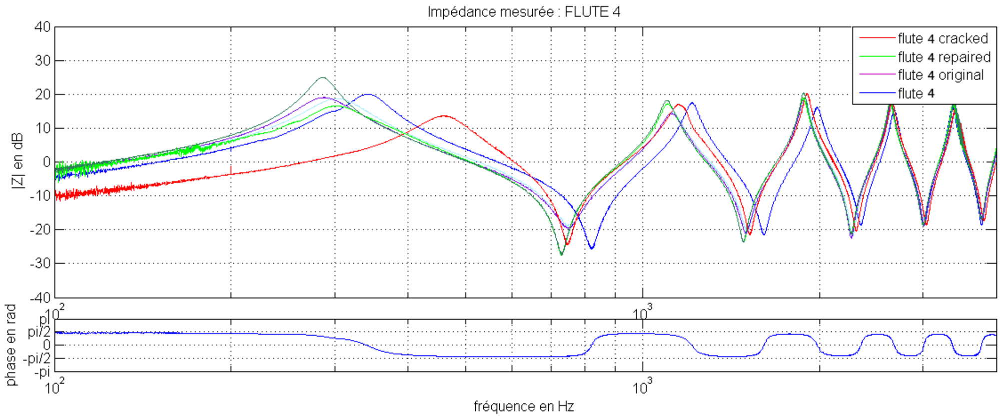
The 4th spectrum illustrates the recorder restored with the polyvinyl acetate glue. As it is observed, the restored spectrum has not returned to its initial state after the restoration and both picks and hertz have been shifted.



Spectrum 3: Third recorder restored with Paraloid B-72, (blue: original, red: cracked, green: restored).

In spectrum 2, it is observed that the flute repaired with the fish glue has approximately the same picks as the original; but its frequency has shifted right. In contrast, figure 3 shows that the spectrum of the repaired recorder with Paraloid B-72, has shifted some hertz to the left but its peaks remained the same.

The 4th spectrum illustrates the recorder restored with the polyvinyl acetate glue. As it is observed, the restored spectrum has not returned to its initial state after the restoration and both picks and hertz have been shifted.



Spectrum 4: Fourth recorder restored with polyvinyl acetate glue, (blue: original, red: cracked, green: restored).

4. Conclusions

The most appropriate adhesive/filler based on the preservation of recorder's audio properties, appeared to be a traditional material used in Greece for re-pairing wooden wind instruments, which is a blend of beeswax and mastic "keromasticho", followed by Paraloid B-72. Nevertheless, keromasticho does not meet some conservation standards regarding biodegradability, durability and properties after curing, unless it is improved with additives. Paraloid B-72 could be a candidate material as it can compromise good physicochemical properties over time with acceptable acoustic properties of the recorders. Finally, acoustic impedance was proved to be a reliable method for investigating woodwind instruments performance.

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Acoustic Wood Properties of Norway Spruce Growing in the Ukrainian Carpathians

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Abstract

The research work are represented the qualitative characteristics of Norway spruce wood growing on North and East slopes of Ukrainian Carpathians at the altitude from 801 till 1000 m asl. The resonance wood are well characterized by the velocity of the acoustic wave of the tangential polarization in the longitudinal direction in the correlation with wood density and wood macrostructure. Wood density of research samples are in the range of 320 to 380 kg·m-3 and the average width of annual rings – from 0.8 to 2.5 mm. The average width of annual rings - 1.3 mm and the average content of the late wood - 20.2% are mainly the diagnostic characteristics of the resonance wood in the Ukrainian Carpathians. The elevation range is one of the decisive factors for the formation of the resonance wood.

1. Introduction

Norway spruce (*Picea abies* (L.) Karst.) is of economic importance for the wood products industries in Ukraine. The spruce stands are common on the north-east mega-slope of Carpathian Mountain and it covers presently about 46 % of Ukrainian Carpathians timberland. There are permanent demands on spruce logs and especially high-quality structural lumbers [7]. Timber resources in the Carpathian region have gradually shifted from unmanaged old (over 120 years) growth to intensively young (60-80 years) managed growth stands. Known that young stands yield lower quality timber in comparison to old one, because of the higher proportion of juvenile wood [3]. Identifying the stem quality in the stand and determining most appropriate use are steps to increase product values [9]. Specific end uses of logs and their classifying into categories are addressed to enhance the forestry profitability [6, 7].

Research into technologies for measuring stem quality attributes are of forestry importance. Sonic technique is one of the most rapid way to identify the wood quality features [5]. The accurate estimation of wood properties requires simultaneous views of the wood macrostructure that mostly in conifer trees it could be expressed by tree-rings width and the percent of latewood [8]. It is necessary to note that wood structure can be considered as a rectangular system of cross-homogeneous closed "tubes" (tracheid) embedded in a matrix. Wood as an orthotropic material is characterized by nine elastic stiffness. The propagation behavior of acoustic waves in wood are affected by wood structure like a natural filter [1, 2]. However the modulation of propagating acoustic waves by structure of wood must be understood in terms of both propagation and polarization direction. The influence of the tree ring width and the percentage of latewood is very strong in the tangential direction when the propagation vector is parallel to the layering (axis) [1].

Good measurements and predictions of the external and internal properties of the wood in growing trees are crucial to rationally stem utilization with desired wood quality. In 2008, the research work was launched to study the wood quality of Norway spruce growing in the Ukrainian Carpathians at the altitude from 801 to 1000 m asl. The article summarizes the results of the investigation into modelling the effects of tree-rings width on the propagation behavior of acoustic waves in the Norway spruce wood.

2. Material and Methods

Research materials and data were collected in Norway spruce growing on south–west and north–east expositions of mountain "Dovshka", which is located in the Ukrainian Carpathians at the altitude from 801 till 1000 m asl (48°45´12´´N, 23°45´39´´E). Sampling wood was selected by using the destructive (discs) method. Wood discs were taken from six model trees at breast height. Specimens were cut out from mature wood. Testing wood samples were cut off progressively from the bark to the pith as rectangular cuboids with a base of 20×20 mm and length along the fibers of 340 mm. Totally, 70 wood samples were studied after about 12 month's storage and wood samples reached an equilibrium moisture content of 10 %. The study of physical wood properties were done according the international standards [DIN, 2009]. Acoustic properties of wood were studies within 1000 - 10000 Hz using software of GoldWave 6.09. Excel procedures, SPSS 13.0 and Statistica 10.0 was used for statistical analysis.

3. Results

The relationship between the velocity of acoustic wave tangential polarization in the longitudinal direction and basic wood density are shown in Figure 1.

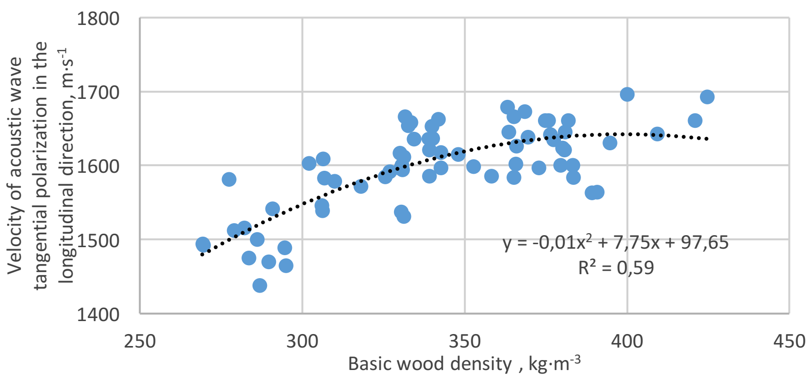

Figure 1: Relationship between the velocity of acoustic wave and the base wood density

Basic wood density of Norway spruce essentially determines the speed of the acoustic waves plain polarization in the longitudinal direction and is described by the equation of the second order (R^2 = 0,59). Most samples are characterized by wood density in the range of 320 to 380 kg·m^{-3}.

The relationship between the velocity of acoustic wave tangential polarization in the longitudinal direction and wood density by the moisture content of $W_{abs.}$= 10 % are shown in Figure 2.

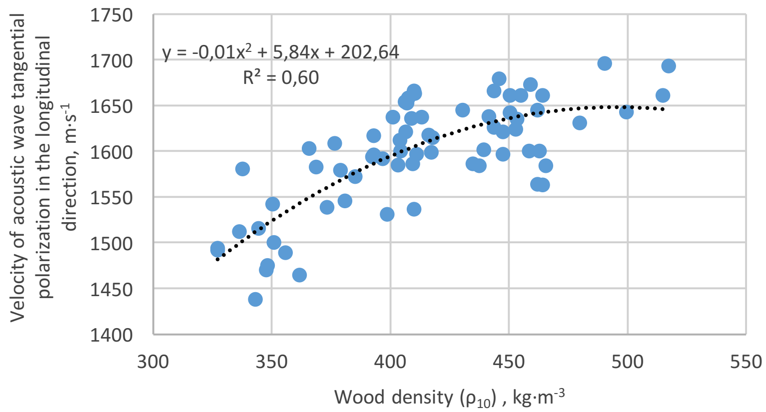

Figure 2: Relationship between the velocity of acoustic wave and the wood density (ρ_{10})

The Influence of wood density (ρ_{10}) on the velocity of the acoustic wave of the tangential polarization in longitudinal direction are defined by the coefficient of determination (R^2) in the range of 0.59 to 0.60. It should be noted the similarity of changes in the acoustic wave velocity in wood when changing its moisture content.

Of special note is the influence of the width of the annual rings of wood on the velocity of the acoustic wave of the tangential polarization in the longitudinal direction (Figure 3).

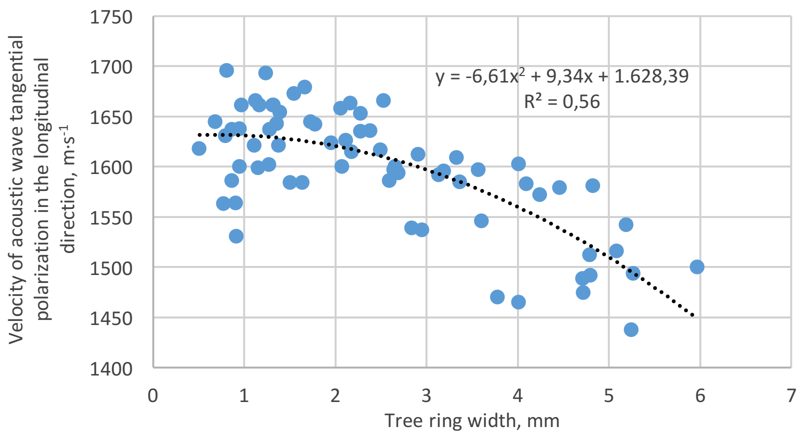

Figure 3: Relationship between the velocity of acoustic wave and the tree ring width.

The analysis of the chart that are defined the dependence between the tree ring width and the velocity of acoustic wave indicates about high correlation R^2 = 0,56. The percentage of late wood rings ranged from 8.5 to 51.9%.

4. Discussion

The high value wood of Norway spruce are common identified on North and East slopes of Ukrainian Carpathians. The relationships between the wood density, the macrostructure and the velocity of the acoustic wave of the tangential polarization in the longitudinal direction are the diagnostic criteria of the resonance wood of Norway spruce growing at the altitude from 801 till 1000 m asl. The resonance wood are crucial determined by the macrostructure, including the average width of annual rings, which range from 0.8 to 2.5 mm, and the ratio of early and late wood is ¼ [1, 2]. It is important to note that the resonance wood determined the average width of annual rings - 1.3 mm, the average content of the late wood - 20.2%.

Summarizing the research results of diagnostic criteria of the resonance wood is expedient to note that there is a straightforward relationship between the velocity of acoustic waves and the macrostructure as well as wood density of Norway spruce growing in the Ukrainian Carpathians. The quality wood of Norway spruce are simple to select in natural stands, where the short vegetation time generates small annual tree rings with low latewood proportion. The elevation range is mostly to be one of the decisive factors for the formation of the resonance wood.

Acknowledgements

The authors gratefully acknowledge to administration of State Enterprise "Vyhoda Forestry" for providing the testing material in 2007.

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Documenting the Construction Technology of a Portable Wooden Pump Organ

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Abstract

This study investigated a portable wooden pump organ, in order to document and comprehend its construction technology. The instrument was regarded to be an Indian harmonium, however various manufacturing elements, indicated that it could be either a variation of a harmonium or an ancestral form of the instrument.

The diagnostic survey undertaken, aimed to provide key information, on materials and techniques used which could point out possible origin, maker, time or place of construction.

Initially the organ was 3D scanned in order to obtain accurately its dimensions. Identification of the main construction wooden parts followed down to genus or species level with light microscopy. Coatings were finally examined by long wave UVA light and spot tests.

Results obtained demonstrated that the main wood species used, were *Populus* sp., *Picea* sp. and *Fagus sylvatica.* Under the water soluble ebonized-style finish of the sound box, traces of shellac have been located. These results along with various construction details indicate that this wooden reed instrument is more likely constructed in Europe around the late nineteenth century. Investigation is ongoing for documenting other data of its construction technology in order to confirm this hypothesis.

1. Introduction

Forgotten in the basement of a mansion in Northern Greece, a portable wooden pump organ (fig. 1) came to light when the demolition works of the house started.

The musical instrument has 39 keys (3 ¼ octaves) and its dimensions are ≈52x26x30cm. At first it was considered that it was an Indian harmonium, however the fact that i) the seven-fold bellows pump was attached on the top of the instrument and not to its back; ii) had 3 stops and no drones; iii) the absence of cover as well as other technological characteristics, indicated that it was either a variation of a harmonium or a type of its past antecedent.

Therefore, in order to a) establish the category of the instrument, its origin, age, manufacturing date etc; b) acquire knowledge about its construction and decoration materials and techniques and c) determine the need for its active or passive conservation, a detail documentation of the wooden musical instrument was undertaken [1].

This paper presents some preliminary results which led to a better understanding on the construction technology of this musical instrument.

2. Materials and Methods

The instrument was firstly scanned with an Artec Spider 3D Scanner and the model was exported to CAD software. Then, examination with a stereoscope and a UVA portable lamp, at 340-400 nm wavelength, was undertaken for providing information on the type and the condition of wood and its finishes. The UV investigation was supported by spot test where polar solvents (water, acetone, ethanol) and mineral spirits have been employed to characterize the coatings. For the identification of wood, several main parts of the instrument were selected (sound box, bellows' base, inner parts etc), where thin sections were taken *in situ* in transverse, tangential and radial directions. Keys of Schweingruber, [2] and IAWA [3] were used for the identification to genus or species level.

Figure 1: The portable wooden pump organ.

3. Results

3.1 3D scanning

Documentation with a 3D scanner provided quickly an accurate capture all of the physical measurements of the object (fig 2). All instrument' details and important information were automatically acquired in the 'point cloud' with an appropriate resolution with minimal contact with the object.

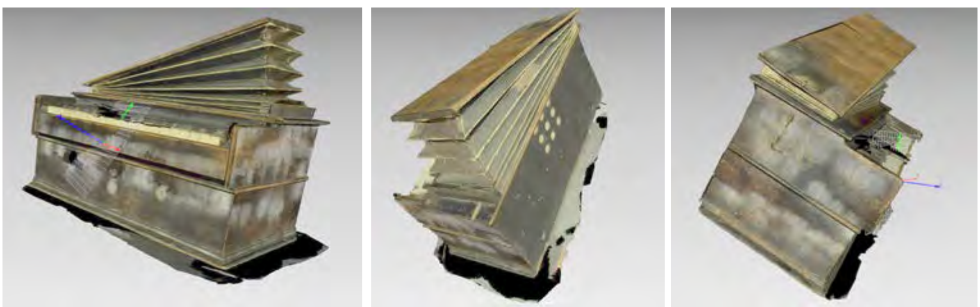

Figure 2: 3D models of the pump organ

3.2 UV examination

Examination with UV revealed an orange emission under the ebonized-style surface that is assigned to shellac fluorescence (fig. 3). This could indicate that shellac has been applied as a primer prior to the "ebonized" finall coating, or that the dark brown-black finish is a recent intervation. However, the fact the dark coating was water solube, could support the later assumption. Finnaly, it was observed that the the keyboard was made of keys with ivory facings

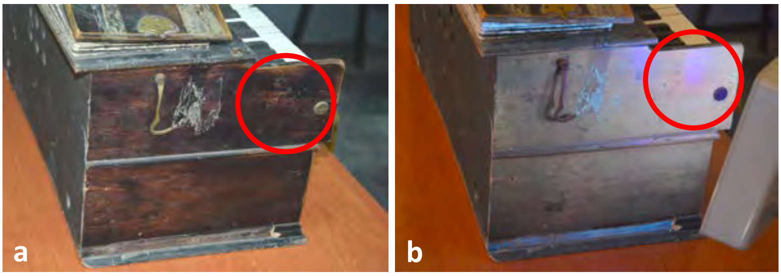

Figure 3: Side panel, viewed under visible (a) and UV light (b)

3.3 Wood Identification

The sound box and the bellows' base were identified as a *Populus* sp. This was concluded because vessels were found numerous, in multiples, in radial rows and were allocated in a diffuse-porous pattern. Furthermore rays were found to been exclusively uniseriate with an average height of 3–25 cells. Helical thickenings were absent. In the radial section, perforation plates were simple and intervessel pits were alternate. Finally rays found to be homocellular (fig. 4).

Some of inner wooden parts (fig. 5) were identified as *Fagus sylvatica,* as wood showed vessels in multiples under a diffuse-porous pattern and the perforation plates observed were both simple and scalariform. Furthermore all type of intervessel pits have been observed (scalariform, opposite, alternate). Rays were found to be multiseriated (1–25 cells in width) and to be composed of two or more cell types.

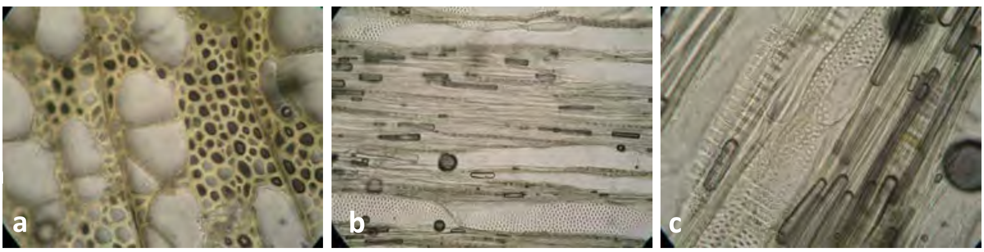

Figure 4: Cross (a), tangential (b) and radial (c) section of the sound box sample

Finally the intermediate board was identified to be a *Picea* sp. This was concluded based on the presence of radial and axial resin canals with thick-walled epithelial cells, piceoid and cupressoid crossfield pits and rays that composed or parenchyma cell and ray traheids. Ray parenchyma radial walls were also conspicuously pitted with nodular end walls.

4. Discussion and Conclusions

Results obtained indicate that this wooden reed instrument is more likely an early construction of a harmonium, made in Europe around the late- nineteenth century. Harmonium was invited in 1842, by Alexandre Debain and it was around the mid-nineteenth century when Christian missionaries took it to India [4]. In 1875 Dwarkanath Ghose, in Calcutta, altered the design of the instrument and made the construction of the harmonium simpler in order to fit better to the Indian lifestyle [4]. With the progress in electrical engineering and with the technological achievements of the twenty century, harmoniums became unfashionable and by the mid twenty century stopped being produced. Therefore the life time spam of this instrument was placed between the late-nineteenth century and mid-twenty.

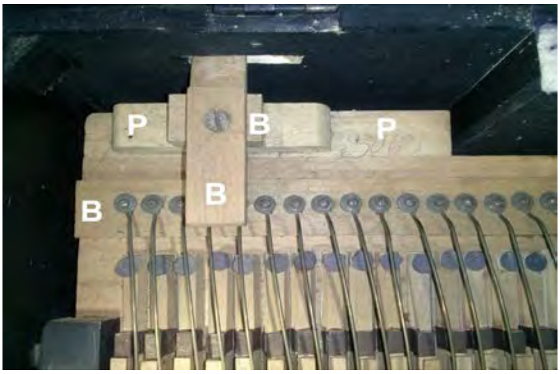

Figure 5: Inner parts of the instrument, where beech (B) and poplar (P) were used

Furthermore, portable harmoniums are commonly constructed with hardwoods such as teak or mahogany in order to produce a very resonant sound or with softwoods like pine or fir in order to be light. Poplar beech and spurce, found used in this instrument, are three European species indicating a possible construction in Europe; however it is also probable that this wood was imported to India. Further investigation is essential for the all construction materials of the musical instrument (coatings, dyes, ivory and bellows' paper etc.) in order to confirm this hypothesis.

Acknowledgement

The authors wish to thank Mr Giannis Mataragas for undertaking the 3D laser scanning.

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A Window on the World of Guitars of Granada, the City of Guitar-Makers

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1. Introduction

Talking about the Guitars of Granada is like talking about the violins of Cremona, and nowadays the builders are internationally recognized artisans who learned from old master guitar-makers, capturing not only the process of building an object but its soul, with a sensitivity and know-how that results in high quality, handcrafted, unique instruments, something that can only be achieved through many years of learning and sheer hard work. These guitars have so-called duende and a peculiar style acquired and passed from generation to generation, under very favourable weather conditions for wood and with great cultural influences reflecting the character of Granada. Many people have established in this city attracted by the romanticism of this profession, but our guitar-makers are united by infallible ties such as family bonds, daily work and a culture that is nurtured from the cradle. It is the only way you can truly perceive and master this profession: Granada Guitar-making, declared Intangible Heritage of Andalusia in 2014.

2. Historic background

Granada was for centuries a palatial city and the nerve centre of the Nasrid dynasty. After the Reconquest of Granada by the Catholic King and Queen it became a milestone for Christianity and the unification of Spain. Granada then became the focus and centre of the judiciary with subsequent social, cultural and musical ramifications. We have documentary evidence of this profession in Granada dating back to the Middle Ages, although the documented direct hereditary line dates back to 18th and 19th centuries precisely when the interest by some virtuoso guitarists raised the profile of the guitar to that of a solo instrument.

This, combined with the fact that professional associations disappeared, giving more freedom to guitar-makers to innovate in the construction of instruments on the one hand for popular or pre-flamenco music: flamenco guitars and, on the other hand, instruments for more educated music: classical guitars. Both are Spanish guitars, a term already coined in the eighteenth century, but are aimed at guitarists of different acquisitive levels and built with different wood and architecture.

The guitars of humbler clients who played Andalusian popular music were made with more affordable and accessible cypress wood and that taken from old furniture and were played in Zambras (flamenco dance performed by gypsies of Granada) barber shops, taverns and flamenco singer cafes; these gave a particular sound and architecture: the pre-flamenco and the current flamenco guitar. The guitars made from imported wood, that used traditionally for bowed string instruments such as Palo Santo, cedar or maple, were innovated at the request of guitar virtuosos or on the initiative of the guitarreros themselves to gain access to the more cultural and international world of music, with a unique sound and architecture, that of the classical, neoclassical and modern music in the current classical guitar.

Back in the eighteenth century, Granadine Guitarreros included great builders such as Jose Contreras, who became Philip V's luthier and restorer of the Stradivari instruments, whose instruments are highly regarded nowadays. Other great luthiers of the time were Rafael Vallejo, who built a Guitar-Psalter for Carlos IV located at the Victoria and Albert Museum in London and Agustin Caro, awarded by the Sociedad Economica Amigos del País of Granada (the Economic Society of Friends of the Country of Granada was a private association established in various cities throughout Spain during the Enlightenment) in 1815. Already in 19th century we have the guitar-makers del Valle, namely Nicolas awarded by Sociedad Economica Amigos del País in 1857; the luthier José Pernas, continuer of the School or Agustín Caro, also awarded by the Sociedad Economica Amigos del País with the Gold Medal in 1851. Later on, Antonio de Torres Jurado learnt at his workshop, according to Diccionairo de Guitarristas by Domingo Prat and oral tradition. Nowadays, Antonio de Torres, born in Almeria - Kingdom of Granada in the 19th century- is considered to be the creator of the modern Spanish guitar due to his ability to synthesize innovations and trends of the time: Antonio de Torres was a sponge who soaked up the best of the Spanish Guitarreria (Cadix, Granada and Seville) thanks to his training as a carpenter first and guitarrero later, and thanks to his knowledge of music - he learned from the international and virtuoso guitarist and teacher Dionisio Aguado and played several instruments. He imbued his instruments with all his research and innovations and he was able to share them thanks to the disappearance of the restricted guild at the beginning of the 19th century, his social relationships and geographical mobility with his work as a mining stock seller.

He also received recognition in 1858: the Bronze Medal at the Exhibition of Seville in 1858.Antonio de Torres was not only influenced by Granada guitar-maker Jose Pernas, his teacher according to the Diccionairo de Guitarristas by Domingo Prat with said influences reflected in some of his early instruments, but, probably, also by visiting other workshops during his stay in Granada; he was able also to analyze and restore guitars: such as a Francisco Ortega guitar that belonged to Federico Cano and was restored in 1885 by Antonio de Torres, according to the label, probably during his visit to Barcelona that year.

Other highlights were Juan Ortega Castellon guitar-maker who built guitars with a scrolled head like Caro, Pernas and Torres and trained Benito Ferrer and he in turn trained his son Jose Ortega. Benito Ferrer trained a large number of guitar players of the next generation such as his nephew Eduardo Ferrer and indirectly Manuel de la Chica. He also introduced important innovations in his instruments such as the exact and definitive rules for distribution of frets on the mandolin and lute and changed the old catgut and silk strings for wire ones. By implementing this he significantly strengthened the inside of the instrument so that it would support the pressure of wire strings. In fact, the first guitar of Andres Segovia was built by Benito Ferrer, a guitar identical to that preserved in the House-Museum of Manuel de Falla, Granada. His successor in the early 20th century was Eduardo Ferrer who trained the guitar players of the latter half of the twentieth century and these, in turn, were masters of present-day Guitarreros from Granada. The Yamaha factory hired him from 1966 to 1968 for three months each year to advise this multinational company about building guitars.

The historical guitarreros of Granada include: Jose Contreras "The Granaino" (1710-1782) and his son Jose Melito Contreras (1741-1791), Domingo Molina (1787), Rafael Vallejo (1790), Agustin Caro (active 1800-1820), Agustin del Valle (1801) and his sons Nicolas and Antonio del Valle (active 1840-1860), Jose Lopez (1801), Francisco Lopez Gascon (1804), Francisco Ortega Ayala (1816) and his father-in-law and sons Manuel Avila and Jose de Avila Bataller, Francisco Ortega and Rafael Avila 1858), Juan Ortega Castellon (1827) and his sons Jose Ortega Ruiz (1854) and Nicolas Ortega Ruiz (1861), Jose Pernas (active 1830-1870), Antonio Llorente (active 1830), Benito Ferrer (1845-1925), S. Malgareyo, Francisco Moya, Enrique Llorente (active 1860-1900), Nicolas Ortega Ruiz (1861), Jose Castaño, Milan Bernardino Suarez (active 1890-1940), Miguel Robles (1902-1970), Eduardo Ferrer Castillo (1905-1988) and Manuel de la Chica (1911-1998).

Most notable early twentieth century luthiers include maestro guitar-makers Eduardo Ferrer and Manuel de la Chica. Eduardo Ferrer trained the majority of the next generation of guitar-makers, who exported and put Granada guitar-making on the map during 1950s, 1960s and 1970s, some of whom are still active. Today there is a new wave of maestros guitarreros, those who began working in the workshops in the 1980s and that are now an icon of Granada guitar-making and who are responsible for preserving this indigenous craft, unchanged by time.

3. Conclusions

But, what are the characteristics of the Granada Guitar? As well as unique and individually crafted, hand-built guitars, the main features include: smaller plantilla that gives more dynamism and colour to the guitar, built up from the top, Spruce tops, Top domed on solera, Torres type strutting (usually 7), Peones instead of continuous lining, 650mm scale length, Mosaic rosette construction technique, French polish finish, resulting in greater elasticity guitar producing a more natural vibration of the wood, spruce or cedar top.

In short, it has always been said that the Granada Guitar was a continuation of the Torres plantilla, although there have been developments according to trends and demands of guitarists of every age. There was a time when they began to demand guitars with a larger plantilla in search of greater volume and now, again, the smaller plantilla seems to be fashionable looking for a greater harmonic content.

The process of making guitars and other plectrum instruments begins with the choice of wood from different parts of the world, which will ultimately influence the sound of the instrument. There woods include: Rosewood, Mediterranean Cypress, German Spruce, Honduras Cedar, Madagascar Ebony, and so on. The drying process of the wood is important and takes between 10 and 30 years depending on the model of guitar. Natural drying gives higher quality and structural strength and is done to ensure the maximum harmonic splendor of the instruments. Natural glues or so-called "hot glues" are used in the building process to give the instrument the necessary seal and tension. Varnishes are made by hand using shellac, which allows the guitars instruments to acquire the maximum response given the elasticity of the varnish.

And what is the Guitarrero Granadino profile? Guitar-makers born and bred in Granada, who have lived and experienced the culture and traditions of Granada.Guitar-makers leading this profession for more than 15 years.

Guitar-makers trained for at least 2 years, full-time, as an apprentice in the workshop of a master guitarrero of Granada.

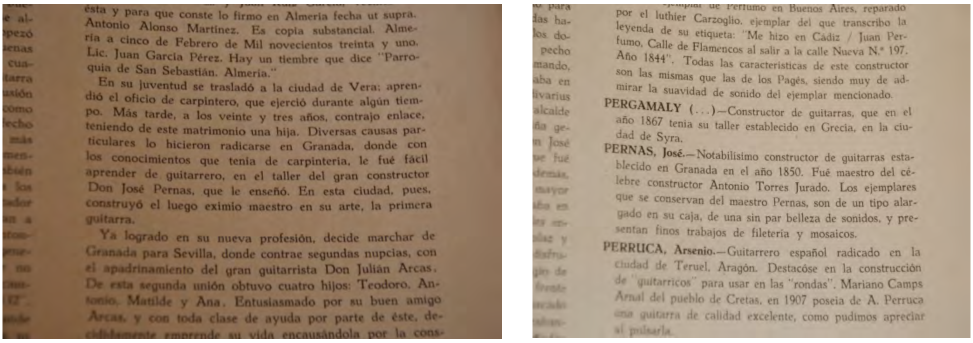
The uniqueness of Guitarreros of Granada is how they work: individually, in small workshops or shops, accompanied by apprentices, who are usually relatives and remain in the same workshop for years and who will come to inherit and pass on this profession, its sensitivity and know-how. In the early twentieth century, many workshops in other Spanish cities expanded using a large number of workers and this together with the introduction of machinery, resulted in the loss of the individual and artisan character of the guitarrero with the trend towards industrialization of this profession: constructors of guitars, Spanish lutes and bandurrias (traditional Spanish instruments). It is anecdotal and necessary to say that the construction of guitars has always been closely related to the construction of plectrums. In Granada this remains unchanged in the 21st century and something that must be preserved.

Table 1: Characteristics of the Granada Guitar

1. Smaller plantilla that gives more dynamism and colour to the guitar
2. Built up from the top
3. Spruce tops
4. Top domed on solera
5. Torres type strutting (usually 7)
6. Peones instead of continuous lining
7. 650mm scale length
8. Mosaic rosette construction technique
9. French polish finish, resulting in greater elasticity guitar producing a more natural vibration of the wood
10. Spruce or cedar top

Table 2: Master Guitarrero Granadino profile

1. Guitar-makers born and bred in Granada, who have lived and experienced the culture and traditions of Granada.
2. Guitar-makers leading this profession for more than 15 years.
3. Guitar-makers trained for at least 2 years, full-time, as an apprentice in the workshop of a master guitarrero of Granada.
4. Guitar-makers work individually, in small workshops or shops.



ésta y para que conste lo firmo en Almería fecha ut supra. Antonio Alonso Martínez. Es copia substancial. Almería a cinco de Febrero de Mil novecientos treinta y uno. Lic. Juan García Pérez. Hay un tiembre que dice "Parroquia de San Sebastián. Almería."

En su juventud se trasladó a la ciudad de Vera; aprendió el oficio de carpintero, que ejerció durante algún tiempo. Más tarde, a los veinte y tres años, contrajo enlace, teniendo de este matrimonio una hija. Diversas causas particulares lo hicieron radicarse en Granada, donde con los conocimientos que tenía de carpintería, le fué fácil aprender de guitarrero, en el taller del gran constructor Don José Pernas, que le enseñó. En esta ciudad, pues, construyó el luego eximio maestro en su arte, la primera guitarra.

Ya logrado en su nueva profesión, decide marchar de Granada para Sevilla, donde contrae segundas nupcias, con el apadrinamiento del gran guitarrista Don Julián Arcas. De esta segunda unión obtuvo cuatro hijos: Teodoro, Antonio, Matilde y Ana. Entusiasmado por su buen amigo Arcas, y con toda clase de ayuda por parte de éste, decididamente emprende su vida encausándola por la cons-

...ejemplar de Perfumo en Buenos Aires, reparado por el luthier Carzoglio, ejemplar del que transcribo la leyenda de su etiqueta: "Me hizo en Cádiz / Juan Perfumo, Calle de Flamencos al salir a la calle Nueva N.º 197. Año 1844". Todas las características de este constructor son las mismas que las de los Pagés, siendo muy de admirar la suavidad de sonido del ejemplar mencionado.

PERGAMALY (...)—Constructor de guitarras, que en el año 1867 tenía su taller establecido en Grecia, en la ciudad de Syra.

PERNAS, José.—Notabilísimo constructor de guitarras establecido en Granada en el año 1850. Fué maestro del célebre constructor Antonio Torres Jurado. Los ejemplares que se conservan del maestro Pernas, son de un tipo alargado en su caja, de una sin par belleza de sonidos, y presentan finos trabajos de filetería y mosaicos.

PERRUCA, Arsenio.—Guitarrero español radicado en la ciudad de Teruel, Aragón. Destacóse en la construcción de "guitarricos" para usar en las "rondas". Mariano Camps Arnal del pueblo de Cretas, en 1907 poseía de A. Perruca una guitarra de calidad excelente, como pudimos apreciar al pulsarla.

Figure 1: Diccionario de Guitarristas, Domingo Prat, 1934

La Crónica Meridional.

DIARIO LIBERAL INDEPENDIENTE Y DE INTERESES GENERALES

AÑO XXV. | Sábado 2 de Agosto de 1884. | NÚM. 7,314.

Guitarrista.—Leemos en *El Diario de Barcelona:*

«Se halla en esta capital D. Antonio Torres, distinguido fabricante de guitarras, establecido en Almería, y que sin duda es hoy día el primero de los constructores españoles de este instrumento, que bien puede llamarse nacional, por la plenitud de sonido y belleza de los que salen de los talleres del señor Torres. En una reunión á que asistimos y á que fueron invitados varios guitarristas, otros artistas y personas competentes, puso de manifiesto el Sr. Torres alguna de sus guitarras, una de ellas magnífica que le valió un primer premio en la Exposición de Sevilla del año 1858. A mas de las notables condiciones de sonoridad de la expresada guitarra, es el instrumento una obra maestra de ebanistería, en la que resaltan hermosos y diminutos mosáicos que la adornan, de un trabajo artístico tan delicado como de buen gusto. El Sr. Torres se ha conquistado gran nombradía como fabricante de guitarras, pues que las suyas son consideradas como las mejores por los célebres guitarristas Cano, Arcas y Tárrega.

Es tanto más de encomiar la supremacía del Sr. Torres en su ramo de fabricación artística, en cuanto puede decirse que esta industria fué innata en él, sin que nadie se la enseñase. Como hubiese aprendido desde niño á tocar la guitarra con el célebre don Dionisio Aguado, y no encontrando nunca ninguno de estos instrumentos que le satisfaciese, después de haber adquirido alguna práctica en la ebanistería, siguiendo el señor Torres sus inclinaciones, dedicóse á hacer estudios para mejorar y perfeccionar la construcción de las guitarras. Catorce años empleó en sus ensayos, hasta que habiendo obtenido los resultados que apetecía en 1856 se decidió á presentar en Sevilla sus instrumentos, los cuales tuvieron tanta aceptación que se veía apremiado para poder cumplir los encargos que se le hacían. El Sr. Torres se estableció más tarde en Almería, donde ha ido acrecentándose su fama por las muchas y excelentes guitarras que ha fabricado.»

Figure 2: Magazine La Cronica Meriional 1881: Article on Antonio de Torres Jurado

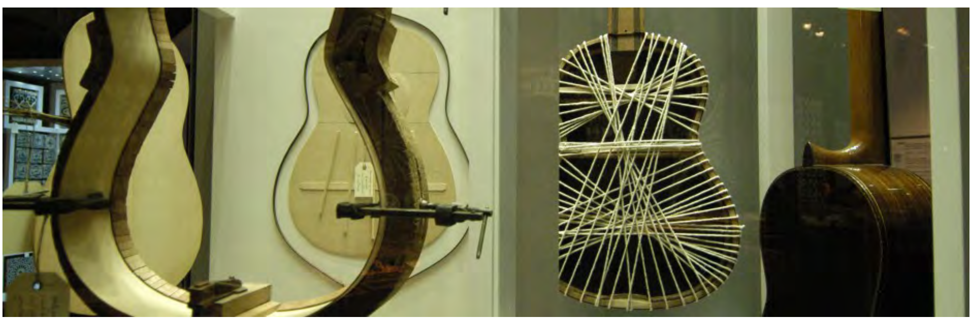


Figure 3: Guitar Making Process, Exposition at the Museum of Andalucia CajaGranada by Daniel Gil de Avalle

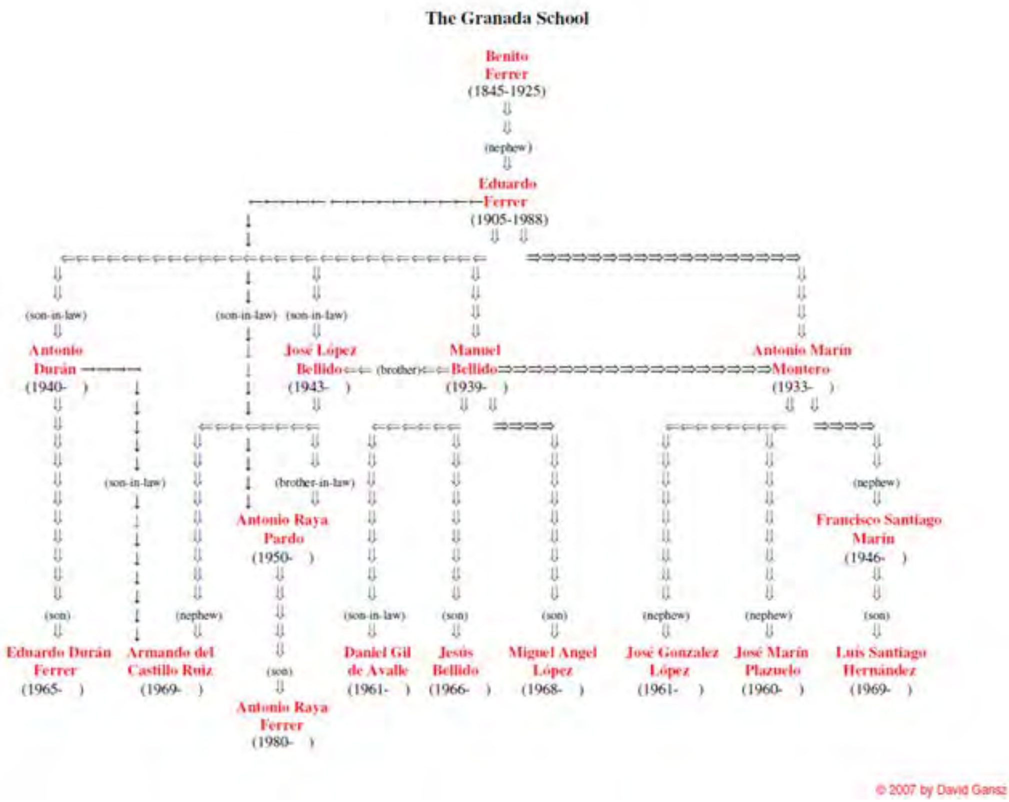


Figure 4: The Granada School of Guitar Makers Scheme, David Ganz 2007

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[1] *"Guitar-making techniques are not passed from master to disciple in a matter of months, but years."* Jose Luis Romanillos.

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Relationships between Quantitative Anatomy, Microstructure, and Vibrational Properties of Wavy Maple Wood

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Abstract

Wavy sycamore maple wood is highly prized in the market for its utilization as manufacturing material for violin. However, studies on its peculiar wave-like properties are still limited. Thus, the aims of this research are to determine the anatomical, microstructural, and wave-like figures characteristics and their correlation with each other, in link with vibrational properties.

1. Introduction

Sycamore maple is capable of possessing a particular type of figure known as wavy wood [1]. This unusual characteristic is scarcely found in the natural settings and, even in the rare trees that will exhibit this prized figure, it requires seven to ten years to manifest itself [2]. Coupled with its high value among the musical instrument makers [3], there is a great interest in deepening the knowledge of its properties. Most past studies took into account some of sycamore maple's physical, mechanical, and acoustical characteristics which influences strongly on the quality of manufactured instrument [4], [5]. However, these studies were often based on a reduced panel of wood variability, and, currently, studies on its anatomical properties, and their relationships with other characteristics of the wood, are still limited. Thus, this research was conducted with the aim to quantify the anatomical properties of the wood and its wave-like figure; moreover, the relationships between said anatomical properties with microstructure and vibrational characteristics are also discussed.

2. Material and Methods

Two types of maple (wavy and non-wavy) wood were used for measuring the vibrational properties. The experiments were conducted using Vybris testing device according to the methods described by Brémaud *et al*. [6]. For anatomical and waviness measurement, 12 wood specimens with varying wave-like figures were used in this research; all specimens were actual blank plates sold for violin back plates, under different "quality grades". 11 of them are *Acer pseudoplatanus* L. and 1 of them is *Acer campestre* L. From each specimens, two 2 cm × 2 cm × 2 cm cubes were cut, one for microfibril angle (MFA) measurement and one for rays measurement. Small blocks with different sizes (width 2—3 cm, length 3—4 cm, height 3—4 cm) were also cut for the measurement of their wave-like figures. For MFA measurement, microtome slices were made based on the light microscopy MFA methods [7]. For rays measurement, slices with 15 µm thickness were made using rotary microtome and measured using light microscopy. Using ImageJ, the measurements of wave-like figures were conducted with the scanned images of the wood blocks that had been split parallel to its grain. From the figures, amplitude (A) and wavelength (λ) were measured. The waviness (*w*) was calculated by comparing the amplitude and the wavelength of the specimens ($w = A/\lambda$).

3. Results

3.1 Wave-like figures

From the vibrational properties measurement results (Figure 1), it can be seen that there is a strong correlation between internal friction and specific modulus for sycamore maple wood. It also needs to be noted that the specific modulus of wavy maple wood is lower while its internal friction is higher than those of non-wavy maple wood.

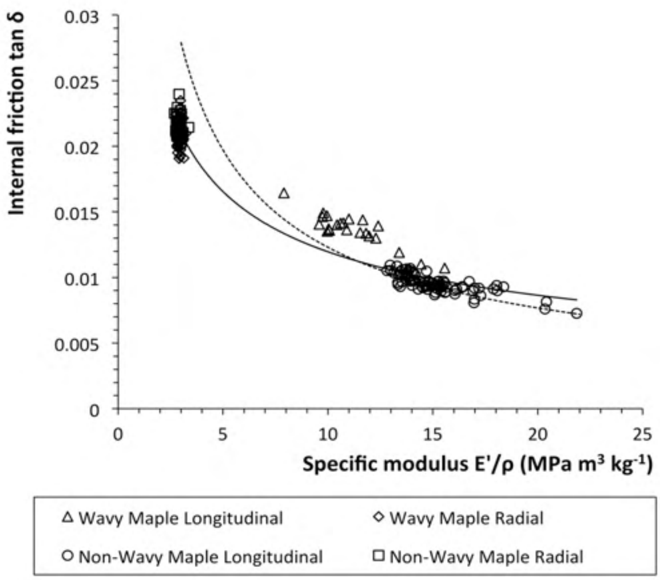
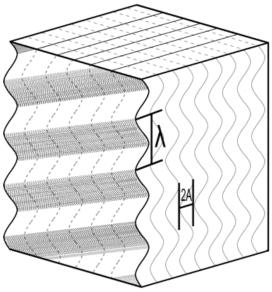


Figure 1. Internal friction and specific modulus of wavy and non-wavy maple

From the scan results of splitted wavy wood, the measurement of its figures was conducted. The waviness of the figures for each specimens of the wood are different, with some having wavier figures than others (Figure 2). The MFA of wood specimens shows high correlation value with the waviness (Figure 3): the wavier its figures, the higher its MFA. It has also been known that MFA correlates strongly with physical and mechanical properties of the wood and they, in turn, affect the vibrational characteristics which are important for the suitability of wood as musical instrument materials [8]. Thus, it is implied that, from material point of view, the waviness of the wood correlate with the suitability of wood as musical instrument material and may act not merely as visual aesthetic criteria in the selection process.

For the measurements, the rays were divided into big and small rays. The big rays consist of more than two seriates and significantly larger than the small rays, which consist of only one and two seriates. It is found that the big rays' height correlates significantly with waviness (Figure 4).



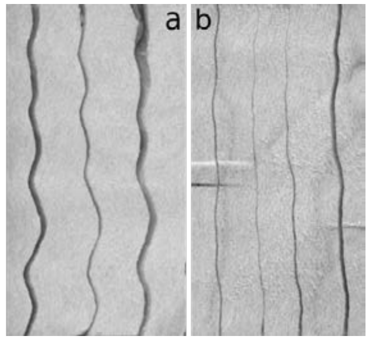


Figure 2: left: 3-Dimension depiction of splitted blocks, right: two examples of splitted wood blocks, showing different waviness, with (a) showing wavier figure than (b)

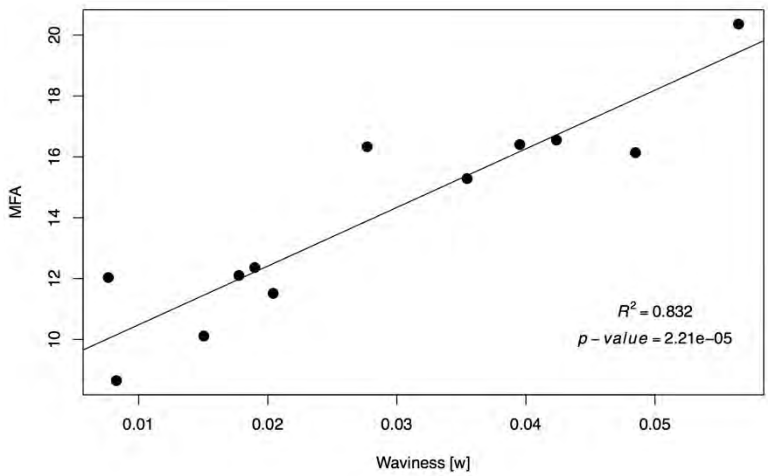


Figure 3: correlation between w and MFA

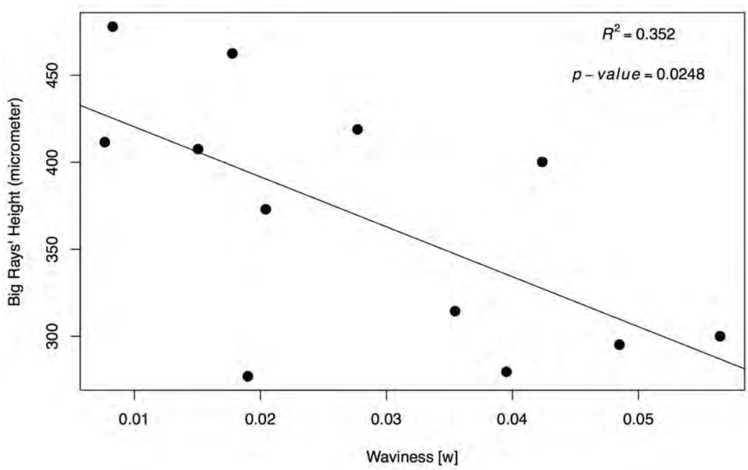


Figure 4: correlation between w and big rays' height

It needs to be noted that ray cells differ from fibres in term of physical and mechanical properties [9]. The variation in ray cells dimensions thus will lead to different composition of fibres and rays within a wood, and it is possible that these differing compositions will lead to variation in wood physical, mechanical, and vibrational properties.

Acknowledgement

The authors would like to acknowledge Daniel Guibal, Alban Guyot, Febrina Dellarose Boer, and Emma Guillon from CIRAD and LERMaB for their assistance and hospitality during the course of this research, Dr. Joseph Gril from LMGC for his guidance, the administrations of AgroParisTech and Bogor Agricultural University for their administrative and academic support, and CampusFrance and Ministry of National Education of Indonesia for the scholarship and financial support.

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Assessment of Volatile Organic Compounds (VOCs) Emission from Wood Applied to the Conservation of Wooden Musical Instrument. Preliminary Results

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Abstract

The object of the present study was to investigate and describe the emission of volatile compounds from wood samples. In the specific, emissions from Norway spruce (Picea abies) samples were monitored after drying and rebalancing cycles as to simulate natural ageing of wood material. We hypothesized that most of these VOCs might have originated from structural changes and degradation processes that involve the main polymers constituting the cell wall of wood. Therefore, this study tried to monitor the VOCs emitted by wood specimens, hoping to be able in next works to identify compounds due to degradation processes of wood ultrastructure, that involved the main components of wood (cellulose, hemicelluloses and lignin).

1. Introduction

The emission of volatile organic compounds (VOCs) from wood and wood based products has been gaining more attention in the recent past. Indeed, the monitoring of specific VOCs is fundamental in evaluating the impact of the material on indoor environment, its effect on human health and on other selected materials [1, 2]. Emissions from wood depend upon different criteria including species, age of wood, storage time and conditions, pH value and depend on hardwood or softwood [3–5]. VOCs emission characterization might have important implication for conservation of wooden musical instruments, providing information about material ageing and micro-climate in conservation cases. Volatile organic compounds (VOCs) emissions from Norway spruce (Picea abies) samples were monitored in response to ageing cycles of the material. Proton Transfer Reaction - Time of flight - Mass Spectrometry (PTR-ToF-MS) has been used to rapidly determine VOCs present in fresh samples and monitoring their profile during ageing cycles.

2. Material and methods

2.1 Sampling design

A 80-years -old Norway spruce log from Vallombrosa Forest (Reggello, Florence, Italy) was selected for cutting samples with dimension of 10cm x2cm x5mm of sapwood, heartwood or a mix of two. In fact, spruce was the most common wood species used for the production of musical instruments [6].

2.2 Ageing procedure

The analyses were repeated several times. Indeed, after the first analysis on fresh wood samples, the following drying and moistening schedules were applied and repeated:

each sample was placed in a desiccator (volume: 5l) and dried with magnesium nitrate hexahydrate Mg(NO3)2•6H2O at T 20°C and RH 54% under vacuum until reaching a constant weight. Samples with a moisture content MC of 12-15% were analysed by PTR-ToF-MS and subsequently they were moistened again at T 20°C and RH 100% under vacuum in the same desiccator. At the end of the rebalancing phase, another drying cycle was applied.

These cycles were intended to simulating the natural aging of wood due to the water exchange that wood structure achieves in a long period [7].

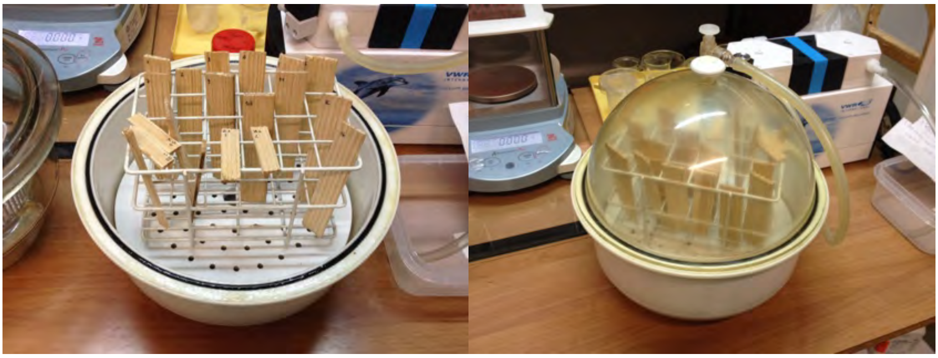

Figure 1: Norway spruce samples in the desiccator

2.3 PTR-ToF-MS

PTR-ToF-MS is a useful analytical technique largely applied for pro-vide an overview of the mass spectra of volatile compounds emitted from different materials [7–9].

The real time detection of VOCs emitted by wood samples were acquired using PTR-TOF system. The tool used was a PTR-TOF 8000 model (Ionicon Analytik Innsbruck, Austria). The same samples were analysed again with the same equipment to monitoring the VOCs profiles in response to subsequent ageing cycles. Indeed, these cycles were intended to simulate natural aging of the wood material.

3. Results and discussion

Several mass peaks in the range of measured masses (m/z= 20-205) were detected from the spruce samples. The mass peaks detected from green state wooden specimens decrease after several ageing cycles. The most interesting supposed molecules identified in addition to their measured m/z ratio, protonated molecular formula, chemical name and the related reference are shown in Table 1.

The main compounds detected by PTR-ToF-MS were m/z = 33.033 Tentative Identification: 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 = 81.069 TI: monoterpene fragment, m/z = 93.070 TI: toluene or p-cymene fragment, m/z = 137.132 TI: monoterpenes, m/z = 153.127 TI: terpenoid compound, and m/z = 205.195 TI: sesquiterpenes.

Table 1: Compounds emitted by *Picea abies* identified via PTR-ToF-MS

Measured m/z	Protonated chemical formula	Tentative identification	References (ToF#; Wood*)
31.018	CH_3O^+	Formaldehyde	[3]*
33.033	CH_5O^+	Methanol	[11]*, [12]*#
39.022	$C_3H_3^+$	Isoprene fragment	[12]*
45.033	$C_2H_5O^+$	Acetaldehyde	[11]*,[13]*#
47.049	$C_2H_7O^+$	Ethanol	[12]*#
59.049	$C_3H_7O^+$	Acetone	[11]*, [12]*#
61.028	$C_2H_5O_2^+$	Acetic acid	[11]*, [12]*#
69.036	$C_4H_5O^+$	Furan	[12]*#
69.069	$C_5H_9^+$	Isoprene	[12]*#, [14]*#
73.065	$C_4H_9O^+$	2-butanone (MEK) and 2-methylpropanal	[15]*#
75.043	$C_3H_7O_2^+$	Acetol / propanoic acid	[16]*#,[17]#
79.054	$C_6H_7^+$	Xylene fragm. / benzene	[12]*#, [16]*#
81.069	$C_6H_9^+$	Monoterpene fragment	[12]*#
83.048	$C_5H_7O^+$	Methylfuran	[16]*#
83.084	$C_6H_{11}^+$	C6 compounds	[16]*#
85.059	$C_5H_9O^+$	Acetylacetone fragment	[12]*#
87.081	$C_5H_{11}O^+$	C5 carbonyl compounds	[11]*
89.059	$C_4H_9O_2^+$	Butyric acid	[18]#
91.054	$C_7H_7^+$	Xylene fragment	[12]*#
93.070	$C_7H_9^+$	p-Cymene fragm./toluene	[12]*#/[15]*#
95.086	$C_7H_{11}^+$	Vinylfuran/phenol	[15]*#
101.059	$C_6H_{13}O^+$	Hexanal	[11]*, [16]*#
105.069	$C_8H_9^+$	Olefin	[16]*#
107.084	$C_8H_{11}^+$	Monoterpene fragment / p-xylene	[12]*#/[16]*#
137.132	$C_{10}H_{17}^+$	Monoterpenes	[11]*, [12]*#
153.126	$C_{10}H_{17}O^+$	Terpenoids	[12]*#
205.195	$C_{15}H_{25}^+$	Sesquiterpenes	[19]*

We monitored the trend of these compound emission after several ageing cycles. We could observe masses spectrum changes after several ageing cycles: some VOCs, such as ethanol, decrease in intensity, methanol and acetaldehyde continue to be emitted during all time analysis, other masses appear in the last analysis, but at the moment their connection with eventually depolymerisation processes is unknown and need to be better studied.

4. Conclusion

The aim of this study was to highlight the extent and type of VOCs emitted by Norway spruce samples. We observed that the emission rates of all revealed compounds decrease only after few ageing cycles. However, the monitoring of specific emissions

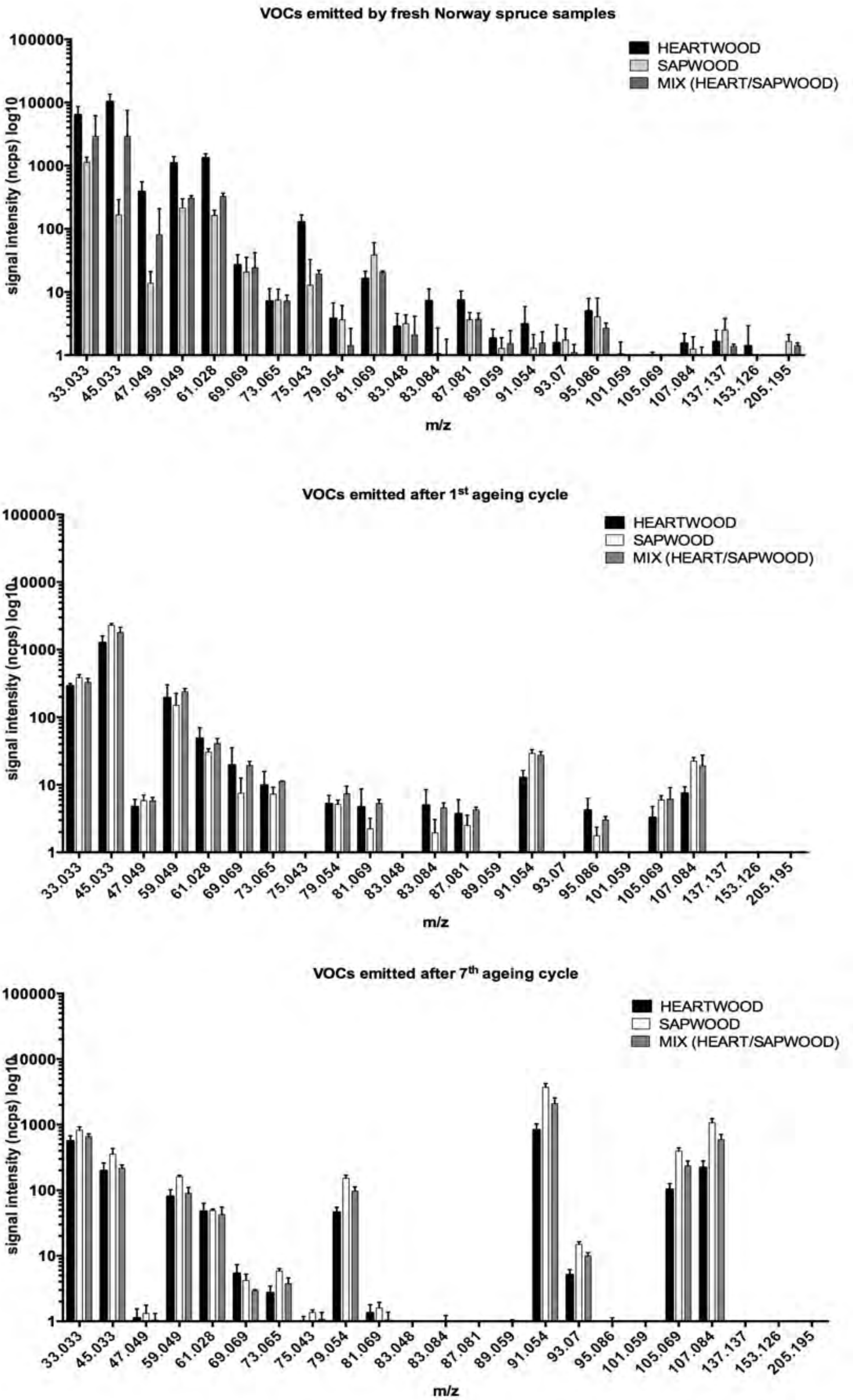

Figure 2: Trend of the main emitted compounds at different steps: a) green state; b) after 1st ageing cycle and c) after 7th ageing cycle.

during ageing of wood could allow the identification of VOCs as marker of cell wall de-polymerization, especially hemicellulose derivate compounds.

PTR-ToF-MS were used as a rapid tool of screening com-pounds emitted by spruce samples, but the identification and the monitoring of emissions due to chemical modifications need to be better addressed in future studies.

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Methodical Center of Documentation, Conservation and Restoration of Musical Instruments (MCMI)

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1. Formation of MCMI – Main reasons, needs and targets:

- on the basis of a thorough evaluation of the current situation in the field of documentation, care and management of musical instruments
- based on the need to unify the methodology of documentation, conservation and restoration terminology of musical instruments (nationally and internationally)
- as a tool and guidance for institutions, professionals, collectors and other interested persons
- the need to establish a uniform policy guidance on proper documentation of musical instruments in according of all standards
- goal is a standardized output for inclusion in a database accessible musical instruments
- another goal is to made uniform terminology and methodology and linking databases at national and international level

2. Intention

Need for formation of Methodical center of documentation, conservation and restoration of musical instruments (hereinafter as MCMI) is a logical consequence of the current unsatisfactory state of the processing and treatment of specific categories of movable cultural heritage - musical instruments - in the Czech Republic.

3. Target

The aim of the project of MCMI is professional processing of all types of musical instruments of European instrumentation in the collections of the Czech Republic, and there are three basic approaches:

- creating methodological approaches work in the area
- consultancy in the area
- treatment of specific collections

4. Conception

Concept of MCMI builds partially on the experience of other methodical centers operating in the Czech Republic, but methodologically is based primarily on standardized norms CIMCIM, ie. a specialized International Committee of ICOM brings together the museum's collection of musical instruments, and MIMO (Musical Instrument Museums Online).

- The Care of Historic Musical Instruments
- Clasification of Musical Instruments
- Recommendations for Regulating the Access to Musical Instruments in Public Collections
- Specifications of the Common Data Model for the Description of Musical Instruments

5. Range of the Project

Interest of MCMI are all types of musical instruments, primarily instruments of traditional instrumentation of European musical culture, secondarily also instruments of European folk culture.

6. Unique Moments (National and International Reach, the Points for International Cooperation of, Experts Managing Collections of Musical Instruments and Interested Public

- Creation of methodological approaches using the experience of National museum – Czech museum of Music, generally recognized standards for contemporary museology and care of exhibits with an emphasis on the specifics of musical instruments
- Reconciling methodology and individual processes with European and international standards
- Unification of terminology of musical instruments

7. An Example Of Methodical Procedures In The Form Of A Flowchart (Simplified Diagram):

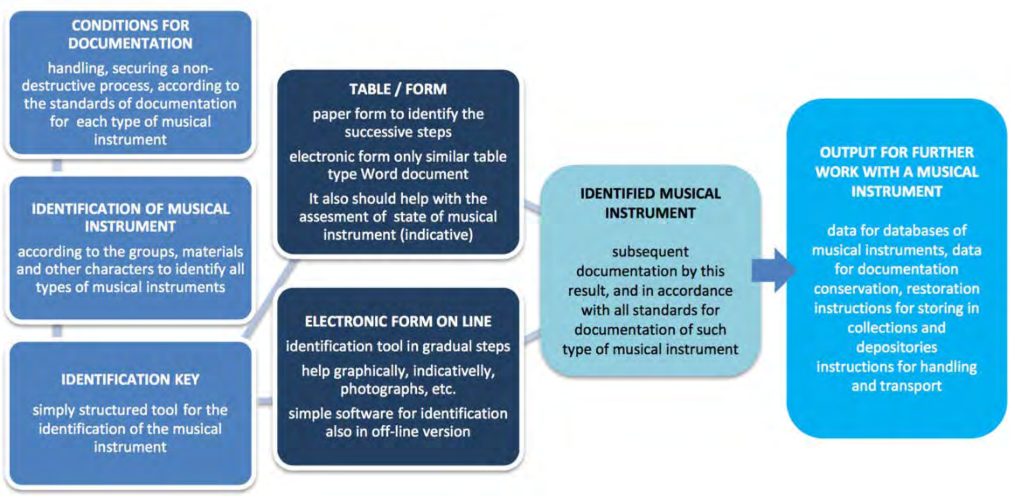

Figure 1: Methodical procedure of documentation of musical instruments.

Changes in Vibrational Properties of Coated Wood through Time from Application of Varnish, with Recipes Used in European or Iranian String Instruments Making

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Abstract

The influence of vanishing process on the vibrational properties of the wood+coating systems was studied using different types and recipes of instrument-making varnishes, used in traditional Iranian string instruments making, or in European violin-quartet making. The focus is on the time evolution of these properties, that can be involved in the changing behaviour of newly made instruments. The different tested varnishes recipes were applied on wood representative of each culture, studied both along-the-grain and cross-grain, and monitored through time for up to more than one year. The different effects, both immediate and their kinetics through time after application, are discussed.

1. Introduction

Surface finish is usually one of the last steps in instrument making. Depending on types of instruments, as well as on cultures, wood finish can consist of different processes. In stringed instruments, in many cases, wood is coated, which can be done with different products, including a wide variety of varnishes. Although the primary goal is probably more related to protection and/or aesthetics, varnishes can also affect the vibrational properties. The acoustical effects of several violin-making varnishes has been analysed regarding their significances in regard to instrument behaviour [Schelleng 1968] and to the diversity of ingredients and combinations found in historical recipes [Schleske 1998]. These studies noticed the evolution through time (years) after varnish application, however the ambient humidity conditions were not regulated, although they have a strong influence [Brémaud & Gril 2015], and/or the steps or measurement were not very detailed over time. Fine kinetics of changes in vibrational properties were analysed in the case of some more industrially used varnishes (Minato et al. 1995) or in the case of the oriental laquer Urushi [Obataya et al. 2001, 2002]. However, different types of coatings or varnishes, due to their different chemical nature, should show different effects on the wood+coating properties [Simonnet et al. 2002], as well as different kinetics of changes during time after application. These changes through time are possibly related to the opinions about changing response of newly built instruments. The objective of the present work is to analyse the detailed kinetics of these changes, starting from the different steps of the varnishing procedure, and followed over long times in controlled climatic conditions. The study includes violin-making as well as Iranian instruments making varnishing processes.

2. Materials and Methods

Studied material included wood+coating systems that are representative of European, and Iranian, traditions of instrument making. The wood species were White Mulberry (Morus alba) and Spruce (Picea abies). Material for both species was selected as high-grade for instrument making. 184 specimens (for Spruce) and 96 (for Mulberry) specimens were prepared, in the longitudinal (L) and radial (R) directions of wood. After measurements of the untreated physical and vibrational properties, they were distributed into matched groups of (6L+6R) specimens each through a careful statistical procedure. Each group is intended for a different modality of the varnishing process: 12+10 groups for Spruce+Violin making varnishes, 5+3 groups for Mulberry+Iranian long-necked lutes making varnishes.

Vibrational properties were measured by non-contact forced vibrations of free-free bars, using the device and protocol described in [Brémaud 2006; Brémaud et al. 2012]. They included longitudinal and radial specific modulus of elasticity (E'/γ, proportional to resonance frequencies) and damping coefficient ($\tan\delta$, related to vibration decay and to the sharpness of resonances also called quality factor).

Tested varnishing procedures and recipes were as follow:

- Spruce was coated according to varnishing procedures used in violin making. 3 kinds of ground layers were tested. 5 recipes of siccative-oil based varnishes were applied, using different oils and resins and proportions. All the steps of application and curing (by UV-light) were done inside a climate-regulated room. The changes in mass and in vibrational properties were monitored during all steps, and then followed during more than 12 months after application (still in progress).
- Mulberry was coated by alcohol-based sandarac varnish, following the same step-by-step monitoring through time, in regulated conditions, as above. Solvent alone, and 1, 3, 6 varnish layers were tested. Monitoring of changes in properties was conducted for about 8 months.
- An additional study on Mulberry was based on actual application by a skilled Tar and Setar maker of 3 different varnishes (2 alcohol-based: Sandarac and Shellac, and 1 artificial: polyester). Application was conducted in the workshop, then properties were measured in lab-conditions after 2.5 and 7 months.

3. Results and discussion

After applying on mulberry wood a single layer of Sandarac/ethanol varnish, the resonance frequency was barely affected in L direction but clearly increased in R, and damping was increased by up to 50% in both R and L (Figure 1). Ethanol solvent alone had very limited effect. With 6 layers (similar to actual instrument making), immediate effects were an increase in frequency in R (+6%) and very strong increase in damping (+100 in L to +160% in R). Over time, frequency continued to increase while damping re-decreased, starting to stabilize only after 2 months. Sandarac-ethanol varnish appears to have, when stabilized or "dry" -which took about 7months- a stiffening effect with nearly no final increase in damping. Workshop application by a skilled maker gave similar results for Sandarac and for Shellac, while polyester proved to induce a more permanent increase in vibration damping.

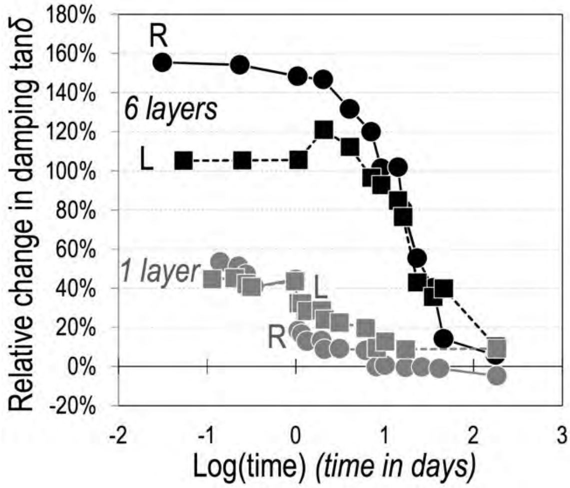

Figure 1: Changes trough time (7months) of vibration damping of mulberry wood varnished with Sandarac dissolved in ethanol. 1 data point = mean of 6 specimens, Time axis in Log-scale (0=1day, 1=10days, 2=100days).

The effects of application on spruce wood of violin-making varnishes is illustrated, in Figure 2, by the example of a linseed-oil + Sandarac resin varnish. The vibrational properties changed little just after application, when varnish is still quite liquid. After UV-accelerated curing, damping is very strongly increased (+40% to +80% in radial direction) for a single layer of varnish applied. On Spruce, the differential of effects between along the grain and cross-grain is much more pronounced than on Mulberry. The protocol we designed allows to separate the effects of varnish itself from effects of moisture changes (due to UV or to slight de-regulations of climatic room). One thick layer of varnish evolves much more slowly than a thin one. Changes in damping are only partially related to added mass of varnish: 2 thin layers result in more added mass than 1 thick layer, but has similar effects on vibration damping. The kinetics of changes in properties after coating with siccative-oil based varnish is obviously much slower than the previous example on alcohol-based varnish. With this example of "fatty" varnish, the properties continue to evolve, without yet clear signs of stabilization, after one year from initial varnishing. The monitoring of changes in properties through time is intended to be continued for several years.

To complete the example described here, the presentation will compare the same protocol and obtained results with 5 different kinds of "siccative oil + resins" violin-making varnishes.

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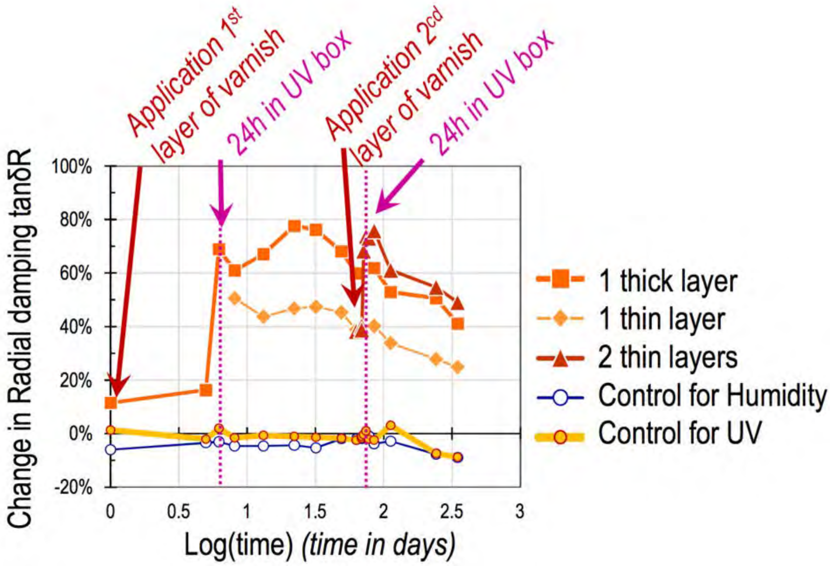

Figure 2: Changes trough time (12months) of vibration damping of spruce wood coated with a "fatty" varnish (Sandarac resin and linseed-oil). 1 data point = mean of 6 specimens, Time axis in Log-scale (0=1day, 1=10days, 2=100days).

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Tonewood Selection: Physical Properties and Perception as Viewed by Violin Makers

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Abstract

The objective of this paper is to improve our understanding of the resonance wood and more precisely the interactions between their physical-mechanical properties, their natural variability, and the modalities of material's choice by violin makers. To identify craftsmen' practices and opinions, a "socio-technical" survey was created and completed by a psychosensory evaluation conducted with makers to evaluate directly 9 top plates and 9 back plates. These tonewood samples of various "qualities" and provenance were also characterised for their physical/vibrational properties and their visual/structural characteristics.

1. Introduction

Norway spruce (Picea abies) and Sycamore maple (Acer pseudoplatanus) are respectively used for the making of top and back plates of violin family and are known under the term of "Resonance Woods" [Bucur, 1992]. The mechanical and acoustical properties of these species are quite well characterized: high quality resonance spruce has low density, high specific modulus of elasticity, low damping and high anisotropy [Ono & Norimoto, 1983; Obataya et al. 2000]. As a pre-selected material, Resonance spruce shows unclassical relations between visual/structural features (Ring width, Latewood percentage) and the mechanical/acoustical properties. Empirical knowledge of makers is precious and can help to appreciate the concept of "resonance wood" but the perception of the raw material by luthiers, their practice and opinion has seldom been explored. According to the only psychosensory study on the subject [Buksnowitz, 2007] wood selection made by violin makers would rather rely on visual criteria than on mechanical or acoustical properties that seem difficult to be assessed on raw supply planks. It could also reveal the use of indirect indicators, and/or take into account personal or cultural preferences in wood choice [Brémaud, 2012]. The current challenge is now to take into account both the point of view of the practitioners (craftsmen and/or foresters) and of interdisciplinary scientific research. Therefore, the objective of this study is to improve the understanding of the interactions between physic-mechanical properties of resonance wood, their natural variability, and the actual expertise of violin makers in the selection, qualification and processing of their raw material.

2. Material and method

2.1 Survey

To identify craftsmen' opinions, practices, empirical knowledge and their main questions, a "socio-technical" survey on both qualitative and quantitative grounds has been created. It was first developed as face-to-face interviews using a modular and detailed questionnaire and then set to go online in a French and English version.

Suppliers were also questioned and analysis was achieved using Sphinx software. Results are analysed on the basis of 9 questionnaires.

2.2 Mechanical and optical characterisation

To complete our survey a mechanical and psychosensory study was conducted with makers to evaluate 9 top plates and 9 back plates from different provenances and sold under different quality grades.

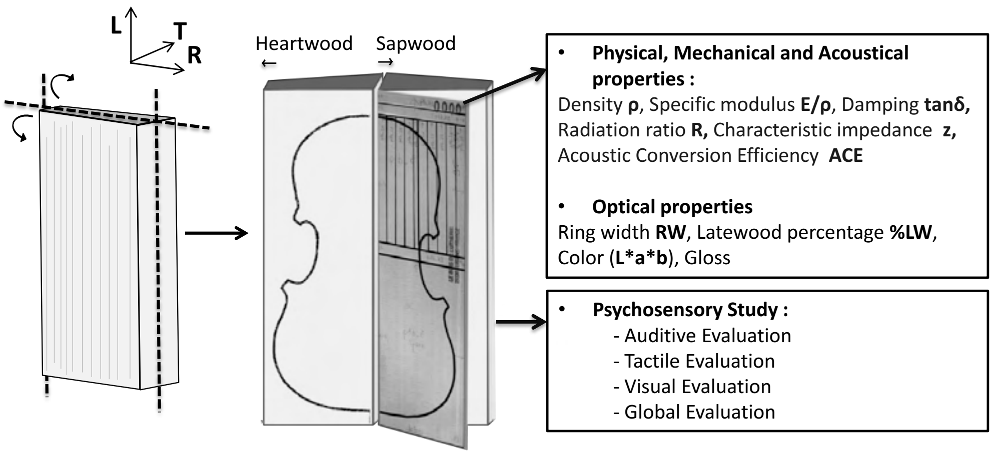

Figure 1 : General sampling plan

During the separation of the quarter cut blank plate into two halves of the future top (soundboard) or back plate, a thin board (2.5mm) was extracted from the centre in order to be representative of the plate. Radial and longitudinal specimens were cut from this board (figure 1) in order to assess the properties of the wood and their variations in these two directions. For a board, one to three radial specimens (120 × 2.5 × 12mm, R × T × L) and seven to ten longitudinal (12 × 2.5 × 150mm, R × T × L) specimens were obtained. They were stabilised at 65 % relative humidity and 20 °C for at least 3 weeks, to reach the equilibrium moisture content at circa 12%. These specimens were characterized for their physical/vibrational properties and "performance indexes" (Density ρ, Specific modulus of Elasticity E/ρ, Damping tanδ, Radiation ratio R , Characteristic impedance z, Acoustic Conversion Efficiency ACE) and their visual/structural characteristics (Ring width, Latewood percentage, Colour, Gloss) as described in [Carlier et al, 2014].

2.3 Psychosensory Evaluation

With the remaining blanks plates, wedge-shaped, two psychosensory studies (for spruce and maple) were designed in four steps in order to evaluate respectively the contributions of the auditory, tactile and visual perceptions of wood. Evaluation is done product by product which are randomly distributed during the four parts: additive, tactile, visual and global evaluation (Figure 2).

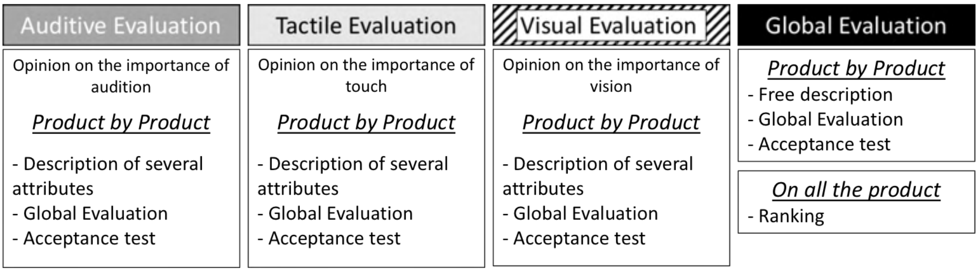

Figure 2: Planification of the four steps of the Psychosensory evaluation of Resonance wood

Except for the global evaluation, which aims to reproduce closely the maker judgement as they do in their workshop, each protocol follows a same outline. First, some attributes are evaluated to establish a sensory profile of the blank according to each sense. This part permits to characterize the product and learn how the attributes define a board as excellent or unusable. The blanks plates are then globally evaluated. Finally, an acceptance test is performed to determine the emotional attachment to the product. Results are at this time not complete to be statistically significant and are based on seven participants

3. Results

From the survey, it appears that empirical choice of violin makers are based on perceptual criteria that can be visual, tactile, physic-mechanical and auditory. The main criteria to qualify the spruce wood are: good quality of cutting orientation, density, percentage of latewood, growth ring uniformity and width. Makers report a lot of interest on several field of research including those on resonance wood. They considered the wood to be one of the most determining factors in sound quality of the instrument. They believed the acoustical properties of wood changed over time and depending on the instrument being played or not.

Thanks to the psychosensory study, the relative weight of the perception senses to choose the material were determined as well as the associated descriptors used by makers to evaluate the wood. The criteria favourably perceived by different senses to define a good top/back plate were isolated.

The evaluation average for each top plate according to the different senses was calculated (figure 3) for the tests conducted at the time of writing (non-definitive results). It shows that differentiations between Spruce blanks are not equal according to the type of evaluation; plates' discriminations are more difficult to assess by additive rating than visual, tactile or global rating.

Moreover the variability of makers' judgments according to the attributes in terms of profile or dispersion lead us to think that this result will evolve until the end of this experiment.

Finally, the evaluations of the makers were analysed in regards to the physical characterisations of the specimens in order to characterize the perception threshold. It permits to reveal how senses reflected the different properties of wood. For this particular case (non-definitive results), the tactile evaluation seems well related to density. Visual evaluation shows correlations with the modulus and specific modulus of elasticity and is well related to the damping and to the "characteristic impedance".

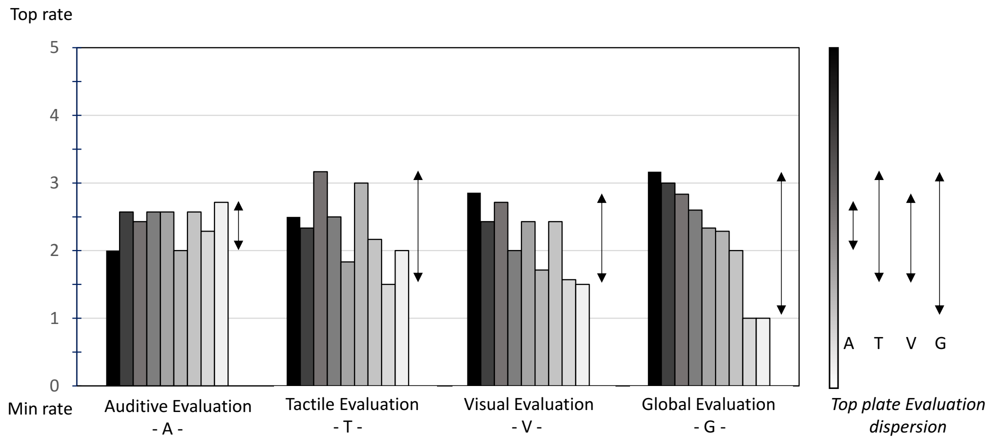

Figure 3: Average rate of the Evaluation of the 9 top plates according to the different modalities of the psychosensory test.

Acknowledgement

We are grateful to the support of CNRS (PhD grant for Capucine Carlier), of the Région Languedoc-Roussillon (Young Researcher Prize to Iris Brémaud), and all the makers and suppliers, for their time, help they granted us and their participation in the survey and the psychosensory evaluation. The author also thanks Daniel Guibal in CIRAD, Montpellier, for the assistance during the experiment, Tancrède Alméras, LMGC, CNRS-Université Montpellier II, for developing the Image J plugin and helping the author for the data analysis and Agnès Burgers for the support during the Psychosensory study.

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Self-Destructive Elements in the Construction of Guitars in the Nineteenth Century

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Abstract

This paper will discuss the inherent problems caused by the anisotropic properties of wood in relation with the construction techniques and structure employed for the construction of guitars during the first half of the 19th century.

1. Introduction

The first half of the 19th century saw the transition from the so called baroque guitar to the classical guitar as we know it today. During this period numerous transformations of the shape and construction took place to eventually give shape to the classical guitar. This includes changing from 5 double courses to 6 single strings, from friction pegs to tuning machines, vaulted to flat backs, and transition from the slender peanut shaped body into a curvier outline with dipper resonance box.

The 19th century guitar, also known as 'Romantic,' can be considered as a transitional instrument, developing quite differently in different regions of Europe, and thus hard to define as a stereotypical instrument of unique characteristics. Nonetheless, there are a number of aspects of its construction which are more or less standardized throughout. The soundboard is made of two book-matched quarter-sawn pieces of spruce or similar coniferous wood; the sides and back are made of a hardwood of radial section, although often the back is flat-sawn to obtain a more interesting grain patterns, and in some schools the back is made of quarter-sawn spruce and then veneered with the same wood as the sides.

Most relevant for this paper though, are the modifications that took place inside of the body of the guitar: the internal braces made of quarter-sawn spruce glued to the inside of the soundboard and back, which work both as structural reinforcement as well as to improve the acoustical quality of the instruments.

Although effective at the time, these structural reinforcements, are the cause of a series of long-term almost inevitable self-destructive phenomena that compromise their physical integrity and therefore the focus of this presentation.

2. Construction, destruction, and possible solutions.

Whilst the pieces of wood employed for the construction of the soundboard and back of 19th century guitars are quarter-sawn and their grain is oriented parallel in the same direction, the internal braces, although also quarter-sawn, are glued perpendicularly. This makes sense form a structural/acoustic viewpoint. However the anisotropic volumetric shrinkage due to the hygroscopic nature of wood turn these reinforcements into long-term self-destructive devices. That is, due to the release and absorption of moisture, wood shrinks in different proportions in different directions; therefore, whilst the soundboard and back are shrinking width-wise, the braces are not. As a result, if left in their original state, even if stored in proper conditions, and properly preserved, most of the guitars built during this time will suffer substantial deterioration and structural damage.

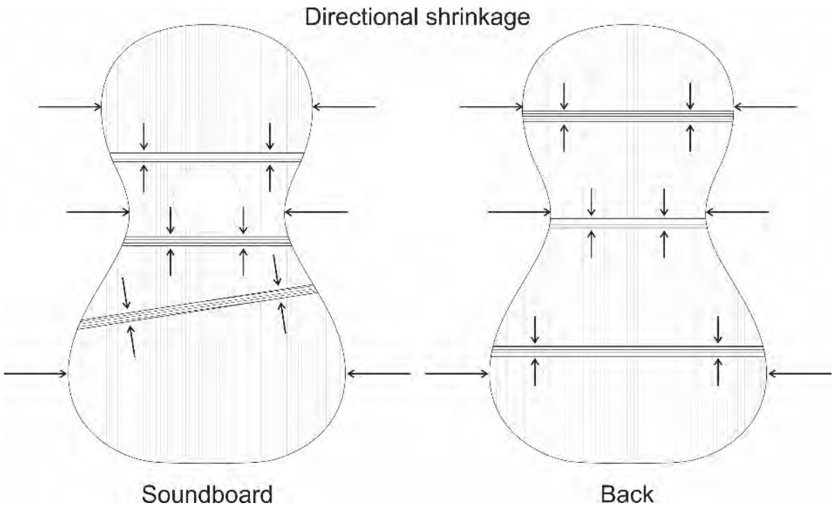

Figure 1. Diagram of the dimensional shrinkage due to anisotropic properties of wood.

The most common problems related to this phenomenon are: Longitudinal fractures in the soundboard and back; detachment of the bridge and decorative elements of the soundboard; and deformation, protrusions, and fractures on the sides, therefore altering the outline and potentially causing damage to the bindings.

Figure 2. Fracture in the back. Guitar by Genaro Fabricatore, Naples 1825, Private collection.

A similar phenomenon sometimes takes place in the neck, often made of a solid core of softwood either ebonized or veneered in ebony. The volumetric shrinkage of the core wood is not followed by the perpendicular metal frets inserted in the fingerboard or the veneering, causing deformations and damage to the veneer.

Figure 3. Fractured sides with protruding brace. Guitar by Genaro Fabricatore, Naples 1817, New York Public library.

This leads to the unavoidable question: what to do? Although there are diverse approaches to this problem, all of them have deep theoretical and ideological implications.

Musical instruments can be regarded as objects of use, thus their relevance resides in the perspective in how we approach or define this use.

Form a musical viewpoint they are used as sound producing devices and they are maintained in 'playable' condition, which often involves repairs and modifications. However when kept in public collections as historical objects they are used as teaching devices, either to be displayed or as research documents. Their functionality is then seldom regarded as their most valuable asset, the aesthetical or historical aspects being more important. Therefore the preservation treatment will depend in the 'use' we intend for the object, and certainly there is no single treatment that can be applied to all cases.

A first and conservative approach is to preserve the damaged instrument 'as is' and assume the degradation process has stopped. This line of thought involves the preservation of an unstable and fragile object often with loose parts, and the potential of further damage during its storage and handling. Yet preserved in a completely original condition.

Another option is the consolidation of the parts from the outside, for example via reversible adhesives and Japanese paper. This approach will prevent some of the problems; however, this is not adequate for instruments intended for display.

Often the most suitable solution to stop and reverse this damage and deterioration, involves highly invasive treatments, which in some cases involve the dismantling of parts of the instrument and the removal of original material.

An overall description of this full on procedure step by step starts by removing the back of the guitar; the soundboard is rarely removed because of all of the other pieces attached to it and its involvement in the 'action' of the guitar.

Figure 4. Guitar by M. Fernandez, ca.1880 National Music Museum, NMM 14615.

Once the resonance box is opened, the braces which as a result of the dimensional shrinkage of the soundboard are too long for the instrument are removed. Similarly the bridge often needs to be removed at this point. I want to make special emphasis in the importance of a thorough documentation of all the processes and the parts. All the treated pats of the guitar should be individually measured and documented.

At this point we are presented with an interesting dilemma; since the braces will not fit the guitar as it stands now we have two basic options: to alter the size of the original braces by removing a portion of their ends to adjust to the new dimensions of the back and the soundboard; or to replace the originals with new braces made following the shape, and dimensions of the originals but slightly shorter?

The latter option allows us to consolidate and structurally reinforce the guitar whilst the original braces can then be stored unmodified, and preserved for further research. However, replacing such a significant amount of original material can be questionable, even if we preserve it separately.

Altering the original braces by cutting the ends will allow us to keep the original braces inside the instrument, therefore maintaining all the original parts together and structurally stable. Yet, it presents us with a different set of disadvantages. It is certainly a non-reversible procedure and implies the removal of original material and therefore the loss of a potential evidence of the original dimensions of the guitar. The removed material should be documented and archived for further research; since it could be used for a number of scientific analyses, e.g. microscopic wood identification, carbon dating, XRF, etc.

The deformed areas of the sides can be brought back to shape via a 'mould and counter-mould' system. A convenient solution for this process is to use Polycaprolactone (PCL) polyester, commercially known as 'Friendly plastic' to make the moulds. PCL is a biodegradable polymer with a low melting point of around 60 °C (by immersion in hot water), which can be moulded by hand whilst warm, and once cooled to room temperature it hardens considerably to nylon-like plastic characteristics. To produce moulds of the right shape the PCL is modelled by using the adjacent area of the sides as a cast, both inside and outside of the guitar sides. Then the bulging area is moisturized with ultrasonic vapour and clamped into place via the two PCL moulds and left to dry for several days. A similar technique can be employed to treat the deformed areas of the veneered neck.

Figure 5. Correcting deformed sides. Guitar by Genaro Fabricatore, Naples 1817, New York Public Library.

The cracks of the soundboard and back are closed either by joining the two parts together using a system of small clamps, or by filling the gaps using wood shims. The consolidated cracks are reinforced from the inside using Japanese paper adhered via reversible adhesives (commonly water soluble protein based adhesives e.g. fish glue).

Frequently the edges of the back in the vicinity of the braces will present some material losses that have to be replaced; this is achieved either through a flat joint grafting or an angled edge doubling depending on the extent of the damage.

Once the back and soundboard are consolidated, the braces can be reattached. Clamping the braces to the soundboard can prove challenging due to the height of the sides; a common solution is to use a Go-bar system to hold the braces in place. Small clamps can be also positioned through the opening of the sound hole to reattach the bars as well as the bridge.

The resonance box can be then closed by reattaching the back into place. It is important to keep in mind that the angle of the neck with respect to the soundboard can be dramatically modified with this process, impacting directly on the 'action' or playability of the guitar. It is therefore a good practice to rectify the action on a dry run, and when reattaching the back.

The guitar is now in good shape and ready to be displayed (or played, if that was the original thought). As you can appreciate, this treatment can be regarded as highly invasive; it is quite demanding and it is a delicate operation.

3. Conclusions.

The treatments presented on this paper are not the only available options, but merely a few viable solutions to a very common problem. Certainly no treatment is suitable or

Figure 6. After treatment. Guitar by Genaro Fabricatore, Naples 1817, New York Public Library.

necessarily the best option for every damaged nineteenth century guitar; each case should be thoroughly pondered individually, and the treatment adjusted accordingly.

Nowadays, modern guitars continue to be constructed in a similar manner, braces are still glued to the inside of guitars to reinforce them structurally and acoustically. However, most modern luthiers are aware of the hazards and perils inherent to this devices, and take precautions to avoid future damage. The braces are left significantly shorter or they are glued diagonally to the grain, hence anticipating the radial shrinkage of the soundboard and the back. The wood used to make instruments is air-dried for several years before it is used, and modern materials like carbon fibre are starting to replace or complement wood as structural reinforcements. Only time will tell if these precautions will succeed in avoiding the slow damage awaiting from within.

Acknowledgements

The author gratefully acknowledge, the organizers of WoodMusICK COST Action FP1302, the staff of the Museu de la Música of Barcelona, MIMEd, the Metropolitan Museum of Art and its Musical Instruments Department, the New York Public Library, The National Music Museum, Sarah Deters, Gabriele Negri and Tiziano Rizzi.

Influence of Different Bridge Timbers on the Resonance Behavior of Acoustic Guitars in the Traditional Maccaferri Design - Preview

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Abstract

Traditional violin and guitar builders consider it a fact that the bridge, which transfers the vibrations of the strings to the resonance board, has a significant influence on the sound of the instrument. In this context, one can assume that different timber species produce a defined sound which can be related to the anatomical structure of the wood. The timbers used traditionally for the bridge are usually selected for their assumed positive acoustic behavior and also for their decorative appearance, dimensionally stability and high abrasion resistance. While it is fairly easy to determine the physical and mechanical properties of wood for acoustic use, it is more difficult to measure the influence of a single wooden component on the instrument's sound.

1. Introduction

The assessment of the acoustic properties of different individual components of musical instruments is very complex; in particular, the contribution to the acoustics of the bridge is always influenced by the resonance behavior of other components. Furthermore, the construction as well as the constructional implementation may have a significant influence on the resonance behavior of the instrument. Therefore, an explicit assessment of an individual structural component is only possible if it can be assessed independently while all other components remain constant.

To understand the acoustic behavior of wood and wooden components in instruments, most investigations concentrate on the physical and mechanical properties of the wood species. Several investigations have shown that there is a significant relationship between the resonance behavior and the physical and mechanical properties of wood. This applies in particular to the density and the modulus of elasticity [2, 3, 5, 6, 8] as well as to the type and orientation of individual cell elements [2, 9, 11]. However, until today several investigations have focused on the bridge of lute instruments [4, 10] but only few on the replaceable bridge of an acoustic guitar.

In the proposed study, wood of six different species will be used for the bridge and assessed as to their individual contribution to the resonance behavior of the instrument. This analysis is carried out with an acoustic guitar of the traditional Maccaferri design built by Sandner (2015) with a soundboard made of European spruce. Contrary to other traditional designs (Torres, Martin) a peculiarity of the Maccaferri guitar is that the cord supporting bridge is neither glued nor pegged to the soundboard. Thus it is possible to substitute different bridges and assess their influence on acoustic properties independently. The aim of this study is to find out whether wood species with different properties and anatomical cell structure used for the bridge exert a measurable influence on the resonance behavior of a traditional Maccaferri acoustic guitar.

2. Material and Methods

2.1 Timber species

To measure the variable influence of the bridge in contact with the soundboard, timbers with the greatest possible variability in anatomical structure as well as physical and mechanical properties were chosen. Three of the six timbers to be investigated (*Diospyros* sp., *Dalbergia nigra*, *Pterocarpus soyauxii*) are traditionally used for bridges in guitar building. The other three, partially used for instruments (*Morus alba*) were selected for their different anatomical structure as compared to the other timbers used in this study.

Table 1: Physical properties and structural key features (data according to Wagenführ 2006).

Timber-species*	Density [g/cm]**	Modulus of elasticity [N/mm²]	Brinell Hardness (HBII) [N/mm²]	Growth-rings	Storied structure	Ray height [µm]
*Diospyros sp.**	1,15	13400	136	indistinct	absent	130-500
Dalbergia nigra *	0,97	8800-12900	92	indistinct	present	110-180
Pterocarpus soyauxii	0,80	10000-16600	29-47	indistinct	present	100-200
Morus alba	0,68	9300	30	distinct	absent	150-1500
Robinia pseudoacacia	0,73	9000-13300	67-88	distinct	absent	150-1200
Taxus baccata	0,76	12.000-15000	65-71	distinct	absent	80-230

*Approval for investigation of CITES protected species (Annex I and II) has been obtained
**'Normal' density at approximately 12% moisture content

Diospyros sp., *Dalbergia nigra* and *Pterocarpus soyauxii* (Figure 1 A+B.) are tropical timbers, the first two with a high, the latter with a medium density and hardness (table 1). The tropical timbers are all diffuse porous and have very small rays, multiseriate in *Diospyros* sp. and *Dalbergia nigra*, and uniseriate in *Pterocarpus soyauxii* (Figure 1B). Furthermore, rays and fibres of *Diospyros* sp. are non-storied whereas the rays, axial parenchyma and fibres of *Dalbergia nigra* and *Pterocarpus soyauxii* show a distinct storied structure. Contrary to the diffuse-porous hardwoods, *Robinia pseudoacacia* and *Morus alba* (Figure 2 A+B) are both ring-porous, possess distinct growth increments and very high and wide rays.

Contrary to the diffuse-porous hardwoods, *Robinia pseudoacacia* and *Morus alba* (Figure 2 A+B) are both ring-porous, possess distinct growth increments and very high and wide rays.

The last species, *Taxus baccata* is a coniferous wood (softwood) and belongs to the Taxaceae family. Coniferous wood do not have vessels, they consist of up to 95 % tracheids. In comparison to most of the selected hardwoods the rays are uniseriate and very low. The wooden raw material for the bridges had been stored for a period between 10 and 20 years and has a moisture content of approximately 8 to 10 %.

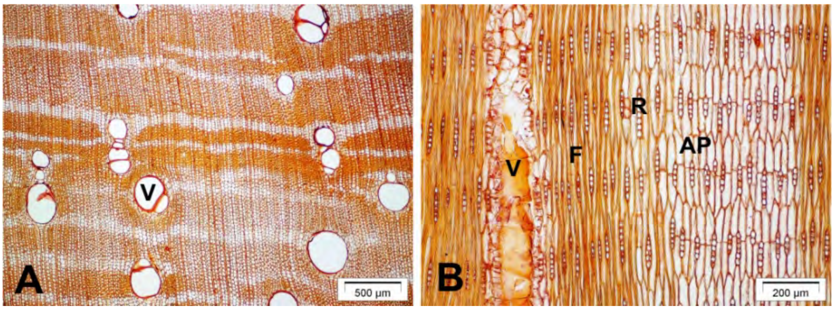

Figure 1. Padouk (*Pterocarpus soyauxii*) A – transverse section and B – tangential section with V = Vessels, F – Fibres, R – Rays (storied structure) an AP – axial parenchyma (storied structure).

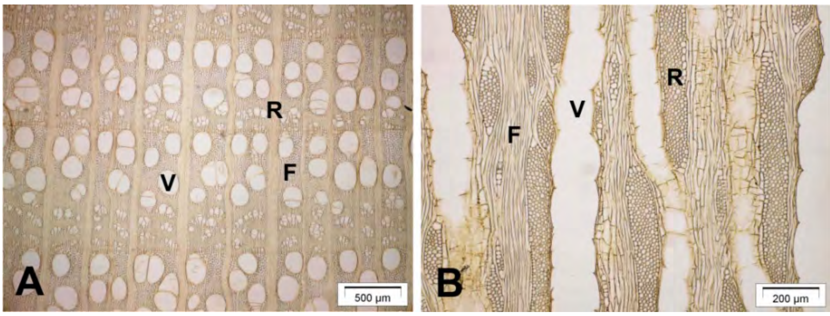

Figure 2. Black mulberry (*Morus alba*) A – transverse section and B – tangential section with V = Vessels, F – Fibres and R – Rays (multiseriate).

2.2 Measurements

The guitar is successively prepared with different bridges and tuned to standard tuning to ensure an identical string loading of the top plate. All strings are damped. Acoustic measurements are performed in an anechoic chamber with climate conditions of 20-23 °C and 50-53 % relative humidity. Signal lengths of one second lead to an uncertainty of Δf = 1 Hz. Bridge mobility measurements are performed with a piezoelectric transducer at the base of the bridge and a hammer impact on the bridge in normal direction to the soundboard. For mobility measurements only the degree of freedom of the mobility matrix normal to the soundboard is considered. The bridge is excited with an impulse hammer (*Kistler 9722A500*) at the termination point of the E2 string. Unfortunately, the Kistler hammer was the only excitation device available at the time of measurements. Due to the high hammer mass of 100 g relative to a lute instrument like a violin or guitar, the contact time during impact is quite long. This in turn results in a limited responsive frequency range. In this particular case, responses are suitable only in the range of 1-1500 Hz. For measurements of top plate deflections a microphone array method is utilized. The bridge is excited with a hammer at the termination point of the E2 string. An array of 120 microphones covers the top plate surface with an inter-mic distance of 45 mm in horizontal and 50 mm in vertical direction and a surface distance of 40 mm. The recorded sound pressure field can be back propagated to the top plate surface applying a minimum energy method [1]. By using a microphone array technique, contrary to an optical method like a laser interferometer, it is possible to study body deflections as well as air resonances radiated by the sound hole.

The considered Maccaferri bridges share the exact same geometrical shape but vary in mass from 7.9 g for *Robinia pseudoacacia* to 17.3 g for *Diospyros* sp. (compare the given densities in Table 1). This is lightweight compared to typical steel string guitar bridges which vary from 35 to 60 g (pins included) [7]. Bridge mobilities for the six different timbers are presented in Figure 3. Eighteen resonances to be taken into account are marked with dashed lines. Standard deviations of the frequencies of each resonance increase from .5 Hz at the lowest resonance (at approx. 72 Hz) to 6.5 Hz at the highest resonance (at approx. 1451 Hz) under consideration. This corresponds to a standard deviation of resonance frequencies of approx 10 cents over the range up to 1.5 kHz. *Diospyros* sp. has mostly the lowest, *Taxus baccata* has mostly the highest resonance frequency in comparison to the other timbers. Damping ratios (ζ) for the resonances up to 1 kHz are derived: Mean ζ for the six timbers decreases from 2E-2 to 5E-3 with a constant standard deviation of 8E-4.

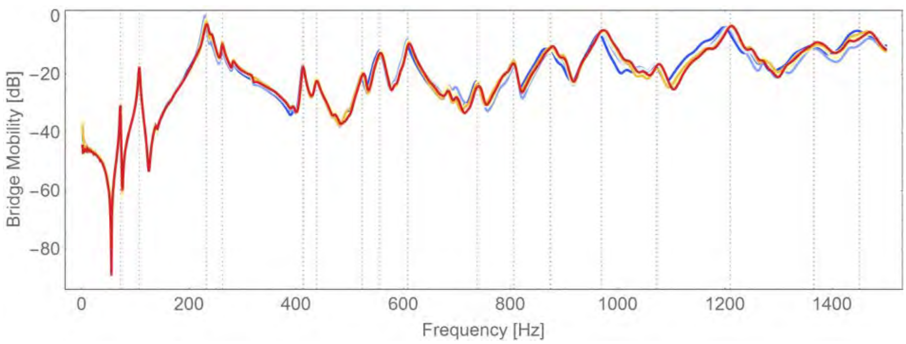

Figure 3. Magnitude of bridge mobilities for bridges from six different timbers.

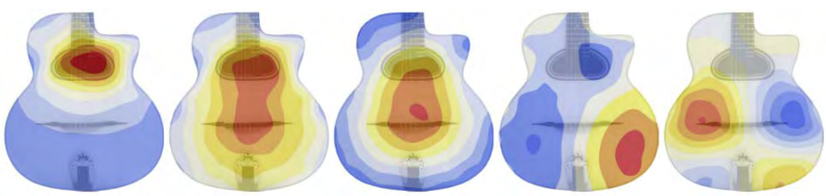

Figure 4. Real value of top plate deflection at low to mid frequency resonances:
a) Helmholtz mode: 107 Hz, **b)** (0,0): 232 Hz, **c)** (0,0): 262 Hz, **d)** (1,0): 413 Hz, **e)** (1,1): 608 Hz

Figure 4 displays deflection shapes of the top plate at the most prominent low to mid frequency modes. The Helmholtz mode at 107 Hz indicates a higher body volume compared to classical guitars, which have their cavity modes at 120-130 Hz. For the two closely spaced (0,0) modes the top plate and the air in the sound hole move in phase. For the higher mode at 262 Hz the bottom plate moves in phase with the top plate. It is noteworthy that for the two prominent mid frequency modes (1,0) and (1,1) the contribution of the plate part above the sound hole is quite low. Radiation efficiencies of the top plates are calculated as the ratio of total measured sound pressures to input force and averaged in the first twelve Bark scale critical bands. The bridges show no difference in radiated output up to 1.5 kHz.

In a subsequent experiment mobilities are measured for the bridges without being attached to the top plate and with free-free boundary conditions. Even if this setup does not consider the actual condition when played it can point to the frequency range where the bridge could be noticed as a material dependent filter. Figure 5 shows the first transversal resonance for the six bridges. Frequencies range from 3994 Hz for *Taxus baccata* to 6028 Hz for *Dalbergia nigra*. Damping ratios of the mentioned resonance range from 9E-3 for *Dalbergia nigra* to 3.9E-2 for *Morus alba.*

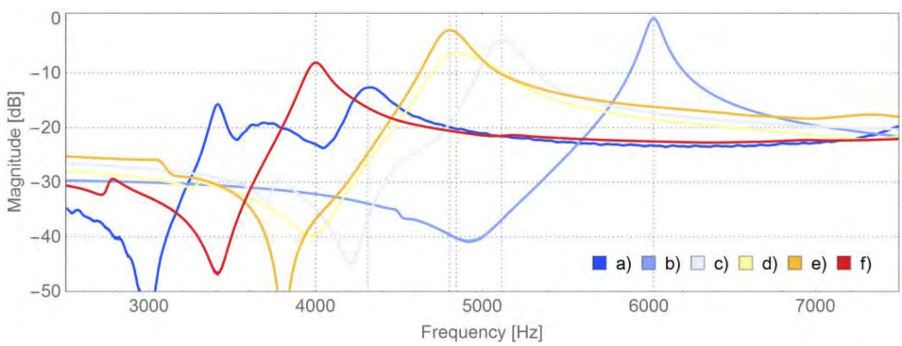

Figure 5. First resonance of sole bridges with free-free boundary conditions:
a) *Diosyros sp.*, f_0 = 4322 Hz, ζ = 3E-2 **b)** *Dalbergia nigra*, f_0 = 6028 Hz, ζ = 9E-3
c) *Pterocarpus soyauxii*, f_0 = 5122 Hz, ζ=2.2E-2 **d)** *Morus alba*, f_0 = 4834 Hz, ζ = 3.9E-2
e) *Robinia pseudoacacia*, f_0 = 4801 Hz, ζ = 2.3E-2 **f)** *Taxus baccata*, f_0 = 3994 Hz, ζ = 2E-2

4. Discussion

In the frequency domain the different examined bridge materials do not notably affect the vibroacoustic behavior of the guitar in the most prominent low to mid frequency range. Mobility measurements of the sole bridges show substantial effects on resonance frequencies and modal damping in the higher frequency range depending on the timber. Validation of an impact of material dependent bridge properties on the vibroacoustic behavior of the Maccaferri guitar in high frequencies is matter of recent research.

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Driving Point Mobilities of a Concert Grand Piano Soundboard in Different Stages of Production

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Abstract

In an on-going project, a series of driving point mobility measurements is taken on a concert grand piano soundboard. The piano is accompanied by measurements during the entire production process, performed at seven discrete stages of the instrument's construction. Mobility functions are obtained at 15 different driving point positions, corresponding to string termination points on the bass and treble bridges. Application of ribs and the bridge decrease the overall mobility by 10 dB each. Clamping the soundboard generates distinct resonance behavior in the low frequency range and greatly increases resonance frequencies. Stringing increases resonance frequencies and lowers their amplitudes. After gluing the soundboard into the rim, the mean mobility stays constant between 1 kHz and 5 kHz, a sudden rise in mobility cannot be confirmed.

1. Introduction

The impedance mismatch between strings and soundboard is a crucial factor for the actual sound produced by a piano. If the mismatch is too small the tone is harsh and short, if it is too great the tone becomes long but too soft [4]. Historically, piano manufacturers tried to find the optimum relation by experimenting with the structural design of the soundboard and strings.

The driving point mobility $Y(\omega) = v(\omega)/F(\omega)$ with ω being the angular frequency is a widely accepted parameter to describe the frequency dependent behavior of musical instrument parts as a ratio between a complex velocity response v and a complex excitation force F for one specific point on the vibrating structure (see [6] for a detailed description of mobility concepts). For the present work, only the direction normal to the soundboard is considered.

Wogram is the first to describe the vibrational behavior of a piano soundboard by means of driving point impedances [14]. He performs measurements on an upright piano soundboard, with and without strings. Subsequent publications question the correctness of his data in the higher frequency range: the impedance falloff above 1 kHz, inversely proportional to frequency, is considered to appear due to decoupling of excitation device and soundboard [9, 7]. Nakamura presents mobility measurements for a completely assembled upright piano [12]. Consistent with Wogram, he observes an increase of mobility above 1 kHz. Even though the resonances of his measurement devices are located in the regarding frequency range, he explains the increase with the ribs becoming fixed edges for high frequency vibrations. Giordano performs impedance measurements on a fully assembled upright piano [9]. He confirms a decrease of impedance above 2.5 kHz for measurements at the bridge. Ege et al. give a synthetic description for the mobility of a fully assembled upright piano based on three parameters: modal density, mean loss factor and structure mass [7]. They explain a rise of mobility in high frequencies to be dependent on the inter-rib effect, to occur when the wavelength equals twice the rib spacing. A transition frequency range between 2 kHz and 3 kHz, from which onward the soundboard motion is governed by the ribs, is also proposed by Berthaut [3] and experimentally confirmed by Moore [11]. After Conklin [5], the attenuation effect due to ribbing should occur at 1.2 kHz for conventional rib spacing. Conklin [4] presents mobility measurements of a concert grand piano (with conventional rib spacing) with and without strings. Stringing seems to increase resonance frequencies and to lower peak values. No influence of downbearing on mobilities is observable above 1 kHz. Contradictory to previous publications, his data does not confirm a mobility increase at high frequencies (he presents mobility functions up to 3.2 kHz).

The present work tries to elaborate on some of the issues and questions remaining with regard to these, often contradictory, findings. It is aimed at understanding the evolution of, and changes in, the vibratory behavior of the soundboard during different stages of the production process, instead of taking only the finished instrument into account, as has been done in previous research.

2. Method

Measurements are taken on a concert grand piano in seven different stages of production, starting with the glue-laminated strips of spruce wood, and ending with the completely assembled piano in concert tuned state (denoted as PROD 1-7, see Table 1). The soundboard is excited at 15 positions associated with string termination points on the bass and treble bridges (denoted as POS 1-15, see Table 2). An impact hammer (*Kistler 9722A500*) with 0.1 kg head weight is used for excitation. For the sake of comparison, a miniature impact hammer (*Dytran 5800 SL*) with a mass of 0.01 kg is used for a series of measurements. Although above 4 kHz the induced energy is greater than for the heavier hammer, the mobility functions obtained do not differ below 5 kHz. The heavier hammer is chosen for the experiment due to the much greater amount of energy transmittable in the frequency band up to 2 kHz. The response is captured with a piezoelectric transducer (*PCB 352C23*) with a mass of 0.2 g, situated on the bridge with a distance of approx. 2-3 mm from the hammer impact position. Since the transducer is sensitive to acceleration, the data is numerically integrated to obtain velocity values. For PROD 1-4 the soundboard lays on felt in the exact same profile as it is later glued into the rim. The boundary conditions for PROD 1-4 can therefore be considered as simply supported. For PROD 5-7 the boundary conditions can be considered to be clamped. Deflection shapes at low frequency resonances are obtained from microphone array measurements of the soundboard in all prior mentioned production stages. A total number of 1289 microphones cover the entire surface with an inter-mic distance of 40 mm. The soundboard is excited by an electrodynamic shaker with an exponential sine sweep, impulse responses are derived with the SineSweep technique proposed by Farina [8]. The measured sound pressure can be back propagated to the soundboard surface with a minimal energy method proposed by Bader [2, 1].

Table 1: Denotation of different production stages.

PROD	
1	blank soundboard (glue-laminated strips of *sitka spruce*)
2	after the ribs have been attached
3	after the bridge has been attached
4	after the ribs have been notched
5	after the soundboard has been glued to the rim
6	after application of the iron frame and stringing
7	after regulation, voicing and tuning - concert tuned state

Table 2: Corresponding keys to driving point positions (1-4: bass bridge, 5-15: treble bridge).

POS	1	2	3	4
Key	A0	F1/G1	B1	E2

POS	5	6	7	8	9	10	11	12	13	14	15
Key	F2	G2	A2/B2	D3	F3/G3	B3	F4	C5/D5	B5	A6/B6	C8

3. Results

3.1 General development through the production process

In Figure 1 (left) mobility functions dependent on production stage are plotted vs. frequency, where dark colors imply low, and bright colors imply high mobility values. Consequently, clear bright lines illustrate resonances. That way the general development of driving point mobilities through the production process can be illustrated: For the first production stage (PROD 1), the blank soundboard has an overall high level of mobility. The first two resonances at 13 Hz and 25 Hz (see Figure 3) are the only remarkable ones. Attachment of the ribs (PROD 2) decreases the overall level of mobility. A more distinct resonance behavior is observable up to 300 Hz. Attachment of the bridge (PROD 3) further decreases the overall mobility level. Notching the ribs (PROD 4) has no impact on the general mobility. Changing the boundary conditions by gluing the soundboard into the rim (PROD 5) affects the vibrational behavior fundamentally in the low to mid frequency range: up to 300 Hz distinct resonances appear. Stringing (PROD 6) increases the frequencies of those resonances and lowers their amplitudes. Besides a slight resonance frequency increase, the voicing and tuning process (PROD 7) has no remarkable influence on the vibrational behavior of the soundboard. Figure 1 (right) focuses on mobilities for PROD 5 dependent on the driving point position. An upper frequency limit for distinct resonances between 250 Hz and 300 Hz is observable. Driving point positions near the ends of the bass bridge (POS 1 and 4) and treble bridge (POS 5 and 15) have generally higher mobility levels than the rest. The clamping particularly prevents low frequency resonances in the treble register. In the highest octave, the soundboard only shows some spare resonances between 200 Hz and 300 Hz. Figure 2 shows operating deflection shapes exemplary for the first three soundboard resonances. Figure 3 shows development of their frequencies through the production process.

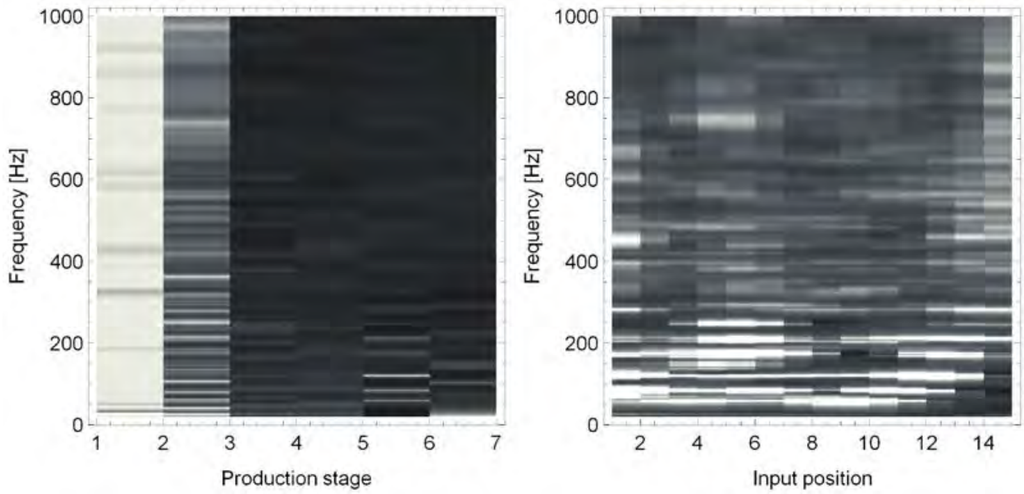

Figure 1: Mobility maps for (left) average mobility per production stage and (right) mobility per driving point position for PROD 5. Dark colors imply low, and bright colors imply high mobility values.

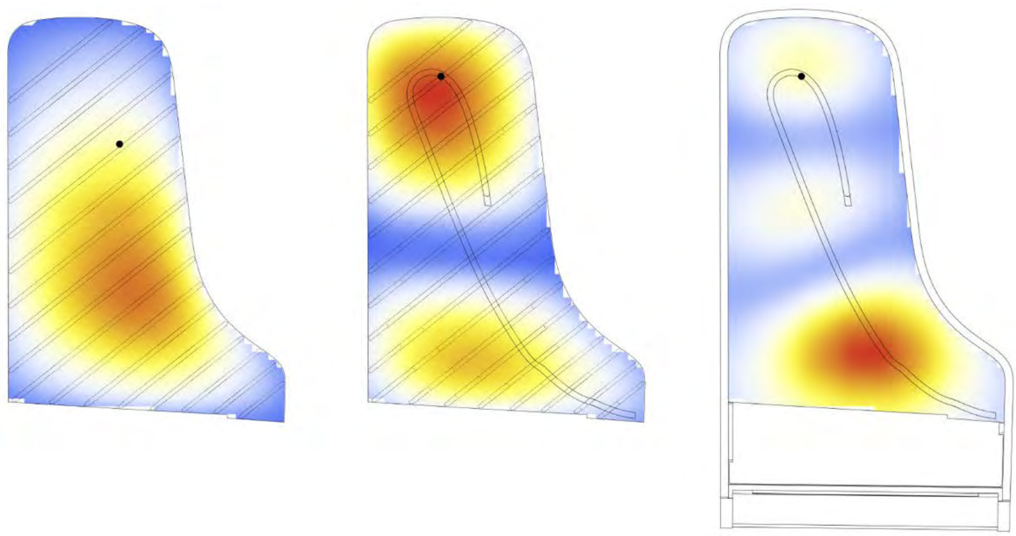

Figure 2: Modulus of operating deflection shapes for the first three soundboard resonances. Black dots depict driving point positions. (a) PROD 2, POS 3, 15 Hz, (b) PROD 4, POS 1, 27 Hz, (c) PROD 5, POS 1, 113 Hz.

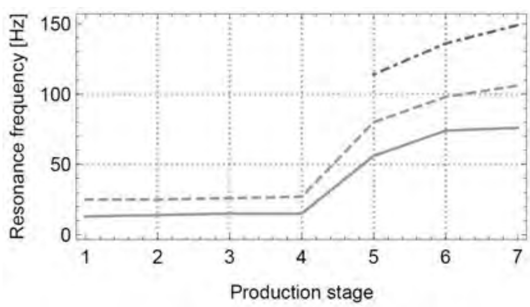

Figure 3: Frequencies of the first three soundboard resonances per production stage. Corresponding to operating deflection shapes in Figure 2: (a) line, (b) dashed, (c) dot-dashed. Deflection shape (c) is not observable in production stages PROD 1-4.

3.2 Detailed view on exemplary mobility functions

Figure 4 shows modulus of mobility vs. frequency at exemplary driving point positions for the four most influential construction steps. Each function is the mean of five independent measurements. Without ribs, the soundboard exhibits no resonance characteristic except for the first two resonances at 13 Hz and 25 Hz. Above 50 Hz, the mean mobility remains constant. Attaching the ribs decreases the mobility level by 10 dB in the low and mid frequency range. In the range up to 500 Hz resonance characteristics arise (see Figure 4 (a)). Application of the bridge further decreases overall mobility by 10 dB and 10-20 dB above 1 kHz (see Figure 4 (b)). Besides a small increase of resonance frequencies in the low frequency range, notching the ribs causes no observable alteration of mobility functions. A major change in low frequency behavior evolves when the soundboard is glued into the rim, observable as a development of strong resonance peaks up to 300 Hz. From 500 Hz to 5000 Hz the mean mobility stays constant (see Figure 4 (c)). Up to 350 Hz, the application of strings and frame causes an increase of resonance frequencies of approx. 20 Hz (see Figure 3) and a decrease of resonance amplitudes by approx. 10 dB (see Figure 4 (d)).

4. Discussion

The decrease of general mobility by application of ribs and bridge is assumed to result of stiffening the soundboard. Clamping the soundboard into the rim, and thereby changing the boundary conditions, has the most prominent effect on its vibrational behavior: Below 300 Hz sharp resonances appear. An upper frequency limit for distinct resonances between 250 Hz and 300 Hz is observable and confirms data presented by Suzuki [13] and Berthaut [3]. Up to 350 Hz, the application of strings and frame causes an increase of resonance frequencies of approx. 20 Hz and a decrease of resonance amplitudes by approx. 10 dB. This is in good agreement with Conklin [4] and Mamou-Mani [10]. In contrast to Conklin, who observed an influence of stringing for a range up to 1 kHz, in the present case the effect is only observable up to 350 Hz. In the frequency range above 1 kHz the presented results cannot confirm a sudden increase in mobility. The mean mobility stays more or less constant for the cases when the soundboard is clamped.

The empirical findings will contribute to the formulation of a real-time physical model to help piano makers estimate the impact of design changes on the generated sound.

Acknowledgement

The authors acknowledge support by the *Deutsche Forschungsgemeinschaft (DFG).*

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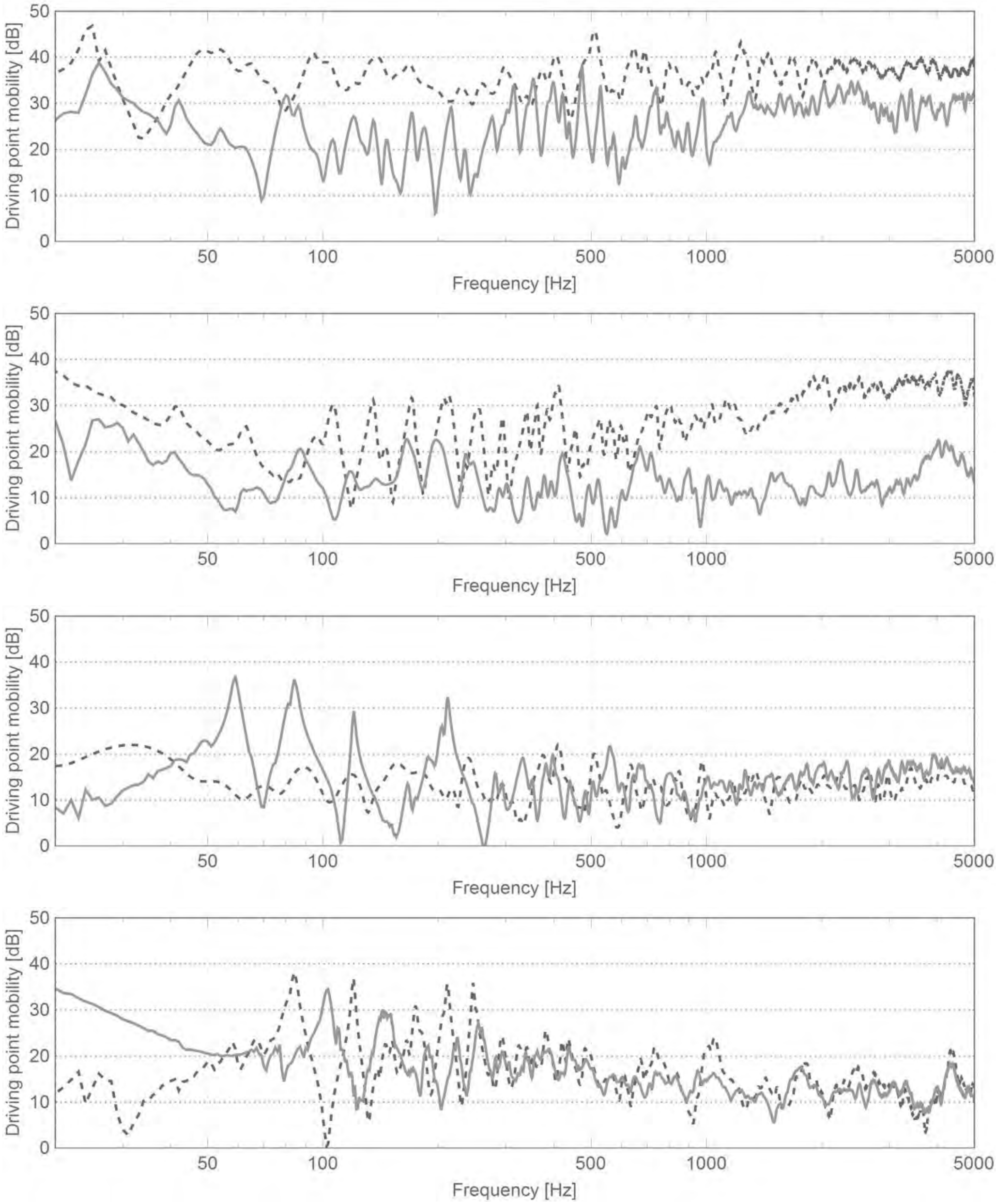

Figure 4: Modulus of mobility for different stages of production before (dashed) and after (solid) the modification is applied. From top to bottom: (a) Attachment of ribs, POS 5 (b) Attachment of the bridge, POS 11 (c) Gluing the soundboard into the rim, POS 10 (d) Stringing, POS 5.

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Wood, Gut and Compass. Strategies for Making String Instruments in the Iberian World (XVI- XVIII Centuries)

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Abstract

Within the context of the ancient European traditions and schools of instrument making, an analysis of the Hispanic and -more broadly- Iberian traditions allows us to outline their particular characteristics, regarding both the employment of the materials and the size and proportions of the instruments. At the same time it contributes to show the early diffusion of the European models of bowed instruments and the role played by guilds in the preservation of said models and their ancient construction techniques. In this paper we will address the characteristics of early instrument making -especially string instruments- in Spain, as well as its ramifications in Ibero-America.

1. Introduction

Since the end of the 15th Century, when the various families of plucked and bowed string instruments of the Renaissance consolidated in Europe, began a process of internationalization for musical genres as well as the instruments needed for them. Within the Hispanic world, current research focuses on the construction techniques, the materials used and the technological innovations (such as the use of set squares and compasses) that were introduced between the 15th and 18th centuries by Iberian *violeros* (string instrument makers). The place of Spanish instrument makers in the international scene is also being analyzed.

Although there are records of *violeros* in the Iberian Peninsula at the end of the Middle Ages, it was in the times of the Catholic Kings (during the late 15th and early 16th century) when, amongst other rulings, the first ordinances for instrument makers or *violeros* were made (originally printed in Seville in 1527 and then reprinted in 1632). The Seville Ordinances were upheld for more than a century and had a great diffusion. Within the territories of the Kingdom of Aragon (in the eastern coast of the Peninsula and strongly connected with the Mediterranean sphere) as well as in the Kingdom of Castile (politically tied to Central Europe through the House of Burgundy and the Habsburgs), there were guilds of *violeros* that separated themselves from the guild of carpenters to which they had previously belonged. Parallel to the commercial growth of said *violeros*, some guilds of string makers were also formed. The development of these associations initiated some interesting local traditions of instrument building.

But what were the features of these local traditions in the Iberian Peninsula and what distinguished them from the practices held in the rest of Europe?

2. Ordinances of *violeros* and string makers. Technology and materials

The term "*violero*" encompasses all builders and repairers of string instruments, plucked as well as bowed, including harps and some lesser known instruments such as the *tiple* and the *bandola*.

The first ordinances were printed in Seville in 1527 (and then reprinted in 1632). They compiled the rules of the general guild of carpenters, valid since *circa* 1500, including a section specifically about string instrument makers. These same ordinances, with some small variations, were edited in Granada (1552, then reprinted in 1672) and Mexico (1568) in the time of Philip II of Spain. In Seville (1527) and Granada (1552) there is no mention of the tools employed in instrument building, but there is a large space devoted to the wood trade. Wood traffic was subject to a strict control in order for it to be fairly distributed among the various workshops, in a protectionist fashion that lasted until the 18th century.

The instruments which the guild members had to master were the same in both Sevilla and Granada: several keyboard instruments (*claviórgano* –claviorgan-, *clavezimbano* –harpsichord or similar- and *monacordio* –clavichord-) plus the string instruments *per se*: *laúd* –lute-, *vihuela de arco* –viola da gamba-, harp, and *vihuela* (both large *vihuelas* with inlaid decorations as well as smaller, simpler ones). The text from the ordinances points out that vihuelas must be ornamented with a carved rose and have inlaid wood decorations. *Mudéjar*-style inlaid decorations appear in many instruments since *circa* 1500 and can be considered a characteristic aspect of ancient Spanish instrument making.

An interesting difference is that the Seville Ordinances from 1527 only admitted "old Christians" (men with Christian ancestries) while in Granada the "new Christians" (converted Jews or Muslims) also had access to the guild. It is plausible that the *mudéjar* influences on instrument decoration came from these "new Christians" inside the guild in Granada. The activity of Moorish instrument builders in Zaragoza is also well known: the Moferriz family made claviorgans and string instruments in the times of the Catholic Kings. In fact, the *mudéjar* fashion can be found in architecture and decorative arts in the early 16th century and is represented in musical instruments through iconographic sources (fig. 1 -left, center-); it also appears in some real instruments, such as the vihuela from the Jacquemart-André museum in Paris (fig. 1 -right-) [1, 2].

Figure 1. Left: Angel whit Synfonía. Triptych of Monasterio de Piedra, Zaragoza, 1390 (Real Academia de la Historia, Madrid). Center: Orfeo with vihuela. Luis Milán: *El Maestro*. Valencia, 1536. Right: Vihuela "GVADALUPE", 16th century. Musée Jacquemart-André (Paris)

Decorations with inlaid wood are also present in the Portuguese *Regimento dos Violeiros* (Lisbon, 1572) [2]. These Portuguese ordinances required examinations regarding instruments similar to those of Sevilla and Granada: a *viola* (*vihuela de mano* in Spanish) with six courses, a harp, a *viola de arco* (viola da gamba) *tiple* or double bass, and a chess board. The inner junctions of the instrument's body have to be lined with stripes of glued cloth. This procedure can be found in many ancient European instruments, while in Spain it's found in some historical harps and in the few string instruments that have been preserved.

In Granada (1552) and Lisbon (1572) some ordinances were added specifically for gut strings makers. Like in Madrid a century later, in 1695, it's insisted that strings should be made only with ram guts. These ordinances aimed to persecute non-guild instrument builders and rejected strings that weren't straight enough or hadn't the otherwise required quality.

3. A case to analyze: the Toledo Ordinances, 1617

These Ordinances [6] clearly show the characteristics of ancient Spanish *violería* (string instrument making). Some of these features can be seen in instruments that are still preserved nowadays, especially in some guitars.

Following the Toledo Ordinances of 1617, those under examination to become journeymen of the guild had to build three instruments:

- "*Una viguela llana de seis órdenes*" (vihuela with six courses) "with its sizes, rules and compasses". It's specified that the builder "first must make a mold in paper and has to make it before the observers and examiners" and should not have before him "but a knife and compass and ruler and a set square" and "is not to employ any patterns except what he knows and understands of this art". Types of wood mentioned: ebony and boxwood.
- "*Un arpa de dos órdenes"* (chromatic harp with two courses). Types of wood mentioned: walnut wood (for the instrument's ribs and head).
- "*Un violín tiple"* (also, the examinant had to draw the remaining instruments of the whole set: *tiple*, *tenor*, *contralto* and *contrabajo*). No types of wood mentioned.

The Toledo Ordinances added some rules about repairing too: the soundboard and back of the instrument had to be made of picea or spruce wood, even in the case of ebony instruments (thus making the repairs cheaper), and it was also advised to use boxwood instead of parchment for the roses. These requirements could have caused the loss of many parchment roses in ancient vihuelas and guitars that were probably replaced with carved boxwood pieces in following repairs. It's also possible that such rules were aimed at stopping attempts to sell repaired instruments faking them as originals (which is still a common practice).

The Toledo Ordinances also require that whenever a plate is changed, the replacement has to be entirely new and not made of different pieces of old wood (something that, by the way, could be sensible to adopt as part of our current criteria for restoring certain instruments). Given that these rules were endorsed until the 18th century, we cannot question whether many of the soundboards of currently preserved instruments are original or not, including violins and their families, violas da gamba, harps or any other string instruments, as they all came from the same workshops.

4. The vihuela llana de seis órdenes (vihuela with six courses)

The guilds were very conservative institutions regarding their norms, and in the case of Spanish *violeros* it has been documented a rigid hierarchical structure that severely punished "professional intrusion" (that is, non-guild professionals trying to establish themselves in the market). This defense of their traditions was very likely what made their instrument models as well as their techniques of construction and employ of materials withstand the passing of time (at least for the entire 17th and early 18th centuries). Something similar happened with the guilds of *violeros* in Madrid (1578) and cities like Lisbon (1572) or Valencia (1599). This conservative aspect is also present in the terminology. That could explain the examination for a "*vihuela llana de seis órdenes*" (vihuela with six courses) in 1617 when at that time the modern instrument was the Spanish guitar (baroque guitar with five courses). Up until the late 17th century, members of the guild of *violeros* in Madrid took examinations on building *vihuelas* that were clearly guitars (there are records for having to build "*una vihuela de 5 órdenes*" – a vihuela with five courses-, that is, a baroque guitar [3]).

5. Compass, ruler and set square

These were the tools used to build the instruments assigned during the examination. Besides the Toledo Ordinances of 1617, they are also mentioned regarding examinations in Madrid in the second half of the 17th century [3]. The use of such tools shows that at least some knowledge of geometry was required of the apprentice and future *violero*. In Madrid, as it has been said before, the apprentice had to cut a mold of the instrument on paper (be it a guitar, a viola da gamba or a harp) before cutting the wood.

6. Conclusions

The characteristics of the ancient tradition of *violería* in Spain and Portugal can be summarized (without being exhaustive) in the following terms:

- The utilization of *pinabete* wood (picea or spruce) for the soundboard and back of the instruments, which, after being cut and manufactured for its commercialization, was distributed among the guild members (at least in Madrid, but most probably in other cities too).
- The employment of native types of wood for the instruments' bodies (*pinabete*, walnut and beech wood), although the more luxurious pieces were made of imported materials such as ebony (usually coming from Portugal and its colonies) as well as silver or nacre (mother of pearl) ornamentations.
- In vihuelas, guitars and bowed instruments, the method of construction and assembling the pieces starts by embedding the ribs into the *zoque* (neck block) (unlike in other European schools) and then close the instrument by placing the soundboard and the back piece.

- The fixing of the ribs and other glued parts within the instrument was necessarily reinforced by straps of linen or other cloths (a characteristic that was shared with European construction techniques.)
- Finally, the strings had to be made of ram guts and no other animal's.

All of these features (except for the gut strings, that have disappeared over time) are observable in the few guitars from the 17th and 18th centuries that are still preserved. They are also found in other instruments, like harps and string instruments that came out of the same workshops.

But most interesting is that bowed instrument building in Spain was transformed *circa* 1750, forgetting the autochthonous tradition to assimilate the Italian style of construction –internationally fashioned at the time-. However, makers of guitars and similar instruments have kept until today the techniques of ancient *violería*, embedding the ribs into the neck block and preserving (partially) the use of native types of wood and traditional construction methods.

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Wood-Wind Craftwork and Numerical World: An Experience

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Abstract

This paper deals with the interactive work between woodwind makers and CAD engineer. The methodology has been then applied to the making of serpents according historical models.

1. Introduction

The goal is to reach more accurate results in the manufacture of woodwind instruments from historical originals. For this, the team is composed of three instruments makers - Fritz Heller, Roberto Bando, Pierre Ribo - and one CAD and CNC engineer - Frank Kamper.

Fritz Heller is specialized in Renaissance woodwind instruments and had his first experiences using 3D data when making copies of mute cornetti from the Vienna collection. During his contacts with curator Dr. Beatrix Darmstädter there was evidence that studying 3D data can give much more information to the maker e.g. traces of the original making process, indications of surface treatment and later corrections / adaptions in the instruments. So collaboration with Germanisches National museum Nürnberg and Musik instrumentensammlung Staatlicher Kulturbesitz Berlin has been initiated. Topics of further research are: direct transfer of bore data to CAD tools, reconstruction of tools at the time the instrument has been made, discussing the problem of "the good copy".

Roberto Bando is a highly appreciated maker and player of Renaissance and Baroque traversos. As a great advantage he makes his tools himself.

After measuring and copying traversos from outstanding collections with analogue devices he is interested using 3D measurements for the reconstruction of the original makers tools and the shape changes of the instrument appeared during its life.

Pierre Ribo used 3D data measurement to initiate his work by making template for carving his first serpents. The process can now be used for others instruments made of 2 half shells carved like curved cornets. And should be easier and more precise through 3D printing or CNC machinery. His interests are printing templates from data measurement for using on a "pantographe", control of dimensions after carving with pantographe, transform data diagram for making this type of conical instruments in different pitch, links with acoustical practices, impedance measurement, software to assist wind instrument creation.

Frank Kamper will contribute to these projects by finding ways to convert CT scanned data (computed tomography) to CAD data (computer aided design) in order to reverse engineer wood wind instruments, using CAD to manipulate shapes of existing parts for various purposes and utilizing 3D print technology and CNC machinery (computer numerical control) to produce templates, prototypes, special tools etc.

2. Methods used for the reconstruction of historical woodwind instruments

2.1 Geometry

Access to Data measurements of historical instruments is the first step (scan, tomography...). Good partnerships with museum or institution are essential throughout this phase. Another way is to use a private scanner and to have access to a good instrument. I will present later my own experience to illustrate difficulties related to this process. As a maker I already used measurements made with Scan or Computed tomography.

Indeed, through publication or documents from Museums, we can use dimensions to order tools like reamer, bell or lead-pipe mandrel.

For example, one way is to use a set of diameter issued from a publication to manufacture a lead-pipe mandrel on a CNC lathe. Other way should be to transfer directly the cloud of dots from a data file to some 3D file used in CNC technology. The precision of reproduction is very good. Nevertheless, one may ask if result should be different from acoustical point of view.

2.2 Information availability

This point is very important for the success of the final result. Actually we have few sharing experiences with experts in CAD/CNC or 3D printing. The fine understanding offered by modern scanning technology allow us to access to very precise information: but this approach requires good capacity to share information all along the process: conditions of scan, limits, transfer to CAD or 3D simulation file, choices of 3D manufacturing technology. More accurate is this share between makers and the different experts, more the characteristics of the final result (sound) are based on well-known and specific parameters.

2.3 Instrument knowledge

The possibility to observe every details of an instrument is a good tool for its understanding. 3D imaging with a high resolution gives a better understanding than the in-situ observation, which is not always possible according the type of instrument - for example it is difficult to measure and observe the internal surface without any tools. It opens interesting opportunity through the manipulation of 3D view, such as comparison of undercutting or mouth pipes, accurate details of geometry or structure, or understand links between different pitch instruments of the same family.

3. Application to Serpent making

An illustration is given here through a concrete experience of production of serpents based on an historical instrument scan.
The steps are:

- The choice of a serpent: the instrument played by Michel Godard was selected due to its interesting sound;
- The 3D imaging: an easy access to a private medical scanner determine the method. Thanks to Doctor Morimont for this free access to his scanner and his precious advices;
- The analysis of results: it took a heavy work to an high level doctor in 3D simulation and CNC software to convert the scan results to usable sizes adapted to my production process. Thanks to Doctor Francis Deblander, retired teacher in engineer university, for this his enormous help.
- The process implementation in my work-shop: it lasted more or less 600 hours from F. Deblander 's results to my first playable serpent. The goal has been achieved thanks to a numerical laser cut template base on mister Deblander work.
  This template was adapted to my process production on a "pantograph".
  This template has been modified basis on sound adjustment on the first prototype: it was an important adjustment of the internal bore, more important than the courant final settings like undercutting or diameter of holes.
  The consequence is that the actual template has different sizes than the one issued from the scan! To understand where is the error it would need a long process: more adapted scan of original and actual instruments (CT?), analysis from geometrical and acoustical point of view, then conclusion.

4. Conclusion

As you can imagine, our tiny crafting business may not be able to support such high technology process. Does collaboration between several makers and engineers will resolve this question?

Does this COST give us other opportunity of development?

Study on the Life, Instruments and Construction Methods of the Eighteenth Century Violin Maker Benoit Joseph Boussu - A Presentation of the Project

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Abstract

This paper aims to introduce a PhD research project on the life, instruments and construction methods of the violin maker Benoit Joseph Boussu, who was active in the middle of the eighteenth century. The project comprises four distinct phases of research: a biographical study, an organological study, the creation of instrument reconstructions and the application of these reconstructions in musical performances. Those four facets, and their results so far, are discussed in the present paper. The PhD project is co-jointly supervised by promotors from the University of Ghent and the School of Arts of the University College Ghent.

1. Introduction

In 2009, research was started on the life and instruments of the violin maker Benoit Joseph Boussu, who worked in the middle of the eighteenth century. Since then, extensive archive investigations have been performed, and a substantial number of surviving instruments was identified and investigated, both from museum collections, such as the collection of the Musical Instruments Museum (MIM) in Brussels (where 9 instruments are preserved), as well as from professional musicians. An example of a Boussu violin scroll is shown in Figure 1.

As a result of the archive research, many new insights in Boussu's previously largely unknown biography have been gained, such as his occupation as notary prior to becoming an instrument maker in his mid-40s. In addition, a more comprehensive understanding of his instruments and construction methods has been obtained. These initial results were condensed in a first publication in 2013 [1]. Since January 2015, the project was continued as a PhD study.

This paper presentation aims at introduction of this ongoing project to the conference attendees, to give a summarisation of the results so far and hopes to evoke feedback from the audience, beneficial for future stages of the research.

2. The department of Musical instrument making at the School of Arts in Ghent

The PhD project is co-jointly supervised by prof. dr. Francis Maes from the University of Ghent (Department of Art, music and theatre sciences) and by dr. Geert Dhondt from the University College Ghent (School of Arts). Since 20 years, the latter institution offers a study program in musical instrument making at academic university college level which consists of a 3-year Bachelor stage and a 2-year Master stage. Students are trained intensively in both the theoretical as well as the practical subjects related to musical instruments, their use, history, technology and construction. The program does not focus on a specific instrument family, but instead introduces the students to a wide range of instruments and their associated construction methods. However, in the Master stage, the students concentrate more on a particular instrument type or research theme of choice. Although the educational program has its foundation in the study of historical instruments, the curriculum also deals with instruments, techniques and applications of the present day, such as the use of new materials and recent research methods such as CT scanning.

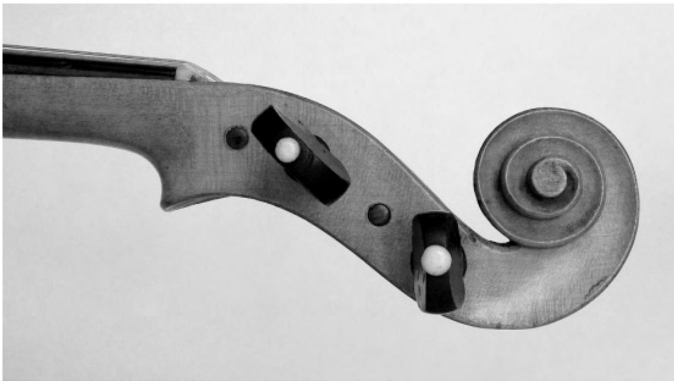

Figure 1: Violin scroll by Boussu on a violin (made in 1750) from the MIM (Brussels) collection (MIM inv. no. 2781). Photo by the author

In addition, several research projects have been and are being performed at the department, of which the research project discussed in the current paper is one example.

The department of Musical instrument making at the School of Arts Ghent maintains close ties with several organisations in the field of music and musical instruments, such as the Musical Instruments Museum (MIM) in Brussels.

3. The research project - objectives, methods and results so far

The PhD project comprises four distinct phases, each with its own objectives, methods and results. These four phases will be discussed in the following paragraphs.

3.1 Phase 1: biographical research

Prior to my research, information on Boussu's life was very scarce. His place and date of birth, family composition, professional life and place and date of death were unknown. My initial archive research, performed between 2010 and 2013, aimed at finding that missing information. Indeed, so far, many biographical facts have been elucidated and published [1]. Further archive studies, performed in 2014 and 2015 yielded additional insights [2]. It is now known that Boussu was born in Fourmies, in northern France, in 1703 from a family of notaries. He was a notary too in his birth area between 1729 and 1748. A cello, built in 1749 in Liège, is the earliest known instrument. Soon after, between 1751 and at least 1762, he worked near and in Brussels, where he was most productive. Boussu married twice, and had many children, the majority of whom died in infancy. The final part of his life, in the years 1767–1772, he lived and worked in Amsterdam, although just one instrument, a cittern, is extant from that period. He died in his native region in 1773.

As part of the current project, I want to perform additional archive research, to clarify some remaining 'blind spots' in Boussu's biography, as well as to find more detailed and 'narrative' biographical information for Boussu's entire life by studying source categories that were not yet investigated thus far.

3.2 Phase 2: study of instruments

The aim of this second phase of the project is to study original instruments by Boussu, to identify their constructional features and to contemplate on a possible sequence for the way they were made. Up until now, more than 40 surviving instruments by Boussu have been identified, both in museums and private collections, and most of these have been studied. In case of some instruments, mostly violins, present-day research methods, such as CT scanning and digital endoscopy, were employed in cooperation with leadings experts. In these latter studies, several instruments of Boussu's predecessors and contemporaries from Brussels were included as well to get a broader view of the violin making techniques practised in that city. The results have recently been published [3]. For the purpose of illustration, Figures 2, 3 and 4 give some examples of the type of images acquired. Future activities within this research phase include similar studies of Boussu's cellos.

The newly gained insights allow us to deduce Boussu's ways of working. Certainly, he made his instruments with a neck and upper block from a single piece of maple, see Figures 2 and 3. This observation, in combination with the small but noticeable foot on the upper block, supports the hypothesis of a making system without a mould. Instead, Boussu likely constructed from the back plate upwards.

Furthermore, the obtained CT scan reconstructions are perfect foundations to produce technical drawings and construction plans, which are indispensable for the next phase of the project.

Figure 2: Endoscopic capture of the neck block area of a Boussu violin from 1753 (MIM inv. no. 2784)

3.3 Phase 3: construction of instruments after Boussu

Two original Boussu instruments from the MIM (Brussels) collection, a violin and cello (MIM inv. nos. 2781 and 1372), are essentially both still in unaltered state, including their original 'baroque' neck with integral upper block and bass bar of limited

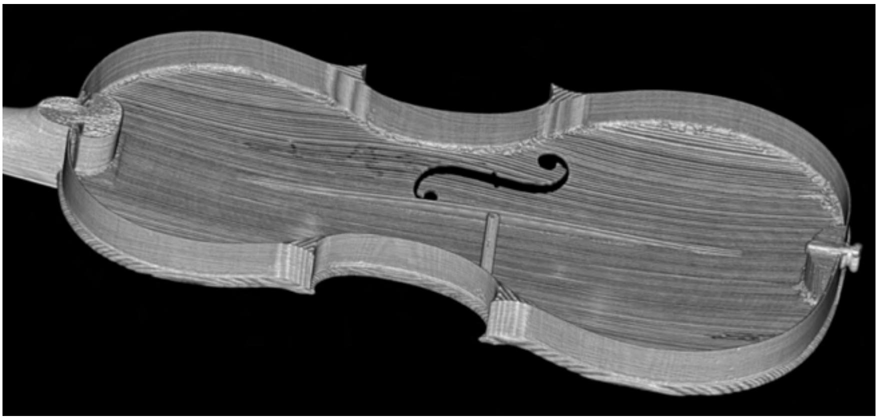

Figure 3: 3D reconstruction of CT scan data: inside of top plate of a Boussu violin (MIM inv. no. 2781)

dimensions. Since these instruments are currently conserved in non-playable condition, solely regarded as museum objects, we cannot experience their sound and playability.

In order to get an idea about their musical possibilities, the goal of this third research phase is to build at least two violins and one cello after Boussu, using construction methods derived from the findings of instrument investigations described in paragraph 3.2. One research aspect is the exploration of the construction sequence hypothesis, by trying out the proposed working sequence(s) in practice. Secondly, the resulting reconstructions will play a main role during the project's final fourth phase.

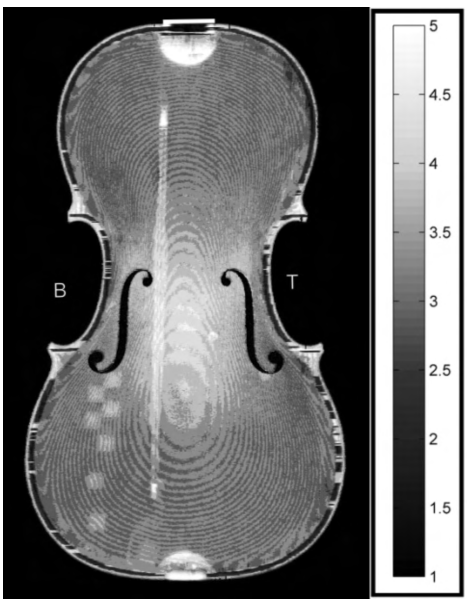

Figure 4: Thickness map of the top plate of a Boussu violin (MIM inv. no. 2784), with a scale in mm. Image produced from CT scan data by dr. Berend Stoel. Remark: this type of map is normally reproduced in colour, allowing for a more accurate reading, see examples in Verberkmoes et al. (2016) [3]

Figure 5 shows a partly finished reconstruction after Boussu as made by the author during an early stage of this intended 'workbench research'.

Figure 5: Partly finished violin reconstruction (by the author) after Boussu

3.4 Phase 4: the use of built instruments for musical performance practice

The built reconstructions will be set up in collaboration with experienced performers of eighteenth century music, and they will be subsequently used to perform Brussels repertoire from the time of Boussu, in order to assess their playability and musical and acoustical possibilities. This final phase, intended to start in 2019, will be captured by both audio and video recordings. Also, concerts, open to the public, will be organised.

4. Conclusions

In the past, instruments of Boussu and his Brussels contemporaries have been studied [4,5], though not yet from the perspective and expertise of a researching instrument maker. Moreover, in the current study, the latest research techniques are employed, such as digital endoscopy and CT scanning, and the results, for the first time, allow for a full visualisation of the internal architecture of the instruments [3]. This research is performed in close collaboration with the Musical Instruments Museum in Brussels and other external experts. Moreover, archive research has revealed the unusual and fascinating life path of Boussu.

So far, a wealth of new information has been gathered, both regarding the violin maker's biography as well as concerning his instruments, and investigations in these fields are still ongoing.

From these results, it becomes possible to derive Boussu's construction methods. Additionally, continued research will be performed on the maker's life, to complement previously published results [1,2].

The study presented here is intended to pursue an optimal realisation of the concept of 'informed instrument making', where eventually reconstructions will be built based on an extensive research of instruments, methods and biography of a maker (in this case Boussu), ultimately in function of the musical performance practice.

By performing and publishing this multi-faceted study on a relatively unknown maker, who maybe is considered just a footnote in instrument making history by those who are commonly more attracted to the famous stars of the trade, the author hopes to inspire future research into the lives and work of some other minor gods of lutherie.

Acknowledgement

I acknowledge dr. Anne-Emmanuelle Ceulemans (MIM, Brussels), prof. dr. Danielle Balériaux and dr. Berend Stoel (LUMC, Leiden) for their cooperation in the CT studies, and for their co-authorship of the article in Galpin Society Journal 2016 [3]. Also, I am grateful to the WoodMusICK organisation and the Museu de la Música in Barcelona for inviting me to present the paper. Finally, I thank my promotors, prof. dr. Francis Maes (Ghent University) and dr. Geert Dhondt (School of Arts Ghent).

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Evaluating the Use of Industrial X-Ray CT for the Reverse Engineering of Bowed Stringed Instruments

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Abstract

For centuries, simple contact measuring instruments (e.g. callipers, profile and thickness gauges) have been used by violin makers for recording bi-dimensional information about their creations. Since its invention, film and digital photography have also been used to document shapes and colours. Traditionally, gypsum castings and RTM replicas are used to store information about the 3D shapes of back, bellies and scrolls.

During the last 30 years the applications of non-contact systems such as X-ray computed tomography (CT), and laser and structured light scanners (LS) have opened new horizons to the bowed stringed instruments metrology.

This work compares two state-of-the-art non-contact systems: an industrial X-ray computed tomography system and a Structured Light 3D scanner. Their results in terms of accuracy, repeatability and uncertainties are assessed and compared to reference tactile Coordinate Measuring Machine (CMM) measurements. Experimental results prove that, with the considered experimental set-up, CT provides better results than LS in terms of deviation from CMM reference measurements, and uncertainty.

1. Introduction

X-ray computed tomography (CT) has proved to be a useful diagnostic tool in musical instruments making and restoration [1]. It has also been used to document the bowed stringed instrument conditions [2, 3].

Non-contact systems like laser scanners and structured light scanners (LS) have positive features in terms of portability, device cost and fast acquisition time. However, they cannot be used with very dark and reflective surfaces, both common characteristics of violin surfaces. Therefore, this type of surfaces should be covered with optically cooperative coatings, which is not always desirable.

Medical CT has been already used for the reverse engineering of violins, as reported in "The Betts Project" [4]. This kind of application of medical CT is limited by its resolution.

Industrial CT may overcome the limitations of medical CT, thanks to higher resolution and better radiographic contrast.

This study focuses on the application of industrial CT to the reverse engineering of bowed stringed instruments. The aim of this work is the evaluation of CT as a tool for the dimensional analysis of a violin soundboard.

This part of the violin is chosen because it presents a wide range of common problems related to the dimensional analysis of wooden free-form objects like violins or other strings.

2. Materials and methods

We focused on the comparison of performances of CT and LS when measuring a violin soundboard.

In order to assess the accuracy of CT measurement results, a tactile Coordinate Measuring Machine (CMM) is used as the reference. Tactile CMMs usually provide the reference in coordinate metrology, due to their proven accuracy and to the availability of internationally accepted standards for performance verification and measurement uncertainty determination (ISO 10360-2 [5] and ISO 15530-3 [6]). However, when measuring free-form handmade components like violins, because of the extreme variability of surface curvatures, and the presence of non-accessible features, tactile CMMs show several limitations, including the risk of damaging the instruments.

We designed and manufactured a test sample (Figure 1, right), machined from red spruce (Fiemme Valley, Italy) with a CNC milling machine.

The test sample was conceived in order to include the typical features measured on a violin top plate, and to be tested by the three systems used in this research: CMM, SL and CT.

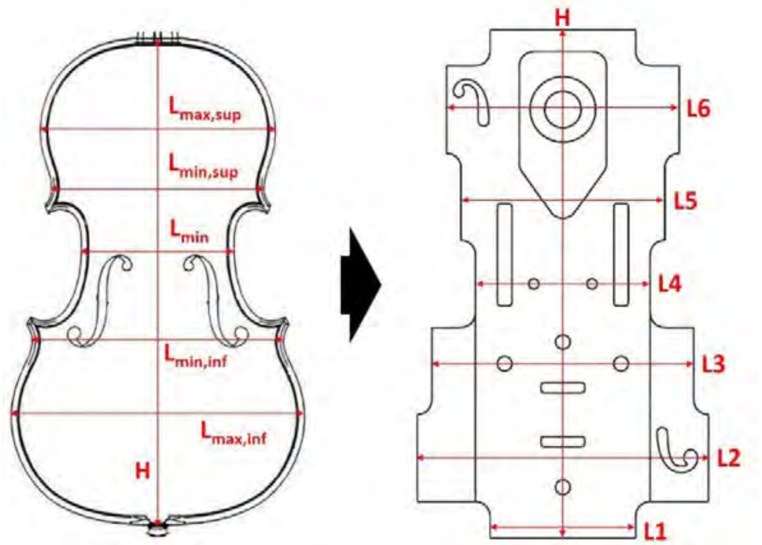

Figure 1: test sample (right) vs a violin top plate (left), with superposed measurands

A set of measurands were defined, each of them representing a feature of the real violin soundboard, such as the overall dimensions, f-holes positions, plate thickness and elevation maps. In compliance with the similarity requirements stated in [6], the sample can be used to assess the measurement uncertainty for real violin top plates.

CT and structured light analysis of the test object were performed in the same conditions and with the same measuring procedure adopted for the analysis of the original violin component.

The sample was measured with a ZEISS PRISMO 7.9.5 tactile CMM at TEC EUROLAB, and then scanned with an NSI X5000 CT system at SIDEIUS. Finally, a set of surfaces was acquired by means of the structured light scanner Open Technologies Cronos 3D. For each measuring technique, three repeated scans were performed.

All the results (corresponding to the measurands) acquired with the different techniques were put in comparison, together with their relative standard deviations.
Deviations of CT and SL from the reference (CMM) were evaluated. Furthermore, the corresponding measurands of a Nicola Amati (Cremona, 1652) violin belly inside surface were measured using CT and SL. The outside surface was too dark and shiny to be scanned with structured light.

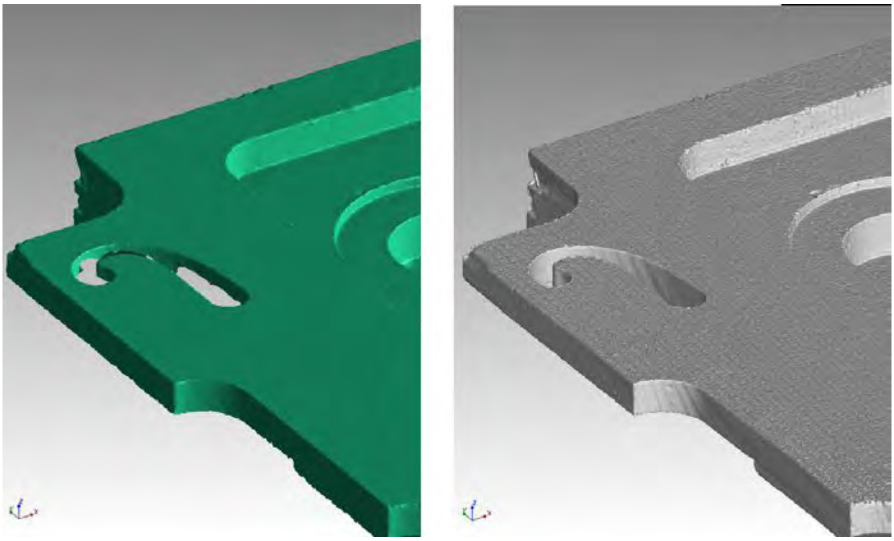

Figure 2: a comparison between SL polygon surface (left) and CT extracted surface (right) of the "soundboard" sample.

3. Results and discussion

Results obtained for measurands L_1, L_3-L_6 (see Fig.1) are reported in Table 1. Temperature and Relative humidity were monitored during all the measuring sessions. The comparison of the results obtained with CMM, CT and SL provides several indications.

Values from CT has an absolute deviation $|\Delta|$ from CMM values ranging from 92 to 102 μm. LS constantly overestimates measures, with a positive Δ deviation ranging from 350 to 560 μm.

Table 1 – Comparison of results for the soundboard sample L1-L6 measurands

	Average value [mm]			σ [μm]		Δ [μm]	
Measurand	CMM	CT	SL	CT	SL	CT-CMM	CT-SL
L1	99.794	99.819	100.144	14	129	26	350
L3	179.654	179.561	180.12	16	75	-92	466
L4	119.782	119.749	120.123	11	77	-33	341
L5	139.755	139.732	140.127	11	47	-23	372
L6	159.54	159.642	160.102	10	33	102	562

Moreover, CT results have a significantly lower standard deviation with respect to SL: CT standard deviations range from 10 to 16 μm, while the SL ones from 33 to 129 μm.

This confirms the good repeatability of CT measurements, and the stability of the environmental conditions during the scanning process.

Uncertainties according to (ISO 10360-2 [5] and ISO 15530-3 [6]). were calculated for all the measurands.

After the uncertainty evaluation, a similar set of measurands was evaluated in a real violin belly: a Nicola Amati (Cremona, 1652), results are reported in Table 2. It is to notice that for each of the measurands of Table 2 the uncertainty U_{CT} is higher when calculated according to the ISO 10360-2. This is because the deviation Δ between CT and CMM measured with the soundboard sample is taken into account into the calculation. On the last columns, uncertainty was calculated using an adapted approach of ISO 15530-3 as suggested in [7,8].

Table 2 – Examples of uncertainty evaluation for f-hole measurands on a real violin

Measurands	Value [mm]	U_{CT} 10360-2 [μm]	U_{CT} ISO 15530-3[μm]
Dinf	9.574	197	28
Dinf	9.824	197	28
Dsup	5.976	163	33
Dsup	5.837	163	33
E	69.286	261	70
E	67.564	260	69
L	4.445	275	22
L	4.655	275	22

4. Conclusions

In this work industrial X-ray CT and LS were investigated as a tool for the dimensional analysis of a violin soundboard. A test sample was conceived in order to include the typical features measured on a violin top plate, and to be tested by the three systems used in this research: CMM, SL and CT.

X-ray CT and LS have proved to be a valid alternative to traditional tactile CMMs for the reverse engineering of bowed stringed instruments.

Experimental results demonstrate that CT provides better results, in terms of measurement repeatability and uncertainty, compared to LS. A major advantage provided by CT is the possibility to extract information on the inner geometries of bowed stringed instruments and to deal with dark and shiny surfaces. This kind of measurement tasks, indeed, are not possible with traditional optical scanners without opening the instrument or altering its optical surface behaviour.

5. Future research

This work represents the first step in the dimensional analysis of stringed instruments by means of industrial X-ray computed tomography. Future development will address the evaluation of different geometrical characteristics of top plates, such as thickness mapping, free form profiles and surface roughness.

Acknowledgments

The authors want to thank: Fabrizio Rosi and Luca Passani of TEC-EUROLAB for supporting the CT and CMM activities, Walter Barbiero for structured light scanning, Franco Simeoni for the Nicola Amati violin.

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Reconstruction of Oboes Made by Christophe Delusse: from the Material Sources to the Sounding Instrument

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Abstract

Landmark of the 19th century European musical expression, the oboe occupies, in the orchestra and in the musical context of that time, a place apart, as well as the French instrument-making school. The instruments of Christophe Delusse, Parisian maker passed out on the eve of the century, were echoed by Antoine Auguste Vény, well renown teacher and his contemporary, « [...] his oboes are very appreciated and are nowadays even rarest than the most famous violins of Stradivari, Amati, Guarneri [...] ».

We propose here to present the facsimiles of many Delusse's oboes and to illustrate the methodology used, result of the Musee de la musique's research group, strictly combining makers and musicians. The ensemble of this project's components has been carefully investigated, from the manufacturing to the playing technique. The research has been conducted by relying on historical, documentary, and material sources able to provide any additional information.

Throughout the study, materials characterization, functional analysis and acoustical tests of the instruments has been set up, providing additional and tangible information to assess the authenticity of the facsimiles made thereby.

1. Introduction

Redesign, rebuild an ancient musical instrument in its entirety -even though the Musée de la Musique has several reliable originals- may seem paradoxical or at least surprising. This choice however is based on a logical approach, the origin of which lies in the uniqueness of scientific and technical information contained in these instruments that might be irredeemably lost by playing these instruments. As we know, a woodwind instrument like the oboe is likely to suffer irreversible damage shortly after having been played upon, particularly the breaking of turned and carved bodies. This is a well known phenomenon that has been widely described today. The hot and moist breath of the musician creates a temperature and humidity gradient between the inside and the outside of the instrument which induces internal stresses in the material and soon irrevocably leads to the sound pipe fissuring. Thus, except if we accept the idea that any historical trace will disappear for the sake of a fugitive restoring to playing condition, the restoration of these instruments appears to be a deadlock. At the current state of knowledge as well as of conservation techniques, the Musée de la Musique — guarantors of the conservation of these witnesses of the history of instrument making and music — restrains from such gambling.

That is why — combining conservation, exploration and dissemination by musicians, of the sound heritage contained in these instruments — requires the making of a new instrument which, in every way, has to be the perfect substitute for the original, unless it fails to respond to its vocation.

Therefore, taking this into account, the Museum regularly implements the making of facsimiles of its collection of instruments, which act as technical and scientific historical research engines in order to strive towards this utopia.

The implementation of the making of a facsimile requires a precise physical and functional knowledge of the instrument that is to be replicated. It is built on a scientific exploration of the object as well as on the identification and the analysis of written sources and testimonies from the time of the original instrument.

Though a perfect and comprehensive replicating of these instruments to match the original has no real sense — neither from the physical nor from the philosophical point of view — the success of the adopted process will be guaranteed by objective evidence that they work the same way as representatives of their time. Experiments and research conducted simultaneously with these projects are aimed to provide objective knowledge the purpose of which is twofold. On one hand, they attempt to provide the essential information required by the process of assimilation of the old skills to be adopted by the man of the art entrusted with the making of the instrument. On the other hand, they should highlight the similarities and differences between the original object and its facsimile. Therefore the initiated work is concerned with the instrument within its historical and musical context, with the original object itself in all its materials, with its reproduction, copying, with its facsimile, in all its stages.

The material corpus:

> The oboe — a beaconing instrument in the realm of musical expression of the 18th century — occupies a particular place in the orchestra and instrumentation of that period. In the European context, French instrument making occupied a prominent place. Speaking of Christopher Delusse — an instrument maker in Paris who died in the late 18th century — Antoine-Auguste Veny, a famous professor of the early 19th century, echoed that reputation "…his oboes are popular and are now even scarcer than the most famous violins of Stradivari, Amati, Guarneri… "
>
> The Musée de la Musique owns six oboes of this maker and particularly two pieces [inventory number E.2180 and E.2182] the conservation status of which allow accurate metrological readings. These two instruments by Ch. Delusse are part of the collection of the Musée de la Musique ever since they have been donated by their former owner in 1934. One of them is made of boxwood (E.2182), the other of granadilla (E.2180) ; they both have two silver keys. These two references have been selected for the reconstruction project and a thorough metrology is carried out based on metric measurements using conventional means, gauges, calipers, etc. Internal parts — bores, undercut holes — are explored using standard investigation means of the Museum : video-endoscopy and radiography.

The material corpus examined also includes several boring tools (used for creating the hollow part of the instrument) which belong to the collection of the Musée de la Musique and are conclusively linked to the workshop of the same maker. They have been carefully measured and compared to the bore of the original instruments. They closely match the shapes in the original instruments which confirms their attribution. These tools will be reproduced exactly to be used in the actual replicating of the instruments.

Fig. 1 C.Delusse tools, E.1508 collection Musée de la musique photo ©S.Vaiedelich Cite de la musique-Philharmonie

2. Joseph-François Garnier's method

La Méthode raisonnée pour le hautbois (A Reasoned Methodology for the oboe) written by Joseph-François Garnier (1755 – 1825) is published in 1798 by the editor Pleyel. It was intended for the most talented students and colleagues of his time and provides information of utmost quality. Joseph-François Garnier was first oboist in the orchestra of the Paris Opera, from 1775 to 1808, and oboe solo in the Concert spirituel, from 1787 to 1791. He was also active in composing music and teaching and was one of the first oboe teachers of the National Conservatory of Music which opened in 1795, in Paris, at whose request he published his book.

In his method, Joseph-François Garnier himself recommends the use of an oboe of the maker Christophe Delusse, of which he provides a detailed engraving.

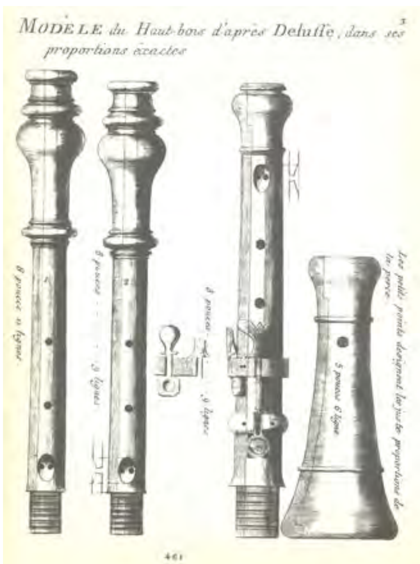


Fig. 2 Engraving of the oboe

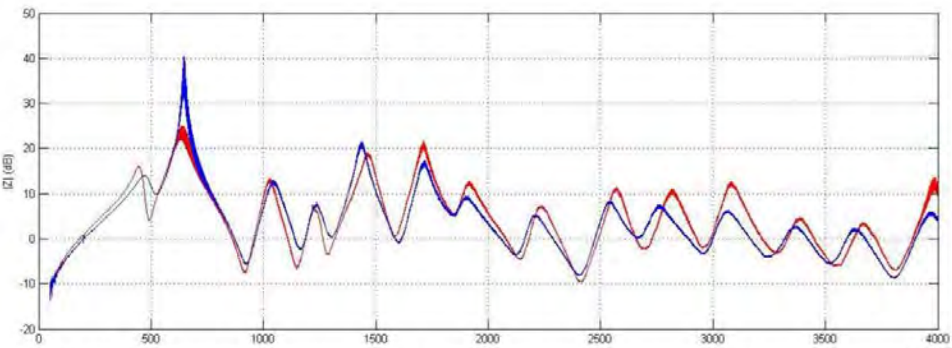
3. About reed and fingerings

In addition to recommending the maker his book proves to be a unique source of technical and musical information. The pedagogue and performer proposes a set of fingerings which by nature should be suitable for our facsimiles. This fundamental element will be acting as the guideline while designing and making the appropriate reed to work on the facsimiles. The effectiveness of these fingerings on the replicated instruments account for the quality of our reproduced instruments.

In chapter 3 of his treatise, the naturalist in Joseph-François Garnier accurately describes how the cane must be chosen for making reeds. He stated that it "must be gathered in southern countries" ... and "must be cut in the autumn, just before frost sets in. The barrel1 of the shaft must be healthy and resilient with the thickness of an ordinary finger. " Further in his method he describes and shows the tools required for making reeds.

4. About tools and bodies

Two oboes have been made, using the copied tools. Before musical tests were initiated, the reliability of the replication could be examined by measuring acoustic impedances. These measurements provide information on functional modalities of the resonant cavity formed by the bore of the instrument. They have to be carried out on each fingering and, when compared with the measurements carried out on the original, will make it possible to evaluate the quality of both geometric reproduction and similitude of the chosen material.



E.2180	468	644	1042	1224
Copy of E.2180	453	633	1026	1227

Fig 3. Compared impedances of a D 2 note. Blue: original oboe, red fac-simile measurement

5. Conclusions

It appears to be generally accepted that at the time when the oboes were made, they were provided with several top joints to allow musicians to tune to the most common pitches of those days. The Museum's collection includes two different reamers which correspond to the reaming dimensions of the top joint. Both reamers bear carefully etched marks — to be used during the working process — that explain small yet existing differences in the sizes of the joints of both oboes (E.2180 and E.2182 in the collection of the Museum).

When fitted on the instruments, the reeds — designed following the principles of J.-F. Garnier and bearing in mind the scrutiny of the reeds made by the maker Guillaume Triebert — produce a particular sound palette.

The way an oboist fingers, produces the note by closing the holes of his instrument is very much like a painter's strokes. His choice produces the line, the colour, the tone of the work performed. By enabling the use of fingerings recorded at the end of the eighteenth century, these instruments favour a musical practice likely to verge on that of the old masters.

By bringing together instrument makers, musicians and scientists, the facsimile program initiated by the Musée de la Musique keeps alive some of the know-how as well as sometimes forgotten practices that present generations of musicians and makers can again make their own to build new and creative musical futures.

Fig. 4: The two facsimiles from E.2182 in ebony, from E.2180 in boxwood photo ©svaiedelich Cite de la musique-Philharmonie

Acknowledgement

The authors gratefully acknowledge Bernard Vanderheyden for the translation.

Rethinking the Possibilities of a Notched Flute: The Case of *Quena*

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Abstract

The *quena* is a notched flute from South America. Notched flutes share the same excitation mechanism but differ in several aspects such as the number of holes, the geometry of the notch and the size and shape of the tube. Today the *quena* is an instrument widely played in Latin America both in rural and urban contexts, where it gradually adapted to tonal music. It is in the latter context that we propose to revise the design of the bamboo *quena* from an acoustic perspective, optimizing the position of the toneholes and modifying the geometry of the bore in order to obtain a flexible and adequate instrument not only to play tonal music but also to adapt to the chromatic needs of contemporary music. The analysis is based on a linear model of the acoustical propagation inside the instrument, which is numerically simulated and optimized in order to obtain a new design of the instrument addressing some of the limitations found in the original cylindrical *quenas*.

1. Introduction

The Grove Music Online describes notched flutes as 'an end-blown flute (open or stopped) with a V- or U-shaped notch cut or burnt into its upper rim to facilitate tone production' [1]. Notched flutes are played widely and can be found in Africa, East Asia, the Pacific Islands and Central and South America. One of the most well known notched flutes is the Japanese *shakuhachi*. It is made traditionally out of bamboo and its most common form has four finger holes and one thumbhole. Variants of the notched flutes are found in China, Korea, Vietnam and Taiwan. The *quena* (or *kena*) is a South American notched flute. Like the other flutes, it is an ancient instrument, with a history of over 2000 years [2]. The instrument is mainly found in Peru, Bolivia, northern Chile and northern Argentina and is less frequent in Ecuador, Venezuela, Columbia and the Guyanas. It can be made out of cane, wood or reed and most instruments have six finger holes and one thumb hole [3].

2. Musical and cultural contexts

All these different flutes are used in specific musical and cultural contexts. Notched flutes were played in Peru as far back as the Chavin era (900-200 BCE). The traditional repertoire of the *quena* is closely associated to the dry winter season and is still played in Aymara communities on the Bolivian *altiplano* [2]. The instruments (*kena-kena*), used in these rural communities, are between 50 and 70 cm long, have six finger holes and are played as part of an ensemble. However, *quenas* were not solely confined to a rural environment. Solo playing developed within an urban setting, consolidated around the mid-twentieth century, when Andean music benefitted from a huge rise in popularity thanks to a cosmopolitan pan-Andean music genre created in Paris, where many

Argentinean, Chilean and Bolivian groups recorded and gained popularity in the 1960s [4]. This led to the modification of the instrument in order to cater to artistic needs such as adjusting to a more tempered scale and playing with other instruments. Today, the standardized urban instrument is generally made out a single piece of cane, wood or even plastic and features six finger holes and a thumb hole at the back [2]. Some modern models are also in two parts, with a joint between the head and the body (Garcia, interview 30 May 2016, Paris).

In Chile, the *quena* and the *charango* were used extensively in left-wing *Nueva Canción* groups, identifying themselves with a pan-Andean revolutionary movement [5]. These instruments were so closely associated with this political movement that they were strongly discouraged after the 1973 military coup, overthrowing Allende's democratically elected government [6],(Wang, interview 5 July 2016, Paris). Despite this, traditional instruments were soon openly played by local musicians. One of these groups, Barroco Andino, was formed immediately after the coup and performed a Western Art Music repertoire initially conceived for different instruments (Wang, interview 5 July 2016, Paris). This led the musicians to push their instruments beyond their limits as they started experimenting in order to meet the demands of the music, leading them to an idealised "well-tempered *quena*" (de la Cuadra, interview, 8 February 2016, Paris). The decontexualization of the instrument from its folk and traditional repertoires triggered a movement that led to further modifications. More recently, for example, flautist and Ensamble Antara leader, Alejandro Lavanderos, contacted Paris-based flute maker Jean-Yves Roosen to create a chromatic instrument that would allow composers and musicians to go beyond the instrument's current limits.

3. Influence of the musician on a flute-type instrument

Changes in repertoire imposed by musical, political or cultural change lead musicians and instrument makers to modify their instruments in order to cater to specific musical needs [7], [8]. If we reverse the position and propose an instrument with slight modifications, how will this impact the musician and his/her musical practice? As the one of the main driving questions of this study we wish to understand if the musician welcome change or if it will be problematic and whether a modified instrument will lead to the performance (and composition) of a different repertoire or if the musician will change the performance of his/her current repertoire.

Although the instrument is a separate object to the musician, both are intricately linked. Indeed, an experienced musician will be able to control his/her instrument in such a way that his/her technique will override many technical or structural issues that an instrument may have [9]. The structure of the instrument will influence how the musician controls the instrument but will not impede the musician's production of a precisely targeted emission. We could theorize this in the following figure:

Although understanding the musician's control over the instrument is not the goal of our study, it is an important aspect of our research in order to understand how the physical parameters of the instrument affect him/her.

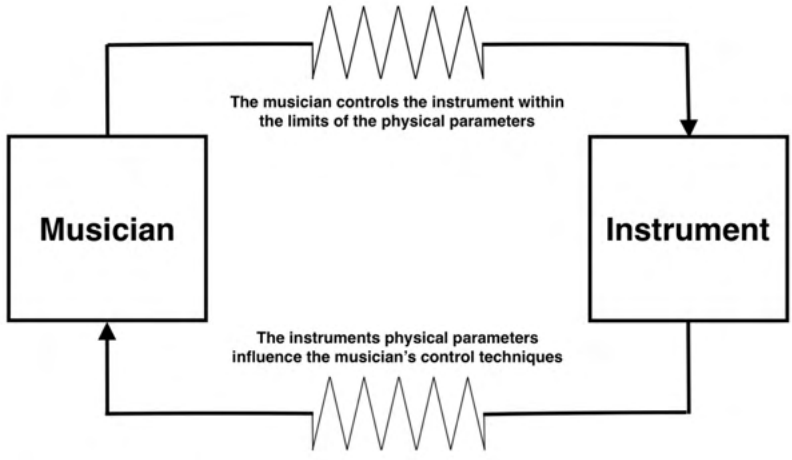

Figure 1: Theorization of the musician/instrument interaction

4. Technical knowledge

In the last decades the knowledge of the physics of flute-like instruments has improved and a new research field, the musician's control over his instrument, has shown to be both attractive and promising [9], [10], [11]. These improvements, together with the possibilities of accurate acoustic impedance measurements and the availability of materializing technologies such as 3D printers and CNC lathes, set up favorable conditions to study and revise the design of musical instruments. Analytical models of non-trivial geometries for instruments from the flute family are too complex to implement. Alternatively, the transmission matrix approach [12] provides a powerful tool to simulate and predict the linear passive acoustic behavior of flutes.

5. Revising the instrument

When conceiving a flute, there are several parameters that the builder can modify in order to obtain a desired intonation (tuning). The most important include the position, size and height of the toneholes, the bore's internal geometry and the shape of the embouchure.

In a previous study [13] we observed that the bore geometry could be crucial in determining the inharmonicity between the first and second register of the instrument. In order to describe more precisely the tuning of the first two registers for every note from a given bore geometry, we simulated several internal bore shapes, cutting the passive end at places where it would produce a tempered scale if the resonator was an ideal cylinder. That is, in places where the length of the n^{th} chromatic note is given by: L/2^(n/12), where L is the length of the bore. For every truncated bore we simulate its acoustic impedance and measure its inharmonicity. Figure 2 shows the simulated response of a set of bores whose internal diameters are displayed on the upper side of the figure with their corresponding inharmonicity below:

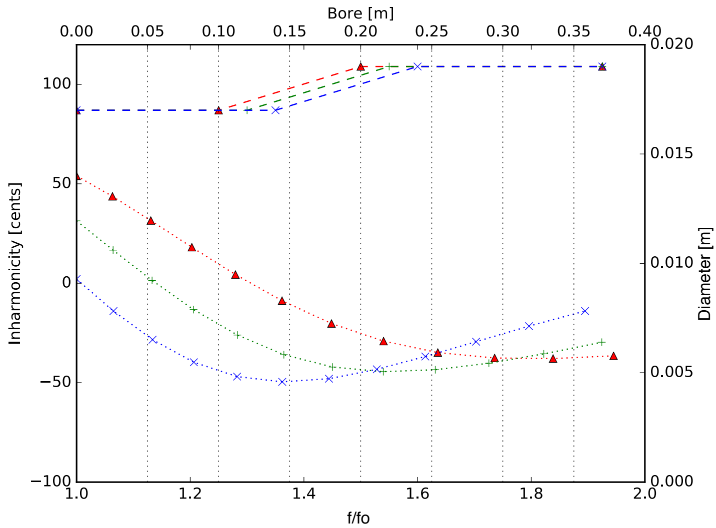

Figure 2: Inharmonicity in relation to the shape of the bore

We observe that the inharmonicity differs greatly among the three geometries and also varies considerably from note to note with differences that can span over a range of over 80 cents. Several bore geometries were simulated in the same way, providing a dictionary of bore shapes with their associated inharmonicities.

Once the geometry of the bore is chosen, the toneholes provide the means to tune the first register and fine-tune the second register. In order to identify how much inharmonicity can be controlled by adjusting the size and height of the toneholes, figure 3 shows a simulation of a 37cm cylindrical bore with one tonehole whose center is positioned at 34.96cm from the embouchure end, that is the length where an interval of a tone would be produced if the bore was truncated.

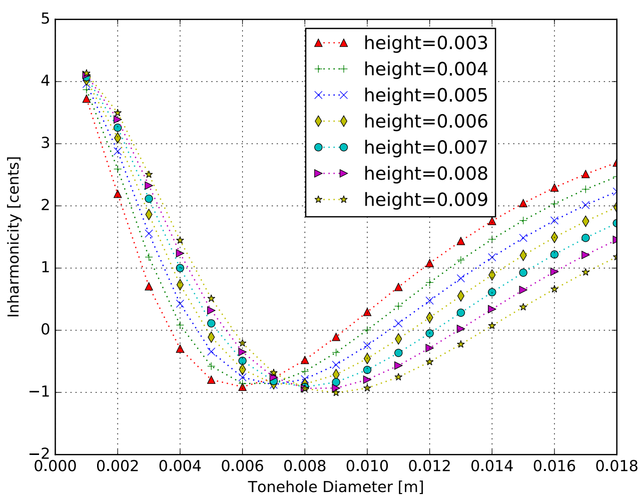

Figure 3: Tonehole inharmonicity in relation to its height and diameter

We notice that toneholes with equivalent inharmonicity can be obtained by correctly choosing a combination of tonehole height and diameter.

The variation of inharmonicity that can be induced by such holes is smaller than 5 cents, which shows that the inharmonicity induced by the bore's internal geometry dominates over that of the toneholes.

With these parameters in mind, two instruments were simulated. The first features an intonation profile emulating the impedance measurements of real instruments (Figure 4, right); the second features a profile calculated to produce a tempered scale with a smooth evolution in the control over the two registers (Figure 5, right).

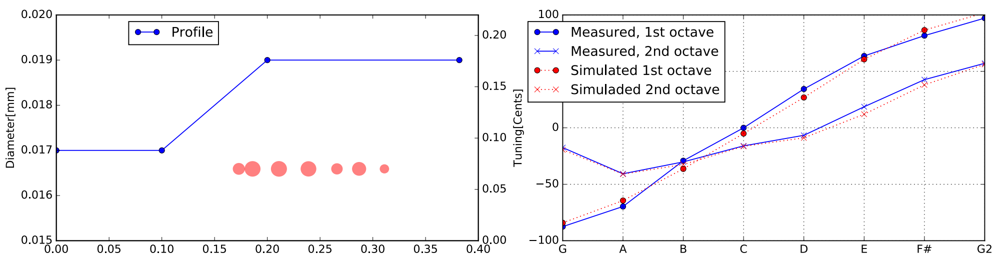

Figure 4: Simulated *quena* based on measurements

Figures 5 and 6 (left) show the bore profile and the size and position of the toneholes calculated to match the desired intonation.

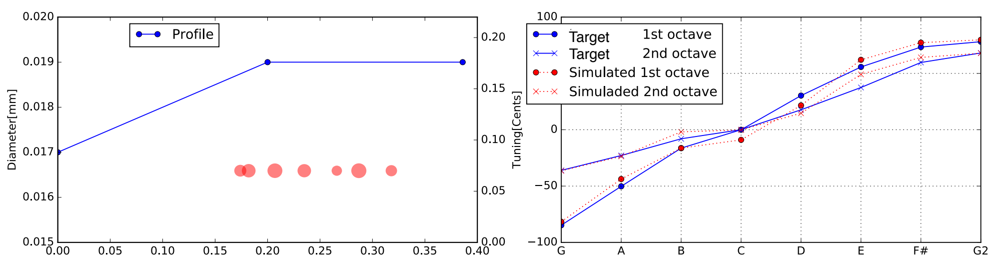

Figure 5: Simulation of the proposed *quena*

In order to address our initial question, posed part 3, we are now in the process of printing both instrument simulations with a 3D printer.

6. Perspectives

Our next step is to measure through motion capture, video, sound and interviews how the musician adapts to the instruments. We are aware of personal differences between musicians and we are currently establishing an experimental protocol including two musicians and their reactions to both instruments within a musical context.

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The Contribution of Archival Research in the Field of Organology. A Focus on Musical Instrument Makers

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Abstract

Archival research in the organological field has always played an important role in Italy. Both in the past and in more recent times, several significant research projects on the study of musical instruments and their makers have been conducted. I have personally taken part in some organology projects, particularly in relation to stringed and plucked instrument making in Central Italy.

This conference paper presents some of the results achieved in this geographical area, more specifically in Pesaro, the city having been the object of a number of research projects some years ago and of further studies recently. Pesaro in the seventeenth century was an interesting place to analyse for its anomaly in relation to the territory surrounding it, which was described especially in the following centuries. Whilst information on numerous makers from Pesaro is available, very little has survived of their instruments.

An exception in this respect is represented by Antonio Mariani, since a good number of instruments having survived to this day. In the present work, I will try to highlight the importance of archival research in the field of organology through the presentation of the stories of Mariani's family members. This is not only a very useful tool for academics, but also for all the different experts in the field, from makers to restorers and instrument collectors.

1. Introduction

This conference aims at consolidating cooperation among makers, museum curators, academics and scientists, with a view to improving knowledge on wooden musical instruments. In this regard, this paper focuses on issues such as the relationship between academics and other actors related to wooden musical instruments of different societies and historical periods.

Over the last ten years, I have taken part in a number of research projects in the field of organology, in particular involving to stringed and plucked instrument making in Central Italy. I have conducted these studies on behalf of musical instrument traders and collectors in particular, many of which are also makers and wooden musical instrument restorers. These studies were commissioned in order to analyse the authenticity of the musical instruments belonging to the principals of the research. By tracking the various changes in ownership of these instruments, we have often been able to find reliable sources relating to their makers and closest first owners.

This type of research has allowed tracking the evolution of the instruments analysed from the point of view of their use and importance, some of them having even become part of museums or private entity collections. This research was carried out through the study of different periods and changes in taste. Another important part of this study in some cases implied the collection of evidence of the makers and the environment in which they evolved through historical research. In this respect, I sometimes came across entire areas of production that were little known or completely unknown. As a consequence, I was able to establish a dialogue with other academics, collectors, makers, restorers and traders, through historical research and archival investigation, focusing on an instrument and the work of one or more makers.

In Italy, the target for my studies, archival research in organology has always played a key role. As regards the origins of Italy's historical organology, the academic Gabriele Rossi Rognoni stressed that the best results in archival research were achieved precisely in the peninsula [1]. Italian academics, inspired by nationalist spirit, started to explore the history of musical instruments when the nineteenth century had already started, with a view to showing that Italy was a leader in the making of some instruments, such as the piano and the violin. The debate on the origins of the piano took place in Florence, referring to the studies carried out by Leto Puliti. As demonstrated by Rossi Rognoni, the initiatives regarding the piano organised from 1868 to 1876 in Florence were made possible also thanks to the collaboration between Leto Puliti, an amateur researcher, Cesare Ponsicchi, a maker and piano tuner, and Alessandro Kraus, a private collector [2].

The importance of research as a key element of this science was also confirmed by Renato Meucci, who demonstrated in several first-hand studies that historical investigation helps explain certain phenomena relating to the evolution of musical instruments. While introducing "L'indagine organologica storica" (Historical organological investigation, TN), Meucci dwelled upon the definition of the contents of organology in one of his texts [3]. He stressed that with particular thanks to historical research we are able to evaluate the importance of a certain model or, as it occurs sometimes, of a single instrumental piece in a specific musical environment and geographical area, as well as by analysing its design and working features. Consequently, the skills required to be an organologist are numerous. These go from iconography, to restoration, museology and musicology [4]. In order to describe an instrument, different intersecting and complementary specialisations are necessary. Amongst these feature the collection of information through archival research.

In this speech, I am going to present a case study regarding a city in Central Italy where several stringed and plucked instrument makers were active in the seventeenth century, this case being an example of the relevant role played by archival research. First, I will present the research on the modern Marche, which involved the whole region, by introducing the stories of a number of makers coming from that geographical area. Following this, I will focus on Pesaro, where I carried out many archival investigations some years ago and where I have conducted further studies recently. Several makers from Pesaro active in the period I am taking into account in this presentation will be referred to as citararo, (maker of cittern).

Finally, I will end my speech by dwelling upon the Mariani family, a sufficient number of their instruments having survived to this day. These are not citterns but stringed instruments.

2. Pesaro, an anomaly of the seventeenth century

Pesaro is currently part of the Marche region, which is located in Central Italy. Marche became a proper region, understood as an administrative and political entity, only after the Napoleonic wars and following the set-up of a new territorial political structure. Before that and during the sixteenth and seventeenth centuries, this concept was impossible to conceive even in terminology. In fact, the term Marca or Marca di Ancona, even during the eighteenth century, did not correspond to the geographical area that represents the Marche region today [5].

Consequently, I am taking into account the relationship between some makers and the city in which they lived. Cities in Marche were very different from one another between the seventeenth and the twentieth century considering the topic I am describing here, namely stringed and plucked instrument making. A group of makers, on which some information has been identified, lived and worked in the city of Pesaro in the seventeenth century. In most of the documents found, they are referred to as citararo. This term is used in this area of Central Italy as a synonym of liutaio, namely stringed and plucked instrument maker.

Between 2009 and 2010, I conducted a number of archival studies in Central Italy, in Umbria and Marche precisely, regarding stringed instrument makers in the period between the seventeenth and the twentieth century. The result of this research was published in The Makers of Central Italy by Florian Leonhard [6]. Florian Leonhard is an instrument expert from this region who collected and analysed a series of stringed instruments that were made by authors coming from this Italian area.

As regards Marche, information on makers can be found in the main dictionaries of the sector of wooden instrument making and in particular in the studies conducted by Giuseppe Radiciotti and Giovanni Spadoni. These two experts developed a bibliographical dictionary, which has remained unpublished, on the musicians from Marche, in which information on musical instrument makers is also available. For this research project we consulted the unpublished version of the dictionary, which is composed of a vast collection of handwritten notes and summary sheets. The dictionary is kept in Macerata's Mozzi Borghetti town library [7]. The document is available for consultation through a guide by Ugo Gironacci and Marco Salvarani [8]. Another reference document is a text by Riccardo Gabrielli on musical instrument makers from Marche, who reported a great deal of information on a number of makers about whom I identified further details during this research project [9].

Florian Leonhard carried out studies on the makers from that area for years and in a first phase, he commissioned a number of archival investigations to the academic Anna Cecilia Poletti. Unfortunately, these studies did not achieve significant results in relation to the seventeenth and the eighteenth centuries. Consequently, I was asked to bring forward this project for different cities, which are currently part of Marche and Umbria. I worked in historical archives, diocesans and libraries in cities such as Ancona, Ascoli Piceno, Macerata, Pesaro, Urbino, Fano and other minor cities such as Ripatransone.

The data I collected covered a rather long period and regard makers that are very different to one another, both in relation to the environment in which they lived and to the quality of their activities. The results of the archival research were passed to Antonio Moccia, who used them within the same project to edit the bibliographical dictionary on the makers. The latter is based on the results of the research and on an accurate bibliographical investigation carried out by the academic, which was published in the volume. Furthermore, Florian Leonhard used the research to analyse a selection of instruments made by Umbria's and Marche's most significant makers, of whom he provided pictures and analyses.

As explained by Florian Leonhard, many of these makers lived in narrow-minded scenarios. Sometimes, maker families operated in small inhabited towns, having started their careers as carpenters or farmers. This was confirmed by the studies I conducted. Florian Leonhard used the term contadino (peasant) to refer to the profession of most of these makers' clients [10]. In this respect, information was found on wooden instrument makers such as the Desideri family, whose evidence take us back to the early nineteenth century.

Information is available on two members of this family, Pietro Paolo and his son Raffaele, who lived in the small town of Ripatransone (in the province of Ascoli Piceno) in Marche. These two men are thought to have approached wooden instrument manufacturing as self-taught people thanks to the manual skills they had developed as carpenters, several members of this family having also pursued this profession. Like many other self-taught makers from Marche, they found the models for their own instruments in the musical environment in which they were living. In one of the documents found, Pietro Paolo is described as a violinaro (1811), while his son Raffaele was both a stringed and a plucked instrument maker [11].

A similar family was the Odoardi family, coming from Poggio di Breta, a small fraction of Ascoli Piceno. These makers owned small plots of land: initially, they were carpenters and then they approached the world of instrument making. Their first clients were probably farmers and then they became famous thanks to Giuseppe Odoardi. Born in Poggio di Breta on 6 April 1746, he was one of the most well-known authors of this Italian area who learned the art thanks to the need to make and fix instruments for his own community [12].

Interesting information was also found on the Baldantoni family, who worked in the early nineteenth century. Brothers Antonio and Giuseppe Baldantoni were gunsmiths, but also musical instrument makers in the port city of Ancona. The members of this family pursued musical instrument making for over a generation [13]. Annibale, one of Giuseppe's nephews, is mentioned alongside his uncle in the section dedicated to wind and stringed instrument makers in a year-book of the city of Ancona referring to 1848 [14]. As dendrochronology studies show, many of these makers used local wood from Marche and Umbria to make their instruments. Even though they were distant from one another, we can find a connection among them in the use of the same raw material, the local wood [15].

As regards previous centuries, the city of Pesaro of the seventeenth century, where the activity of different makers has been clearly identified, represents a unique case. There is evidence of the production of citterns in Pesaro dating back to as early as the sixteenth century, as reported by Franco Piperno [16]. Furthermore, the academic mentions the activity of important lute players in the court of Guidubaldo II Della Rovere (1514-1574). The historical changes that affected Pesaro, which then became the capital of the Dukedom to the detriment of Urbino in the sixteenth century, also influenced the music and the various elements connected to it.

Pesaro became a prosperous place for musical instrument making. In this respect, the instruments of authors from Pesaro were found in other courts from the same period, such as the keyboards of Domenico da Pesaro. He was quoted in the Medici inventories and this factor bears witness to the fame and the presence of instruments made by authors from Pesaro [17]. Therefore, it is hardly surprising that several craftsmen from Pesaro were also identified in the next century. However, the latter saw the devolution of the Dukedom to the Holy See. As a consequence, the musical activity of the area ended up being mostly connected to the city's aristocracy, its academies and cultural cenacles.

Some of the makers who are worth remembering are Carlo Cortesi, the citararo Pier Lodovico Filippucci, Giovanni Antonio Forni from Loreto, Sabatino Sacchini, Sante da Pesaro, Francesco Spadari, but especially the members of the Mariani family.

Florian Leonhard published the main results of my archival research relating to many of these craftsmen for the first time [18]. I will present some of these results again in this paper, as I have recently carried out new studies in Pesaro. In this respect, document identification can help to better understand this maker family and in particular Antonio Mariani, one of its best-known members.

3. The Mariani family

The first person on which information was found is Fabio. Born on 20 February 1637 in Pesaro, he was the son of Lodovico Mariani, who was also from Pesaro. The National Music Museum in Vermilion holds a violin dating back to circa 1620 that is through to have belonged to Lodovico Mariani [19]. This instrument may have been made by Fabio's father, but no document has confirmed that Lodovico was a craftsman, while Fabio is described as citararo in the various documents found. As mentioned previously, the term citararo is used in the Pesaro area to refer to stringed and plucked instrument makers. As regards Fabio and other members of his family, a number of parish family books were collected in San Cassiano, the family's reference parish in Pesaro.

We collected other documents regarding Fabio too: an appraisal of his properties dating back to 1690 and his will, which he dictated from his deathbed in 1708. Fabio got married to Donna Camilla Guerzi and had numerous children. His eldest child was Antonio Maria, who was born between 1661 and 1663 and who lived in his father's house until a few years after he got married to Giovanna di Andrea Capucini from Urbino in 1688. His other children were Arcangelo; born between 1665 and 1666, Francesca, Ginevra, and Margherita, who became a religious woman, and Lodovico. The latter born between 1676 and 1678 and certainly lived in his father's house, even after Fabio's death. His other children were the religious man Giuseppe, Domenico, born in 1681, and Elisabetta, born in 1685. Elisabetta took her vows like some of her other brothers.

The appraisal of 1690, preserved in Pesaro's Oliveriana library, reports interesting information on Fabio Mariani and other members of his family. In addition, other makers who lived in the same period are mentioned in that document [20]. Pier Lodovico Filippucci, described as a citararo, owned two houses and a workshop in the San Giacomo district. The citararo Giovanni Antonio Forni lived in the same district, the man having been the owner of three houses, two in San Giacomo and one in San Nicolò. There, Fabio owned most of his real estate properties. The appraisal indicates that Fabio Mariani owned two houses in San Nicolò, one equipped with a workshop. A third house of his was located in the Jewish ghetto bordering with the Sant'Agostino monastery and his last property was in San Giacomo.

A panorama of rather wealthy craftsmen emerges from this brief description of the year 1690. Mariani was one of these wealthy makers, the man having owned several properties in the centre of the city and a workshop in which others besides his family members must have worked. In this respect, we can mention Lodovico Mariani, who was Fabio's son and heir. He had been hosting the 29-year-older Giovanni Battista Nieler (or Nicler) in his house in the early eighteenth century. He was probably a German apprentice, who spent some time in Pesaro during his training pilgrimage in Italy.

The immigration of countless German makers coming from the city of Füssen in Bavarian Swabia in particular (more precisely in the geographical area of Allgäu) towards several Italian cities is well known and studied in cities such as Venice, Padua, Rome and Naples. The reference bibliography for these cities is rather substantial, while fewer references of the activities of these makers in lesser known cities such as Pesaro are available.

The appraisal of 1690 reports further data relating to the Mariani family that were added later on, indicating the property transfers of Fabio's real estate assets. The most important note reported in the document is the mention of Fabio's will, drawn up by the notary Giuseppe Marella in 1708 [21]. In his will, Fabio appointed his children Mastro Antonio Maria, Arcangelo, Lodovico and Domenico as his heirs. The activity of Fabio's workshop probably went ahead with Antonio Maria, who is described, alongside his brothers, as Mastro in the document. Lodovico was later indicated as the reference person for the Mariani family in the parish family book. Unfortunately, no further detailed information is available regarding Fabio's sons after his death. There are currently no inventories or workshop descriptions either as regards the Mariani family and other makers. Therefore, we do not know exactly what this group of craftsmen made.

Antonio Mariani is an exception, a good number of his instruments having survived to the present day. In the volume mentioned above, Florian Leonhard presents three instruments representing the maker Antonio Mariani, possibly dating back to the period between 1665 and 1670. For this project, only information on Fabio Mariani and his children, including his eldest son Antonio Maria, born between 1661 and 1663, was found. The retrieval of this information led to the hypothesis that Antonio Maria Mariani, Fabio's eldest son, was the author of the instruments that have survived to the present day. Previously, several academics used to attribute Antonio Mariani's instruments to a maker belonging to an antecedent generation. In Florian Leonhard 's publication this was justified by the widespread alteration of Antonio's labels and to the diffusion of fake instruments Attributed to him [22].

The latest research provides other options regarding the dating of his instruments. While exploring musical instrument making in the suburbs of the Papal State between the sixteenth and seventeenth centuries, I was lucky enough to identify another Antonio Mariani. He belonged to a generation even prior to Fabio's generation and closer to that of his father Lodovico. This Antonio Mariani died in Pesaro on 2 June 1667 at the age of 68 and was buried in the church of the monastery of San Agostino [23]. In that place, Fabio Mariani was buried, the man having died on 18 August 1708, as well as the citararo Antonio Giovanni Forni, who died in Pesaro on 30 January 1715. Furthermore, the reference church for the latter Antonio Mariani was the church of San Cassiano, the same as Fabio's church.

This information allows us to better contextualise the instrument production that has survived to the present day in relation to Antonio Mariani. If we consider the two Antonios, two members of the same family, we can state that the Mariani family's production in Pesaro covered the entire seventeenth century and part of the eighteenth century.

4. Concluding remarks

Through the description of the stories of the Mariani family members, I have tried to highlight the relationship between academics and makers by analysing the musical instruments that were made in different regions and historical periods.

As regards Pesaro, we started from little information provided by academics of the past and, thanks to archival research, we have come to a new vision of musical instrument making in that city. Several makers lived in Pesaro and, for one of them only, a good number of instruments have survived. We had attribution problems, but recent investigations have provided a new answer. As current makers and collectors believe, even the retrieval of death certificates can help enormously to clarify instrument dating, as it occurred for Antonio Mariani. His death certificate in fact helped get closer to the making date of his survived instruments.

After the first decades of the eighteenth century, such a significant number of makers were no longer active in Pesaro. Consequently, in the Marche of the following centuries, excluding a number of exceptions, makers were self-taught or non-professional craftsmen who made instruments for their own community and for local use. Examples of this were found in several cities in the region, but no reference city, such as the Pesaro of the seventeenth century, was identified. As a consequence, the environment changed for social and economic reasons and, in this perspective, archival research has helped us describe and confirm these changes.

In conclusion, I think it is worth mentioning Renato Meucci. He pointed out how the stories of musical instrument makers should be analysed also from the point of view of the economic and production changes which occurred in different periods. This allowed us to understand when the stories of the makers we studied and the environment to which they belonged were subject to market laws [24].

Acknowledgement

I would like to thank Florian Leonhard for giving me the opportunity to carry out my research in Central Italy from 2009 to 2010. The results of this research were published in the book on stringed instrument makers from Marche and Umbria. In addition, I would like to thank Professors Franco Piperno and Gabriele Rossi Rognoni, my tutors, who are supporting and advising me on my doctorate research project, which is in the process of being concluded.

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Wood as a Window: Keyboard Instruments in Their Global Context

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The study of historical musical instruments as artifacts of their place and time requires a historical approach in considering the materials from which they were made. Trees are a fundamental resource for civilization, providing such essential benefits as food, fuel, shelter, beauty, and, perhaps least importantly economically, woods for musical instruments. Before wood comes the tree, and before the tree come the fruit and seed. Our own limited interests were put in their place by Petrus de Crescentiis (died 1321) in his *Ruralia commoda*, in which trees were classified according to whether they yield edible products or not. Trees such as walnut, oak, and pear, which to us are important sources of wood for musical instruments, were, and still are, grown for food. Wood was, in many cases, a byproduct.

Accurate knowledge of the woods found in historical musical instruments, in addition to its importance for making copies or for enlightened conservation and restoration, provides a window through which one can view significant aspects of the circumstances in which they were made. The use of wood in keyboard instruments, which typically include no fewer than five or six species chosen for particular acoustical, mechanical, structural, economic, and decorative qualities, is especially complex and can provide significant historical insight.

The detailed technical study of historical keyboard instruments (including organs, harpsichords, clavichords, and pre-modern pianos) was first motivated by the wish of makers to build copies. Research begun in the 1950s by the harpsichord maker Frank Hubbard led to his pioneering book, *Three Centuries of Harpsichord Making*, published in 1965. In the 1970s several museums began to issue technical drawings of keyboard instruments in their collections. Many of these were drawn by instrument makers for the use of instrument makers. The first museum catalogue to include detailed technical descriptions of early keyboard instruments was Hubert Henkel's volume about the harpsichords in the collection of the Musikinstrumenten-Museum in Leipzig [Henkel, 1979]. With only a few exceptions, the identifications of the woods in the instruments described in these books and drawings were made by the unaided eyes of the authors or their consultants. The same is largely true of the identifications of woods in descriptions of other types of instruments in technical publications, historical studies, and auction catalogues. Typically the identifications provided as common names (e.g., for violins "the table is of pine") are vague, misleading, and too frequently inaccurate. Even when scientific names are given, these are sometimes outdated (e.g., *Picea excelsis* for *Picea abies*) or seem to be based not on observation but on supposition or "common knowledge." In this context, the recent trend of using such terms as "coniferous" or "softwood" to describe the woods used for soundboards and other components can be welcomed as being neither misleading nor implying unfounded expertise.

For the catalogue of keyboard musical instruments in the Museum of Fine Arts, Boston, a project was undertaken to put on a scientific basis the identification of the woods in this collection of 54 keyboard European and American instruments dating from the middle to the sixteenth century to the late nineteenth [Koster, 1994]. About 1200 individual identifications were made of the various components of these instruments, primarily using traditional wood-anatomical methods. To date there have been few such systematic investigations, although a noteworthy project involving 133 instruments in the collection of the "Luigi Cherubini" Conservatory in Florence was reported at the Wood MusICK conference in Cremona in 2014 [Falletti et al. 2001; Fiorivanti et al. 2014]. Scientifically based wood identification is also part of a current project for a catalogue of Ruckers harpsichords at the Musical Instrument Museum in Brussels.

Reliable identifications of woods in historical instruments are worthwhile for their own sake and for their practical application in making new instruments. There are, however, other significant ways in which this information can be applied. For example, the identification of North American woods, including *Pinus strobus*, in an English-style spinet in the Museum of Fine Arts, Boston, was crucial evidence for attributing it to the colonial Boston maker, John Harris. The use of *Pinus strobus* for the soundboard of a virginal by John Player, London, 1664, is important evidence of the importation of this wood from the British colonies before the trees were reserved exclusively for the Royal Navy. Discovery that the soundboard of a purportedly seventeenth-century Spanish harpsichord (figure 1) was made of *Thuja plicata* from the American northwest provided crucial evidence of modern forgery [Koster, 2000]. Marks from modern woodworking tools (circular saws etc.) also raised suspicions.

Figure 1: Harpsichord, made circa 1998, falsely inscribed LVIS DE CARBALLEDA ME FECIT A.D. 1641 (private collection)

The Spanish and Portuguese voyages of exploration by Christopher Columbus and Vasco da Gama in the 1490s led to the availability of new woods from the Americas and increased importation of woods from Asia. The effects of these new possibilities are first known from sixteenth-century documents, for example, instruments of *Canna d'India* (presumably black rattan cane, *Calamus* spp.), *Presil Holtz* (Brazil wood, either *Caesalpinia sappan* from Southeast Asia or *C. echinata* from Brazil), and *Ligno Queiaco* (*Guaiacum* sp., from the Caribbean or South America) listed in a German inventory of 1566 [Schaal 1964]. Eighteenth-century Portuguese harpsichords (figure 2) and pianos were frequently decorated with veneer of tulipwood (*Dalbergia decipularis*) from Brazil, then a Portuguese colony. By the middle of the eighteenth century mahogany (*Swietenia* spp.) from Caribbean islands and Central or South America was frequently used for harpsichords and pianos throughout northern Europe and Spain. In pianos made by J.C. Schleip in Berlin in the 1820s and 1830s, the hammer shanks were made of rattan (*Calamus* spp.), presumably imported from Asia. On the other hand, informed examination of the ring-shaped hammer heads in pianos made in the 1700s by Johann Andreas Stein and his pupil J.D. Schiedmayer, casually thought to have been bamboo, disclosed them to be made of barberry stems (*Berberis vulgaris*).

Figure 2: Harpsichord by José Calisto, Portugal (Lisbon?), 1780 (National Music Museum, Vermillion, S.D., USA)

Study of the woods in historical Iberian instruments is particularly interesting because of the complexity of multicultural influences among the makers and of the sourcing of woods from different regions and other continents. In a *salterio* by Salvador Bofill, Barcelona, 1760 (figure 3), the structural wood of the sides, including the wrestplank, is walnut (*Juglans regia*), which is also known from documentary sources [e.g., Nassarre 1724] to have been commonly used in Spain for stringed instruments. The bottom board is of spruce (*Picea abies*) while the soundboard is of fir (*Abies* spp.), which is also found in the soundboard of a square piano by Juan del Juan del Mármol, Seville, 1788 (National Music Museum, Vermillion). The key levers of the Mármol piano are of *Cedrela*, which is almost certainly the *cedro* mentioned in eighteenth-century documents concerning instruments by Diego Fernández, harpsichord maker to the Spanish royal family from 1722 to 1775 [Kenyon de Pascual 1985]. The observation of *Cedrela* in an unsigned harpsichord (figure 4), previously regarded as a nineteenth-century fake, was crucial evidence for assigning it a Spanish rather than Portuguese origin and, with additional evidence, permitted an attribution to Fernández [Koster 2011]. Much further study of the woods in Spanish and Portuguese keyboard instruments remains to be done and will eventually provide answers to such questions as whether a "Flemish" octave harpsichord in the Museu da Música, Lisbon [Ripin 1970] which appears to be made of pine (*Pinus sylvestris*) might rather be of northern Netherlandish or Portuguese origin.

Figure 3: Salterio by Salvador Bofill, Barcelona, 1760 (National Music Museum, Vermillion, S.D., USA)

Strangers introduced to musical instrument makers often ask "What wood do you use?" in addition to "How many do you make in a year?" and "How much do they cost?" The first question shows a welcome curiosity about the subject at hand, while the second and third questions, even if impertinent, indicate an interest in the economics of instrument making. Those of us who are museum curators or who, as stewards of our shared cultural heritage, wish to promote recognition of the significance of what we do, might well take heed. Historical musical instruments in museum collections, more often than not standing silent – and rightly so for reasons of conservation – appeal mostly to the small segment of the public with a particular interest in old music. By highlighting the significance of musical instruments as fascinating artifacts in the context of history and technology, they can be presented more effectively to a larger audience. Wood is a significant part of the story that can be told.

Figure 4: Harpsichord attributed to Diego Fernández, Madrid, c.1755–60 (Smithsonian Institution, Washington, DC; cat. no.315,749)

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A New Approach to the Design of Cremonese Violins, Using the Roman Oncia

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Abstract

The analysis of the outline and design of an instrument, if carefully done, can provide a lot of information about the luthier, its origin and the construction of the instrument. It can help to reconstruct missing parts of the instrument or realize its former state, too.

The basis of geometrical analysis, is knowledge of the drawing and measuring tools of that time and the historical background, especially the multiple links between music, mathematics and philosophy. The historical design of instruments and other pieces of art is strongly influenced by the ideas of Pythagoras. The use of numerical proportion is documented for buildings, paintings, furniture and even the construction of cities. [1].The question of the measuring unit is of importance. With regard to this, new findings on a possible standard length unit, used in Cremonese Instruments will be presented.

These discoveries, based on the rulers and drawings from the Stradivari workshop [2], led to a completely different constructional system of the violin, using concentrical circles, distanced by a particular unit, named Roman oncia.

1. Introduction

Until now, the question of geometrical construction (or: reconstruction) of the violin outline has been the subject of numerous hypotheses. Without doubt, instruments were designed using the tools of that period, namely, a ruler and a compass and applying the ideas of Pythagoras or Vitruv, to achieve a perfectly balanced instrument. In particular, the question of a "standard unit" is of importance. Recent research has mostly dealt in geometrical construction and not in a "standard unit" [3,4] .

What are the foundations of design between the 16th and 18th century? There are plenty of writings dealing with beauty and proportion in architecture, based on the idea that beauty lies in the perfect balance of numbers, proportions and many of these can be represented by beautiful sounding ratios like the fourth and fifth. The use of numerical proportion is documented for buildings, paintings, furniture and even the construction of cities. For musical instruments, being the most obvious object related to the musical proportions, only very few sources survived. The earliest and only plan for constructing a lute and a harpsichord are the drawings of Arnould de Zwolle [5] showing outline and internal bracing of the belly of a lute. Unfortunately, no other plan has survived, but a lot of templates and forms from the workshop of Stradivari did. These items have at least, preserved measurements, compass marks and techniques from that period of time.

Generally the use of a compass for design and measuring was very important, one of the earliest portraits of a luthier, Kaspar Tieffenbrucker, depicts the master surrounded by various instruments, holding a compass in his hand. Calculations or other divisions made by a compass are seen on several sketches of Leonardo da Vinci, too. Besides the utilization of the compass for designing instruments, the knowledge of the applied unit is also crucial: Firstly, to understand the construction, because the simple comparison of measurements does not reveal in all cases its design. Secondly, to have a possibility to attribute instruments to certain regions or instrument makers.

With students of the luthiers school in Hallstatt, Austria a research project was initiated for the construction of the violin, based on the information Sacconi [6] provided and the original sketches of Stradivari. The final aim was to achieve a clear and practical method for the construction of the violin. It became quickly apparent, that the awareness of the used measuring unit, is essential, because all other approaches did not lead to a complete understanding of the design.

F. Najmon had investigated two brass rulers of the Stradivari workshop and had stated a possible measuring unit of 18.66 mm, but he also mentioned the Roman oncia, being very close to this value (18.55 to 18.6). Also a parchment, showing the design of a Stradivari violin and some concentrical circles distanced each by 18,6 mm was found and taken into consideration. Therefore this unit was chosen for further investigations. Later a method to construct the violin based on the Roman oncia was developed and compared with the measurements of original Cremonese and Brescian instruments.

2. The Roman Oncia

The understanding of Italian metrology is quite complex, many different local units for different materials were existing and various subdivisions in palmo (hand), piede (foot) and braccio (arm) were common. For Rome, or more specifically, the Vatican City State, 3 to 4 different sizes were existing. Namely, palmo romano architettonico, was used for all normal measurements of objects, buildings and woodwork. Thus:

Canna architettonico = 2.2319 m, divided in 10 palmo architettonico, then each divided in12 oncia, then divided in 120 decimo.

The Roman oncia in the 18th century is thus, a unit corresponding to 18.62 mm. The palmo romano is documented in many drawings and plans of architecture, for instance, in the construction of St. Peters Cathedral in Rome, and it varies between 223 -225 mm. Due to the historical variations of this unit (18.58-18.75mm), for this study, a value of 18.66 mm for the Roman oncia was chosen, based on the studies of F. Najmon. He indicates that this value was the most probable size for a unit, due to the brass rulers of A. Stradivari he had investigated. The Roman oncia will be abbreviated with the sign [″].

3. Material and Method

3.1 Material

- Photographs: Thirty-eight photographs of violins, violas and violoncellos of high quality were scaled and calibrated to the exact measurements. Furthermore, the pictures were adjusted to take into account the geometrical distortion of the camera´s objective. This was necessary in order to discover a possible geometrical design.

- Drawings, templates and sketches: Stradivari´s templates published by Sacconi and Pollens [7] were calibrated to their true size and measured with the Roman oncia and compared with our construction.
- Parchment: A parchment of Cozio di Salbue, now owned by the National Museum of Music, showing concentric rings was investigated.
- Rulers of A.Stradivari: Najmon had investigated two brass rulers attributed to the workshop of Stradivari. The rulers are named parziale and perimetrale, from the parziale certain values could be identified and were indicating the use of a unit of 18.66 mm.

3.2 Method of geometrical analysis

Geometrical analysis of the shape of an instrument is based on the idea that luthiers made conscious use of numerical proportion. Unfortunately, the only historical source for instruments is the manuscript of Arnould de Zwolle, but lots of templates and sketches of the Stradivari workshop have survived, showing the use of compass and the construction of the F-holes, but hardly any numbers or pointers remained. Just a few decades after the decline of the Cremonese school, the interest in the constructions of the violin increased, and led to a publication in 1782 by Bagatella. From this point, numerous attempts to understand the design of the violin were published, some of them oversimplifying the topic, others complicating it. Some authors are doubting the use of compass in designing the outline of the violin, e.g. Stewart Pollens, but the recent work of Francois Denis shows a way to construct these shapes, mainly using proportions, which is quite persuading. Several points in his construction are perfectly matched to our new approach, too.

3.3 New approach to geometrical analysis

Following the ideas of H. Heyde and K. Coates [8] for the construction of stringed instruments, many different types of instruments could be successfully analyzed, so the same approach was applied to violins: The violin does not reveal such an obvious construction system, therefore, it was necessary to find the measuring unit, to understand the design. More than that, a constructional system should be found which is clear, logical and not too complicated for the application in a luthiers workshop and should be supported by historical facts.

After choosing a unit of 18.66 mm for our research, first the maximum width of the violin was investigated, because this is often the starting point of a construction. The Roman oncia successfully fitted into the standard width of most of the Cremonese violins 11 times (11x18.6 = 204.6 mm).

The length of the instrument can be constructed in two ways, for instance, placing two equilateral triangles of 11 inches, one above the other. This gives a length of 19.2 inches or 356 mm, or simply choosing 19 units. (353mm) But the relationship between the numbers did not fully reveal itself, until a completely, new system of construction, using concentric circles, was applied. From the geometrical center of the instrument, circles in distances of exactly one oncia spacing were drawn. Consequently, all necessary reference points (such as maximum width of upper and lower bout, waist, position of the bridge) for the construction and the radii of the contour, can now easily be deduced.

3.4 Method of analyzing photographs and templates

Initially, photographs of violins or violas were calibrated to their true size, and were transferred into autoCAD, a software used for technical drawing. Then, whole or half number Roman oncia radii (for instance 3,5", 4", 5") were applied to the outline. Tolerances of 0.5 mm were allowed and the deviation was documented in percentages. The distance of the centers of the radii defining the lower or upper bout, and the body stop or the distance of the bridge from the geometrical center, was measured. Finally, the distance of the centerline of the lower F-holes to the center was documented, because this line was visible in all sketches of A. Stradivari, regarding the construction of F-holes. The used radii were drawn over the picture of the analyzed violin. Templates of A. Stradivari and the parchment of Cozio di Salabue were also calibrated to their true size and visible compass marks and measurements were compared to the Roman oncia.

4. Results and discussion

I. The width of the observed violins fits into a whole number schedule. The mean value of 32 violins is 10,95", being very close to 11", the difference of 0.05" represents 0.93mm and can be explained by the shrinking of wood or is caused by the working process.

II. The length of the violin is observed to be 19". Although there are several violins measuring 19,5" the average of all violins is exactly 19.0".

III. The main reference points of the violin shape could be constructed in the following manner: The maximum width of the upper bout is constructed by using the vertex of a 6"circle, the lower bout is manifested by drawing a horizontal line to the vertex of a 5,5" circle, the narrowest point of the violin is 1" from the center. The radii forming the upper and lower bout, are in most cases, 3,5" and 4" or, a combination of both.

IV. Mensur (body stop) could be detected in the first few steps of the construction. Different from most other constructions, the position of the bridge or body stop is found very easily, being in 16 cases exactly one oncia from the center, and in four others cases 0.9" from the center. The mean value is 0.9"

V. A step by step construction for the violin was developed. It could be seen that the main values stay relatively the same, only small variations in the construction of the corners from different types of violins could be seen.

VI. The difference between the value Najmon had stated (18.66 mm) and the Roman oncia of the 18th century (18.62 mm) can be, in our opinion, omitted. In relation to the maximum width of a violin, 11", the difference is 205.26 - 204.82= 0.44 mm and lies within the boundaries of shrinkage and craftsmanship.

VII. The construction of the F-holes could be explained by using the quintization, giving the distance of the line, as seen on the templates of Stradivari, from the center to the lower F-hole, 42 mm. The F-holes of Jakob Stainer are very different (only 34 to 37 mm) than those of Cremonese luthiers. Nevertheless, the mean value of all violins is 40.6 mm.

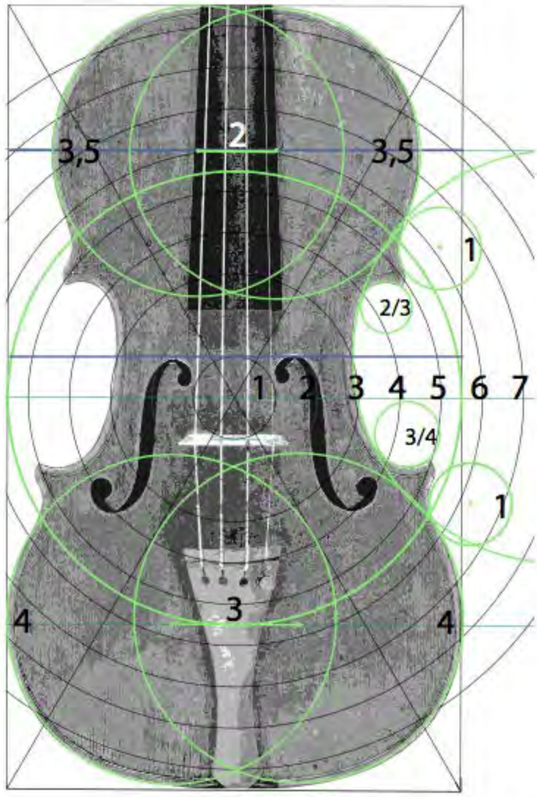

Fig.1 Geometrical analysis of the „Gibson" violin, A. Stradivari, 1713, Cremona, private collection, all measurements in Roman oncia [9].

VIII. The application of the Roman oncia could be found directly on various templates of A.Stradivari. The distances of the centers of the circles for the volute template are 1" and 1.33". The radii used for the scroll of a violoncello are 2.5" and 3.5", the marks of the compass in the middle section of the neck template, probably the width of the neck, is 4". The diameter for the sound hole of a guitar is 3", just to mention but a few examples.

IX. The parchment attributed to Cozio di Salabue, shows three concentrical rings at a distance of 18.5, 19.0 and 18.6 mm from each other, not from the geometrical center, but from the position of the sound post and bass bar.

X. The use of the Roman oncia could be observed in several Brescian instruments. These findings are beyond the scope of this paper and will be presented in another publication.

5.Conclusion

The possible usage of the Roman oncia could be identified in most instruments of the Cremonese luthiers, namely Andrea Amati, Brothers Amati, Nicoló Amati, Antonio Stradivari, Andrea Guaranieri, Guarnieri del Gesú, and others like Jakob Stainer, from

Tyrol and Paolo Maggini from Brescia. The preference of whole numbers for the total width and length of the violin is evident, since the mean value of 32 violins is 10.95" for the width and 19.0" for the length.
On several other items such as a parchment from Cozio di Salbue and templates from Stradivari, circles using whole number Roman oncia could be found.The likely usage of the Roman oncia was also noted in the Brescian instruments, but this topic will need further investigation.

Acknowledgement

The author gratefully thanks the students of the luthiers school in Hallstatt, especially Daniel Bierdümpfl, Hanna Haslinger, Markus Knoll, Mariella Schöngruber, Johannes Mayer, Sebastian Gabler and Bernhard Fischer for their incredible amount of patience and their passionate support and interest.

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Modal Analysis Illuminates the History of the Soundpost

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Abstract

One of the most interesting episodes in the history of Western musical instruments is the extremely rapid evolution of the violin from its renaissance ancestors. The high efficiency of low frequency sound radiation of the modern violin is clearly due to deliberate left/right asymmetry. Without this asymmetry, the left/right antisymmetric modes are easily excited, but they are poor sound radiators; whereas the main volume-change (monopole radiating) shape requires vertical excitation. Looking at the relevant iconography suggests that before the mid 1500s bowed string instruments would have been unlikely to benefit from a soundpost because the requisite features had not yet evolved. We might hypothesise a rather slow development from the late 1400s in which these features first appeared and then became more common, though not all of them in the same instrument at the same time. It was only when all of these were well known to the makers that the final phase could take place. It seems likely that awareness of the benefits of left/right asymmetry preceded the use of the soundpost, possibly by some decades.

1. Introduction

Many violin corpora without neck or soundpost but with bass bar have been analysed. The results have been compared with finite element models and the agreement between the two is good. This state yields data that is more amenable to modal analysis than when the neck/fingerboard and tailpiece substructures are present and is arguably somewhat like a viola da braccio. A surprising feature is that pairs of left/right symmetric and antisymmetric modes occur very close in frequency and can often appear to be a single resonance; therefore a multi-degree of freedom curve-fitting operation is usually needed to identify them. [Fig 1 & 2] The degree of frequency separation varies from one instrument to another. In some instances the pairs of modes co-exist and retain their unique mode shapes but in others we find strong coupling. The conditions for mode coupling to exist are proximity in frequency and shared symmetry. Alternatively, we could say that breaking the symmetry of either mode, by any kind of perturbation of stiffness or mass distribution, leads to them having enough motion in common such that they become a mixture of the two original mode shapes. [Fig 3] When there is coupling we observe that each of the new perturbed pair has a greater or lesser component of the other mode, and in extremis both mode shapes differ only in the phase relationship of the component motions. This suggests that a propensity for coupling of the left/right symmetric "breathing" mode to the antisymmetric modes is intrinsic to the structure and could have been a behaviour observed by makers and musicians as new design features were tried.

2. Crucial design features

Violin outlines are octaform with deep C bouts and extended corners. This outline has more function than making room for the bow. One consequence of using arched plates is that their perimeter expands and contracts only once in each cycle of the breathing mode whereas a flat plate contracts twice. This leads to a strong coupling of the top and back plates and a mode with a large volume change component. This outline shape permits elastic behaviour at the perimeter which could not happen for a lute-like outline. In addition, it is conducive to a rotational motion of the whole C bout areas with twisting of the ribs in the upper and lower bouts. We find a transverse antisymmetric version of this in what is often called the CBR mode and a symmetric version in lengthwise corpus bending. Significantly, the coupled pairs of modes are a mixture of these two forms of corpus bending with corpus "breathing".

The violin's pair of elongated sound-holes (f-holes) creates a partially detached region in the middle of the corpus where the bridge is located. Violin tops, being made of spruce, have lower crosswise flexural wave velocity and a transverse dipole mode at a lower frequency than the longitudinal dipole. It has antinodes near the bridge feet and maximum amplitude at the f-hole wing tips. It is at the same time a means of allowing high input admittance (rotational) and a danger zone for wolf-notes and other minimum bow-force problems.

3. Iconography

The instruments most immediately related to the violin are viola da braccio and lyra da braccio played on the arm, shoulder or possibly supported with a strap as for a guitar. Consistent feature for the late 15th and early 16th centuries are flat soundboards, carved ribs, a low bridge with little curvature, minimal waist indentation and bridge placed far away from sound-holes: in fact, barely different from the plucked viola da mano or the Spanish vihuela. As time progresses we start to see outlines with more pronounced C bouts, bent tops and occasionally a bridge between two elongated sound-holes. The earliest known depiction of a soundboard carved with arching along and across the length (of a viola da gamba) appears to be Raphael's "The Ecstacy of St. Cecilia", 1516-1517 (approx.) An anonymous fresco from Ferrara guessed to be from between 1500 and 1510 shows a viola da braccio with deep C bouts and possibly a carved soundboard. Both have the bridge located below the sound-holes. The San Zaccaria altarpiece, Giovanni Bellini, 1505 clearly shows a large instrument on the shoulder with only slightly indented C bouts but with the bridge between the sound-holes. There are probably many other examples that have not yet come to the attention of researchers. Thus there is no sudden transition to a new violin-like design. The significant features come and go in the iconography but are more consistently present towards the middle of the 16th century. Even if carved soundboards originate from 1500 or earlier they are by no means commonplace until the late 1500s.

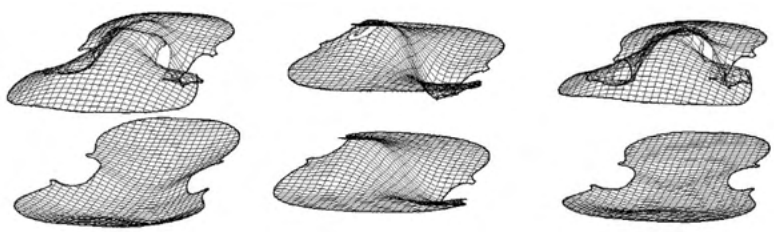

Figure 1: a0 (left), cbr (centre) and b1- (right) - uncoupled modes of corpus without soundpost

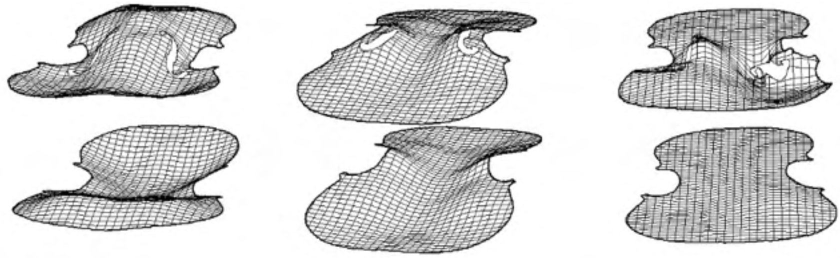

Figure 2: a1 (left), b1+ (centre) and td (right) - uncoupled modes of corpus without soundpost

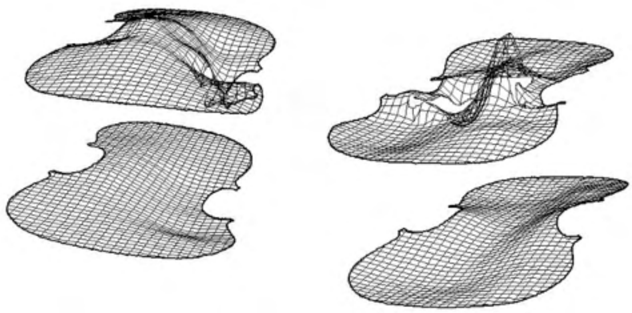

Figure 3: b1- and cbr (left), b1+ and td (right) - coupled modes of corpus without

4. Conclusion

An interesting study and reconstruction of a viol after Silvestro Ganassi provides a precedent for a multi-disciplinary approach to musical instrument history. Two examples are cited of CT scans showing asymmetry in the graduation of top plates, a Ventura Linarol viol and one of the Freiberg instruments. This is a small data set but there may well be more to be found. By the mid 16th century bridges were often placed between sound-holes, perhaps benefiting from the increased admittance and risking a bowing difficulty. Some surviving instruments have rather thick soundboards, some had a central spine and, in the case of Francesco da Linarol, cross bars were used. These could be ways to avoid a bowing problem by lowering the admittance or pushing up the frequency of the transverse dipole to a safer region. They could also help to support the downward force of the bridge. Roughly parallel in time with the development of the violin, gut string technology provided high twist strings that functioned better at low pitches for the same vibrating length. This could be evidence that musicians sought stronger low frequency response from their instruments, or more obliquely, when they heard it they were ready to make use of it. An argument that cannot be casually dismissed is that the soundpost was an accidental discovery: one day someone jammed a stick inside an instrument to fix a sinking top, as one might prop up a sagging roof. However, without the other technological developments and a musical receptiveness it might have been an isolated experiment.

Acknowledgement

The authors gratefully acknowledge the support of Professor Jim Woodhouse and Professor Colin Gough.

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Methodologies and Tools for Characterising Stringed Musical Instruments in the Maker's Workshop

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Abstract

The goal of the paper is to present a methodology for the analysis and synthesis of guitars and violins, based on a hybrid approach. Such tools are designed as decision-support tools for the instrument maker by providing acoustic features during the manufacturing or the fine adjustment process of a stringed instrument. The proposed approach is based on a High Resolution analysis of the impulse response at the bridge permitting the identification of modal parameters of the body. A hybrid sound synthesis is then used in which the body vibrations are described by measured bridge admittances and the string vibrations are described analytically. All tools are gathered in a platform called PAFI (Plateforme d'Aide à la Facture Instrumentale, Music instrument making support platform) including online post-processings, a low cost bridge admittance measurement system and a musical instrument database.

1. Introduction

The engineers and the researchers in acoustics can nowadays propose many sophisticated tools to characterize complex mechanical systems (by identifying modal characteristics of a vibrating structure), to characterize materials (by measuring mechanical modulus), to analyze musical sounds (by proposing tools for processing and representing sound signals). Such techniques can help the instrument maker by providing decision support tools. However, adapting characterisation techniques to the specific context of a workshop is a real challenge: a collaborative approach involving makers and acousticians has permitted the development of a software and a hardware platform called PAFI-lab and Pafi-box Music Instrument making support platform. The created tools are available online and also collaborative.

The case of Santoor is rather different. Artisans normally purchase the cut, dried wood plate, and rarely do any kind of pretreatment before starting to work on the wood. They however have very specific ideas about the quality of the perfect wood for instrument making. This is a combination of cutting, direction of fibers, aesthetic features and internal criteria based on experience.

2. Methodology

2.1 Modal identification using High resolution technique and hybrid modelling

Considering that the free oscillations of an instrument can be modeled as a sum of damped sinusoidal components and white noise, the analysis of such a signal can be efficiently done by using the High resolution technique Esprit (Estimation of Signal

Parameters via Rotational Invariance Technique) [1]. This method overcomes the Fourier resolution limitation and is known to be efficient for identifying modal components even when the modal overlap is important. The main difficulty of such a method is the estimation of the order of the model, which is generally unknown. This can be done using the Ester Criterion (Estimation of Error) based on the assessment of the rotational invariance property [1,2]. Two applications of such an approach are proposed.

- When applied on the impulse response at the bridge of a guitar or a violin, the Esprit/Ester technique can be used to extract modal parameters: frequency, damping and modal shape at the coupling point. These modal parameters are used in an hybrid approach whose principle is as follows: the string vibrations can be efficiently represented by analytical modal models [3]. The body vibrations are more complicated to model in detail, even with Finite Element method since the body is a complex assembly of wood pieces whose mechanical parameters are not easily known and are depending on many environmental conditions. In order to circumvert this difficulty, impulse response at the coupling point is measured, and the modal parameters at the coupling point are identified in order to feed a model of a string/boby coupled system based on a substructuring approach. Such a model is called hybrid because the description of the strings and their excitation is semi-analytical and the description of the soundbody is performed using experimental data. Application of this approach has been developped in the case of the 10 strings brazilian guitar, called viola Caipira [4] and for the violin [5].
- When applied on the response of a guitar plucked by the finger of a musician (ie the measured acceleration at the bridge or the radiated acoustic pressure), the Esprit/Ester procedure can be used to distinguish between the string and body modes (see paragraph 2.2) and thus to investigate some acoustic features of the body [6].

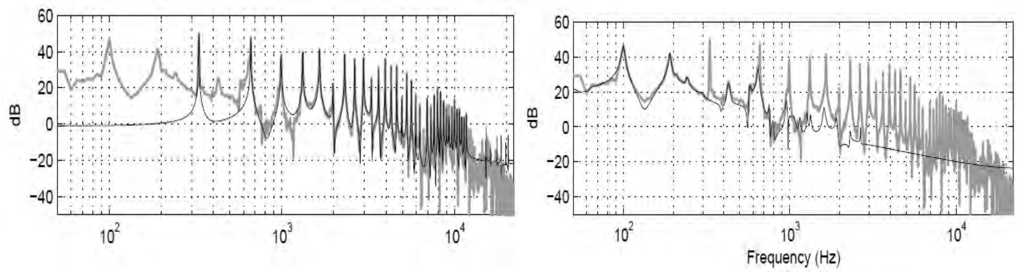
2.2 Analysis-synthesis of the transient phase of plucked instruments sounds

The sound of a plucked instrument is the sum of quasi harmonic contributions, due to the string modes coupled to the body, as well as some transient and quickly decaying inharmonic components reflecting the excitation of the body modes of the instrument. After the identification of modal parameters from Esprit/Ester analysis, a mode selection, based on the damping level is used to separate string modes contributions and body mode contributions. Emergence of inharmonic components due to the body (also called body sound, shown in fig.1b) contributes to the signature of the instrument. It can clearly be heard that the synthetised body sound varies from one instrument to another, which suggests that this feature of the transient phase can have a perceptual relevance for categorizing the instruments.

3. New tools and online platform for musical instrument making

3.1 PafiLab

PAFIlab is a software platform for instruments makers including sounds analysis, modal analysis tools, sound synthesis using hybrid models, access to a database of measurements on stringed instruments, access to pedagogical documents concerning acoustics of musical instruments. The ergonomy of the system is designed in order to take into account the context of the instrument's maker (Fig. 2).



(a) (b)

Figure 1: (a) spectrum of a plucked guitar sound (thick line) and string-sound component only (thin line). (b) spectrum of the same plucked guitar sound (thick line) and body-sound component (thin line), from [6].

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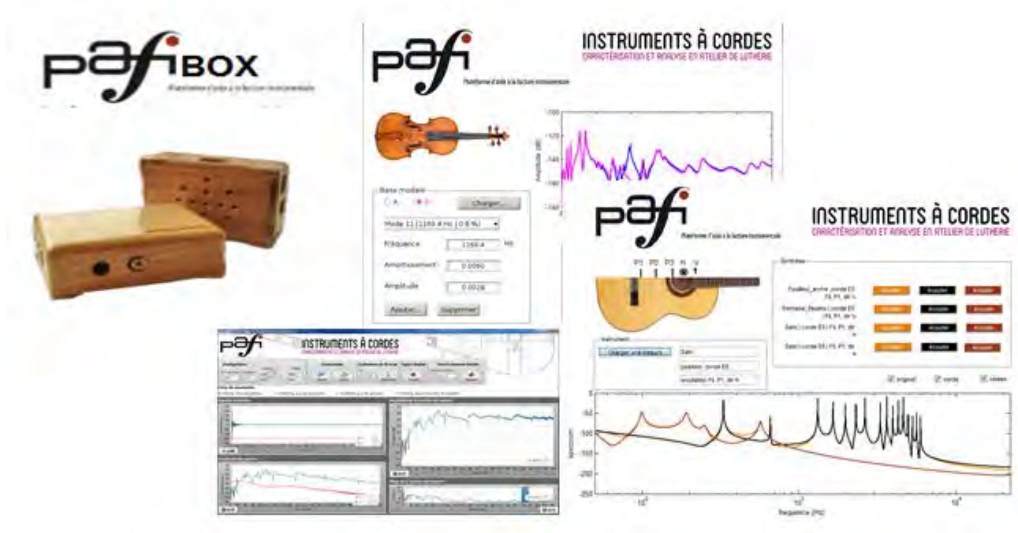

Figure 2: Pafi system http://pafi.univ-lemans.fr/

4.2 Pafibox

PAFIBOX is the hardware kit associated to this system. It gathers an acquisition system along with sensors (accelerometers & microphone) allowing vibration and sound measurements. Bridge mechanical admittances are usually measured by using the impact hammer technique. A low cost alternative measurement technique consist in using the wire breaking technique [7]: all strings of the instrument being damped with paper or foam, a thin copper wire is rolled around a string at the bridge coupling points. Pulling the wire quickly until it breaks produces a step force excitation of the body. Since the acceleration resulting from this step force is proportional to the velocity which would be produced by a Dirac excitation, the velocity impulse response can be computed from the acceleration measured the bridge. This technique is a simple and low cost way to get the bridge impulse response. The bridge admittance is then computed by applying a Fourier transform and a calibration procedure.

5. Conclusions

The hybrid modelling of stringed instrument permits a sound synthesis mixing analytical representation of the string vibrations and experimental data describing the body at the coupling point. Such a method can be used as decision-support tools for the instrument maker by providing acoustic features during the manufacturing or the tuning process of an instrument. PAFIlab is a software platform designed for the maker, gathering tools for analysis and hybrid synthesis. PAFI-box is the hardware measurement kit associated to this system. It is planned that PAFI-lab will be available online at early 2017. It has a moderate cost and is associated with protocols which are robust and easy to set up. Using those tools involves to take part in a collaborative process with makers, researchers, museums and to access to training courses so that makers and users can share their experience on those new processes

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The Industrialisation of the Early Pedal Harp: Detecting Evidence on Wood and Metal

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Abstract

This paper presents and analyses new details concerning the industrialisation of early pedal harps by focusing on a double-action harp by Erard in the collection of musical instruments of the Deutsches Museum, Munich. Using this harp as a case study, and considering similar examples in other collections, the paper provides new information on the manufacture of harps that can be detected on the wooden and metal parts of surviving instruments by combining various methods of scientific examination and organological documentation. The first results from this examination presented here concentrate on previously unknown aspects of the decoration on Erard harps.

1. Introduction

Around the end of the eighteenth and the beginning of the nineteenth centuries, the pedal harp became as popular as the pianoforte in Europe. This was largely the result of the pedal harp's technical and visual upgrading, which turned it into a prestigious 'state-of-the-art' instrument for both amateur and professional performers. As evidenced by the many patents granted for the harp during this time [14], a large number of instrument makers, musicians and inventors worked intensively to improve the instrument's design and function [6, 2]. Through these experiments the harp was gradually transformed into a mechanically, acoustically, and aesthetically innovative instrument whose production reflected, above all, the increasing industrialisation of the musical instrument-making business. This development consequently assisted the harp's integration as a standardised consumer product in the fashionable lifestyle of the contemporary society and also enabled its establishment in the modern orchestra [10, 5].

2. Harp Industry: The Example of Erard

One of the leading figures behind this process was Sébastien Erard, a tireless inventor and one of the most prolific and influential manufacturers of pianos and harps in Paris and London [1]. Like pianos, pedals harps by Erard were complex and expensive instruments whose construction was carried out in large manufactories employing division of labour. For example, in London during the 1810s Erard employed about 60 workers involved in harp production [9], while in 1831 his manufactory of pianos and harps in Paris comprised 19 different workshops occupying 80 craftsmen [7]. On the other hand, Erard is known to have relied also on external suppliers and subcontractors particularly for the decoration of his instruments [11]. However, this significant topic, which could shed more light on the networking and collaboration between various professions involved in the production of musical instruments in Erard's time, has not been researched sufficiently until now.

3. Case Study

3.1 History and Provenance

The focus of this paper is a double-action harp by Erard made in London in 1818 with serial number 2631, in the Deutsches Museum, Munich (Inv. No.: 16147), hereafter referred to as DMO 16147 (figure 1). According to the surviving Erard ledgers in the Royal College of Music, London, the harp was completed on 30 November 1818 and was then sold to the firm of Chappell & Co. at 124 New Bond Street on 18 January 1819. From the correspondence in the archives of the Deutsches Museum it is known that the instrument was acquired in 1908 from J. W. Auerbach, an antique dealer in Berlin [12]. Unfortunately, no records regarding the use, condition and possible repair or restoration of the harp have survived before its acquisition by the Deutsches Museum.

Figure 1: Photograph of DMO 16147 during its examination under visible light (photograph by Hans-Joachim Becker © Deutsches Museum).

Figure 2: Photograph of DMO 16147 during its examination under UV-radiation (photograph by Hans-Joachim Becker © Deutsches Museum).

3.2 Description

The harp is a typical example of Erard's London workshop from the early nineteenth century. Due to its elaborate decoration which was inspired by Greek antiquity, this harp became known as the 'Grecian' model. The harp has a black varnish with double and single thin golden framing lines on the sound body, neck and shoulder, as well as with gilded composition ornaments on the pedal box, and the base and capital of the column. However, a distinctive and less discussed aspect of the decoration of Erard harps that can be observed through *lacunaes* on the soundboard of DMO 16147 concerns the use of 'decoupage' and gilded paper. The outer borders of the soundboard bear cut-out paper decorations with gilded and printed stripes with small ornamental neoclassical motifs, supplemented by two female musicians depicted on the left and right of the soundboard's bottom (figure 3). The same technique has been used on the five vertically arranged swell shutters on the back of the body, each adorned with female figures.

Figure 3: Detail of the soundboard of DMO 16147 showing the distinctive 'decoupage' decoration in neoclassical style (photograph by Hans-Joachim Becker © Deutsches Museum).

Decorations made of cut-out printed papers, glued to surfaces and often varnished, were quite popular in the eighteenth century for both amateurs and specialists under the generic term 'decoupage'. 'Decoupage' techniques included *lacca povera*, often imitating chinese lacquer and chinoiserie patterns. The trade with reproduction prints of famous paintings and engravings for 'decoupage' decoration flourished in eighteenth-century Britain [3].

4. Research Aims, Methods and Results

4.1 Aims

The aim of this research, parts of which will be presented in a forthcoming Bachelor thesis, was to achieve a profound knowledge about the original embellishment techniques ('decoupage', gilding, composition ornaments, etc.) applied to this particular instrument and to identify similarities and differences to other harps produced by Erard. With this information, it might be possible to delineate production strategies, such as serial production and reproducibility of decoration in Erard's London workshop. Therefore, a detailed investigation of the decoration and coating history on DMO 16147 was necessary to differentiate original layers and decorations from changes and reworking on the surfaces which have occurred due to material degradation and damage.

4.2 Analytical methods and results

The examination of the harp took place in 2016 at the Deutsches Museum and at the Department of Restoration, Art Technology and Conservation Science, Technical University of Munich. The first step was the macroscopic observation and photographic documentation using VIS and UV-radiation light (figures 1, 2) in order to characterise the stratigraphy of decorative layers. The second step was to select exposed areas of the harp's coating for stereomicroscopical investigation and to take micro samples to prepare them as cross sections in order to verify the stratigraphy (Figure 4).

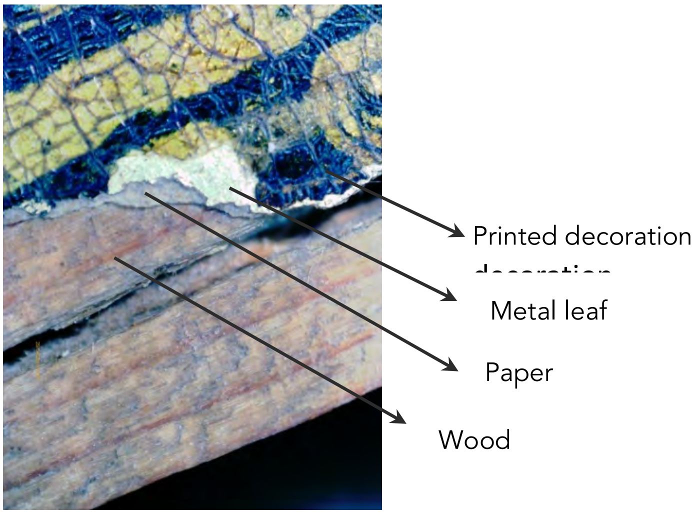

Figure 4: Detail of the 'decoupage' decoration on the soundboard of DMO 16147 during stereomicroscopic inspection (photograph © Luise Richter).

The microscopical inspection of the cross sections provided information about the number, thickness, fluorescence and probable pigments present in the different decorative layers. For instance, micro samples revealing the layer structure of the gilded lines on the body of DMO 16147 were compared to samples taken from a similar Erard harp in a private collection (figures 5, 6).

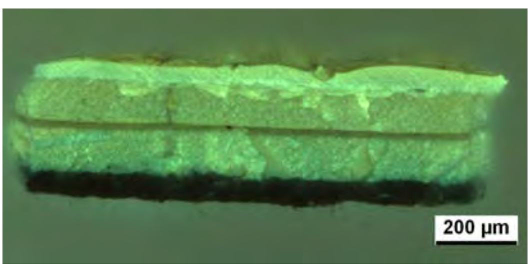

Figure 5: Microscopic photograph of sample from the body of DMO 16147, showing the gilded line embedded in upper and lower layers of varnish (photograph © Luise Richter).

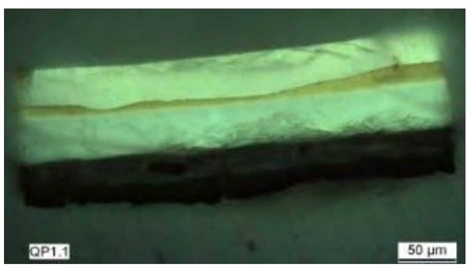

Figure 6: Microscopic photograph of sample from a similar Erard harp (serial No. 3643), showing a similar layer structure as DMO 16147 (photograph © Franziska Bühl).

A further step of investigation was the REM-EDX analysis of cross sections in order to identify the composition of inorganic elements from pigments and metal leaves. Finally FT-IR and Raman spectroscopy was planned to provide complementary information on the composition of binding media and pigments. The results from material analysis were supported by a comparative literature review, focussing on design patterns and production strategies at Erard's workshop [4, 13], and were further confirmed by a study of similar instruments in other collections.

5. Conclusions and Further Research

This on-going research will not only provide a better documentation and contextualisation of the instrument, but will also assist its future conservation and display, particularly because the harp will be exhibited in the future permanent exhibition of musical instruments the Deutsches Museum. Further research will focus on the analysis of the composition ornaments on the pedal box and column of the harp. Additional research could involve non-destructive radiography or CT-scanning in order to examine the internal construction of the soundbox, which is not accessible due to the blocked shutters, as well as of the column containing the pedal mechanism.

Project Information

This research is part of a post-doc research project titled 'A Creative Triangle of Mechanics, Acoustics and Aesthetics: The Early Pedal Harp (1780-1830) as a Symbol of Innovative Transformation', funded by the VolkswagenStiftung (Volkswagen Foundation). For more details see: http://www.deutsches-museum.de/en/research/projects/focal-point-ii/cluster-1/

Acknowledgments

The authors are grateful to the following persons for providing access to and assisting the examination of instruments and archives or for exchanging information on early pedal harps by Erard: Silke Berdux, Anja Kuhlmann, Angela Meincke, Sandra Walter, Alexander Steinbeißer, and Hans-Joachim Becker (Deutsches Museum, Munich), András Varsányi and Sabine Scheibner (Stadtmuseum Munich), Thierry Maniguet (Musée de la musique, Paris), Gabriele Rossi Rognoni, Michael Mullen, and Susana Caldeira (Royal College of Music/Museum of Music, London), Darcy Kuronen and Christine Storti (Museum of Fine Arts, Boston), Roberta Scarzello (Museo dell'Arpa Victor Salvi, Piasco), Mike Baldwin (London Metropolitan University, London), Michael Parfett (Michael Parfett Conservation Studios, London), David Serra (George Jackson Limited, London), Franziska Bühl (Technische Universität München), and Beat Wolf (Schaffhausen). The authors are also grateful to the VolkswagenStiftung (Volkswagen Foundation) for the financial support of this research.

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Ruckers Harpsichords: Specific Acoustic Silhouette?

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Abstract

The idea of this paper is to present the use of the impact testing method to characterize a corpus of non-playable instrument to define an acoustic silhouette. For the study, harpsichords have been compared to distinguish (or not) a specific acoustical behaviour among the Ruckers corpus.

1. Introduction

When we look at a famous painting it is accepted that part of the artist's work has disappeared. The colors have changed, the varnish has been removed and modified, the frame has been updated and sometimes the support itself has been modified. This idea is perhaps less common about musical instruments. According to the international deontology and conservation rules (ICOM) applied to musical instrument collections, very few string instruments are kept in playable condition. Indeed, nowadays, when a musical instrument joins a museum collection it becomes a cultural heritage object that is loaded with a new cultural value in relation to its connection to history, music and culture. However, this implies changes in the criteria that attribute value and interest to the instrument: its historic role and connections, its rarity, the peculiarity of its shape and material may become more relevant than the quality and power of its sound or its usability for concert repertoire. Playing those of these instruments which are in playable conditions or restoring the others to playable state would damage this cultural heritage. Any intervention to return such instruments to playable conditions, however light, automatically requires a modification and/or replacement resulting in the loss of an original part. The functional dimension of the cultural heritage instrument thus seems pushed into the background.

2. Methods

The soundboard is one of the most important elements in the sound production. In most cases it is made of plates of resonance wood (spruce, fir or cypress) of varying thickness glued together over few millimetres on the liner and covered by ribs on the back. The vibrational behaviour of the soundboard depends on its geometry, on its materials and on its boundaries conditions.

Taking into account that the know-how of the maker is to combine the different material properties with the geometry (mainly the thickness of the soundboard), the idea is to survey a quite big corpus using a technique that is independent from the conservation state of the instrument, as much as possible. This will be used to define a vibrational descriptor able to notice different making strategies from an acoustical point of view.

The mobility measurement (MVM), defined as the ratio between the velocity and the force applied on the structure at a given point, could be a good candidate.

To measure the mobility on the instrument, the impact testing method was used. This method is well adapted to our corpus because it is a non-intrusive method.

In other words, the mobility is the ratio between the instrument's response to a known force and the said force. The velocity and the force can be separately measured at the same point or at two different points. The mobility characterizes the capability of the soundboard to vibrate under an excitation imposed to the soundboard. This quantity obviously depends on the instrument and on the measurement points (velocity and force). With this method, a hammer with an appropriate sensor (DYTRAN 5800) is used to apply a known force by impacting the soundboard through the bridge close to every C and F pin. The measured response is the acceleration measured with an accelerometer. Both sensors are connected to an acquisition system OROS34 that will display the Frequency Response Function (ratio between acceleration and force). The figure below gives an example of a measured mobility.

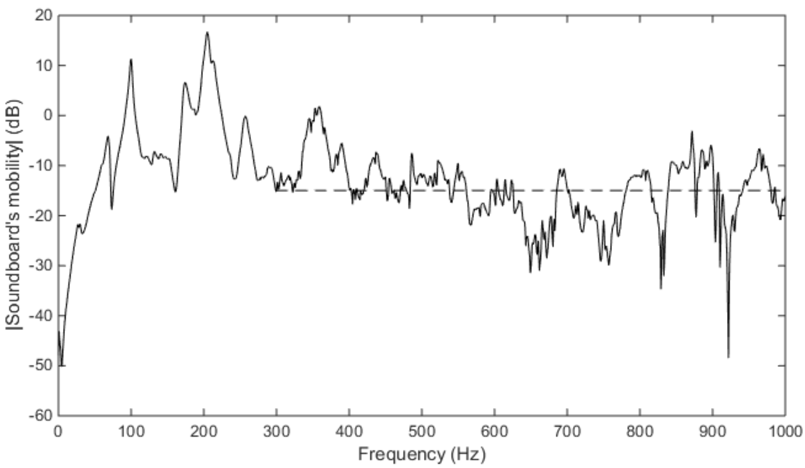

Figure 1: Soundboard mobility at the base of the F-string with Mean-Value of the Mobility in dashed line.

3. Corpus studied

The table below summarizes the harpsichords studied (information comes from G. O'Brien [1] and museum documentation).

4. Results

For every instrument, we obtained two data sets: one for the 8' and another one for the 4'. Each data set contains an average of 8 measurements (one measurement for every C and F impact).

For the instruments made during the XVIIth century, the mvm is relatively flat along the 4' and 8' bridges. Although for the Vater and the Hemsch there is a mvm increase for the middle of the range. Indeed the mvm shows a bell shape centred on measurement 5 which correspond to f1. This result could mean that these two instruments would be

Collection	Inv.	Maker	Date	***Ravallement***	Registers	Keyboard
Musée de la musique	E.1	Ruckers I.	1612	*Grand ravallement*	4' 8'sup 8' inf	FF – f3
MIM	1603	Boni	1619	-	8'	
MIM	0276	Couchet I.	1646	*Grand ravallement*	4' 8' inf 8' sup 8' dogleg	G1/B – f3
Musée de la musique	E.2008.2.1	Vatter	1732	-	4' 8'inf 8' sup	FF – f3
Musée de la musique	E.974.3.1	Hemsch	1761	-	4' 8'inf 8'su	FF – f3
Musée de la musique	E.2003.6.1	Couchet I.	1652	*Ravallement* (XVIII)	4' 8' inf 8' sup	G1/B1 – c3

more powerful in the medium, which is correlated by musicians' observations. Those who regularly play the Hemsch of the Musée de la musique have noticed that the medium radiates more than basses and trembles. Does this mvm shape represent a musical school? While box and keyboards are extended with the grand ravalement, the soundboard is shaped (in addition to be also enlarged) to be more mobile for the middle of the range.

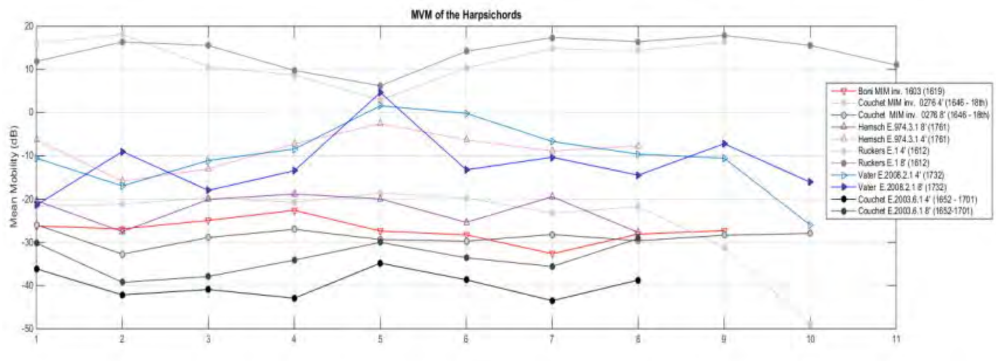

Figure 2: mvm of harpsichords

It is possible to represent the 8' mobility according to the 4' one's (figure 3). The dashed line representes the function mvm 8' = mvm 4'. We can notice that every harpsichord is located close to this line. This means that both mobilities are quite equivalent. This result could demonstrate equilibrium between the 4' and the 8' for every harpsichord of our limited corpus. About this homogeneity, no rupture is observed.

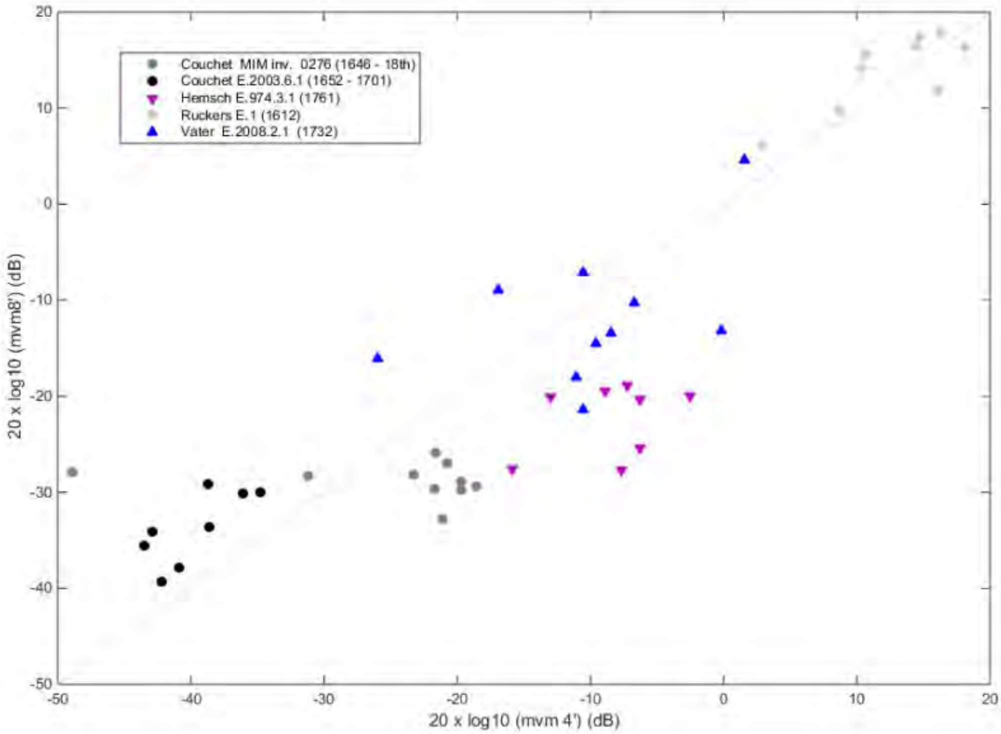

Figure 3: 8' mvm according 4' mvm for harpsichords.

5. Conclusion

It is possible to define an acoustical silhouette which, of course, includes the ageing of the materials and of the structure. The measurement of the mvm on a large corpus has demonstrated some common points but also remarkable differences, two trends have been brought out:

- The instruments produced during the early XVIIth century shows a quite flat mvm along the bridges whereas this measure has a bell shape centred on the middle of the range for instruments dated from the XVIIIth century. This could demonstrate that Vater and Hemsch favoured the middle of the range.
- For every instrument of the studied corpus, the 4' mvm is proportional to the 8' mvm. This means equilibrium in the tone between the 4' and the 8'.

Acknowledgement

The authors gratefully acknowledge the MIM team who has prepared every instruments for this study.

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The Impact of the Second World War on Piano Manufacturing in Britain

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Abstract

By the outbreak of the Second World War, piano manufacturers were accustomed to the rise and fall of the piano market and its vulnerability to economic recession, changes in entertainment outlets, and even to war; but with the British declaration of war on 3 September 1939 the industry would face one of the most difficult times in its history. This period would bring debilitating manufacturing restrictions and then the complete cessation of piano manufacture. The shuttering of the industry was necessary for the war effort as pianos makers had three principal factors that the government needed: manpower, capacity, and raw materials.

Of the materials used in piano production wood was one of the most highly regulated and sought after materials. The need for this material, along with other crucial components, would ultimately bring the industry to a halt. With no pianos to be made, piano manufacturers had to seek out alternative products to manufacture, resulting in an interesting marriage of piano makers and war production. This paper will explore how the limitation of piano production encouraged the industry to explore new types of manufacturing, resulting in the industry being heavily involved in the construction of wooden airplane components. The goal of the paper is to elucidate the Second World War's impact on the British piano industry and the war's lasting effect on piano manufacturing in the United Kingdom.

1. Introduction

By the start of the Second World War the British piano industry had long lost its status as the one of largest manufacturer of pianos in the world. Instead, it was a much smaller industry that consisted of around 40 pianos manufacturers with the majority of makers located in London and two manufacturers located outside of London. Although much reduced from its peak of manufacture in the 19th century, the British piano industry used materials, labour, and factory space, which was essential for the British war effort. In order to force the piano industry to convert to war production, the UK government placed increasing restrictions on piano manufacturing starting in 1939. These restrictions would end piano making altogether by April of 1942 and remain in place until February 1945. With no pianos production, the industry sought out alternative sources of revenue. A natural fit for war production were items that involved skilled woodworking.

2. Mobilisation and the control of raw materials

Prior to the declaration of war Britain's economy was considered semi-mobilized in 1938-1939. During this time, the country was trying to maintain a "business first" type of attitude, with voluntary change to war production and an emphasis on rearmament. With the declaration of war the philosophy of Britain's economy changed and it was made clear that all aspect of manufacturing would be affected.

During the period before the declaration of war, the structure of the overseeing agencies of the wartime economy was organised. For piano manufacturing, two agencies are of the most importance: the Board of Trade, which controlled all areas of manufacturing during the war years and the Ministry of Supply, which controlled the release of raw materials.

Pianos contained a number of materials that were necessary for the war effort. This included timber, brass, iron, copper, lead, steel, and felt. According to the Board of Trade, four of these materials were of the upmost importance: steel, iron, timber and felt. The restriction in the use of these materials were some of the first limitations put on piano manufacturing.

On average it was estimated that a piano used 50 square feet of timber in the construction of the outer case and another 50 square feet for the construction of the internal components including the soundboard, action, and keys. There are a number of types of timber used in the construction of each piano including but not limited to birch, maple or sycamore, beech, mahogany, walnut, spruce, and poplar.

The use of timber was of interest to the Ministry of Supply, which was largest consumer of timber during the war, followed by the Ministry of Aircraft Production and the Air Ministry. The Ministry of Supply was responsible for supplying needs of the military and it needed timber for everything from packing crates to office furniture, tool handles to gun carriages, and rifles stocks to coffins. The Ministry of Aircraft Production needed timber for the construction of aircraft, not only for the bodies of planes such as the Mosquito bomber, but also for the construction of jigs and patterns used in the construction of wood and metal bodies aircraft.

The first limitations placed on the manufacturing of pianos was with the control of timber and felt. The Control of Timber (No. 1) Order went into effect on 1 September 1939 and limited the types of timber available to manufacturers who were not involved in war production. The potential scarcity of materials caused the price of timber to rise 60 percent by October 1939. [1] This control was continuously refined with the ultimate restricting all supplies of timber to the piano industry by August 1941.

Similarly piano felt was highly controlled. Felt parts in pianos included piano hammers and dampers, key bushings, action felt, rail and action cloth, and punchings. Overall there is 2.10 pounds of felt in each piano.[2] By 1 October 1939 the Ministry of Supply controlled all stocks of wool in the country, and by November of that year a strict rationing system was in place which reduced the domestic consumption of wool to 10 percent of pre-war levels.

Steel and iron controls went into effect on 1 April 1940 when all manufacturers had to obtain a license to acquire scrap iron and steel. Obtaining a license was difficult for the piano industry because applications favoured industries that were manufacturing items for the war effort and at the time, the piano industry had no steel or iron related production contracts. The Ministry of Supply was reluctant to grant licenses to piano makers because on average a piano contained 150 lbs of iron used for frames, as well as 4 lbs of high tensile steel wire and 3 1/3 pounds of Siemens-Martin low carbon content mild steel used in tuning pins. High tensile steel was in very short supply and was used not only in the production of the hulls of naval ships and submarines, but also required for balloon barrages, as well as Long Aerial Mines, otherwise known as "piano wire bombs." The need for this materials for the war effort resulted in very little material being allocated to the piano industry.

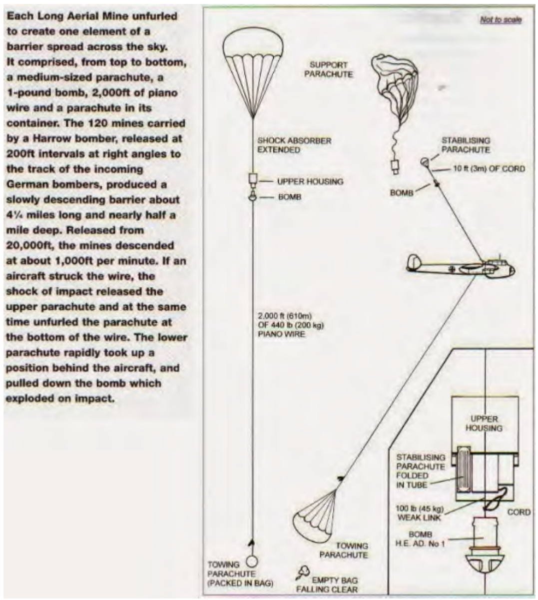


Figure 1. Diagram and description of the Long Aerial Mine.

Although the supply of raw materials was drastically reduced in the first years of the war, this alone did not stop piano production. Many companies had stock piled materials before the start of the war and they were able to continue manufacturing using these stocks. In order to dissuade consumers from purchasing these items and to force the manufacturers to switch to war production, the U.K. government began to heavily tax pianos and then to eventually limit their production.

3. Taxes and Production Limits

Two different tax strands affected piano production and sales. The first was the Excess Profits Tax which by March 1940 put a 100 percent tax on profits in excess of peacetime levels to any profits a company made on non-war related production. The second significant tax levied on piano manufacturers was the Purchase Tax which went into effect in October 1940. The initial tax was set at a flat rate of 33 1/3 percent of the retail value of an item deemed as luxury goods (such as musical instruments) sold in the United Kingdom. The purpose of this tax was to manipulate the buying power of consumers and to collect revenue from purchases that were deemed unnecessary by the government. In April 1942 the purchase tax was increased to 66 2/3 percent and then one year later, in April 1943, the tax was increased to 100 percent. The Purchase Tax was detrimental to the piano industry. Already faced with increased prices because of the Excess Profit Tax, the Purchase Tax made the price of a piano unaffordable to most consumers, resulting in the closure many manufacturing companies.

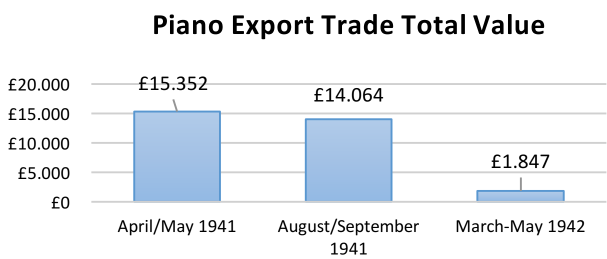
The two final blows dealt to the industry were the Limitation of Supplies Orders and the Concentration of Industry Scheme. The Limitation of Supplies Order restricted the overall quantity of goods manufacturers and wholesalers could sell to retailers. The main objective of the order was to divert raw materials, plant, capacity, and labour from the production of goods for the home trade to the production of goods vital for the war effort. It also granted exemptions for goods that would be sold as export trade as these items brought in needed exchange abroad [3]. The first Limitation of Supply Order, issued on June 1940, restricted musical instruments production to twothirds of the value of instruments manufactured before the war. In November 1940, this restriction was increased to limiting production to 25 percent of prewar levels. In actuality, the Limitation Orders, combined with restrictions on raw materials, caused piano production to fall to only 15 percent of the normal output by January 1941.

The Concentration of Industry scheme was issued in March 1941. The scheme required non-essential industries, such as piano companies, who did not have war contracts to consolidate with more successful manufacturers and then to release unused factory space and workers for essential war work. The purpose of the concentration of industries scheme was to reduce, as far as possible, the number of men and factories involved in the production of non-essential items, so that labour and buildings could become available for urgent production, such as munitions work. This scheme forced many of the smaller firms to shut their factories and move in with their competitors.

4. End of piano production

Although severely limited, pianos were still made in 1941 and early 1942 for export. Instruments made for export were exempt from both the Purchase and Excess Profit Taxes as they brought in much needed revenue into the U.K. The total value of piano production for export was very small, with only £15,352 worth of pianos sold in April/May 1941. Although the export trade brought in much needed money, even this was stopped by the Board of Trade when export licenses were stopped for the piano industry in April 1942. This announcement signalled the end of piano production for the next three years.

Table 1. Compiled export value of the pianos industry [4]



5. War Production

As the war progressed and piano production decreased, piano firms sought alternative sources of revenue. Throughout the Second World War companies had the potential to secure either direct contracts with the government or to work under a firm with a contract as a subcontractor. In general, piano companies who were able to secure any war contracts performed woodworking related tasks. Examples of the types of products piano firms were contracted to manufacture include everything from wooden boxes for ammunitions shipments, rifle stocks, army stretchers, wheels for gun carriages, to furniture. Additional materials may have included coffin manufacture. Additional examples of woodworking contracts include companies that made furniture such as Eavestaff and Supertone.

Figure 2. Occasional table made by Supertone Pianos Ltd., 1945. NT 85153. Photo courtesy of the National Trust.

Airplane component manufacture was another major part of the piano industries' war related work. Piano firms such as Kemble, Stroud, and Alfred Knight were hired as subcontractors by the de Havilland Company to manufacture components for the D.H. 98, also known as the Mosquito, a versatile airplane that was made of an all wood construction.

The use of piano manufacturers in the production of this aircraft was so well known that Herman Göring once said:

> *In 1940 I could at least fly as far as Glasgow in most of my aircraft, but not now! It makes me furious when I see the Mosquito. I turn green and yellow with envy. The British, who can afford aluminium better than we can, knock together a beautiful wooden aircraft that every piano factory over there is building, and they give it a speed which they have now increased yet again. What do you make of that? There is nothing the British do not have. They have the geniuses and we have the nincompoops. After the war is over I'm going to buy a British radio set – then at least I'll own something that has always worked.*

Göring was correct, the Mosquito was a beautiful wooden aircraft and it was the fastest airplane produced at the time. But his description of its manufacture by every piano factory was a hyperbole. A number of piano firms were involved in the manufacture of parts for the Mosquito aircraft, but not every piano factory was building the plane.

The Mosquito was designed by the de Havilland Company independent of any Air Ministry contracts or advice [6]. The innovation of the aircraft was that it utilized an all-wood body made of a 7/16" layer of Balsa wood faced on both sides with 1 ½ mm ply. The outer skin was then covered with an aircraft fabric called Mandapolam that was stretched with dope and then painted. The firm chose wood as the material not because of any technical advantage over metal aircraft construction, but because they would be able to use materials and labour which were not otherwise used in aircraft manufacture. In addition, because the aircraft relied on hand-made wooden construction it reduced to the minimum the number of man hours needed to design and construct jigs reducing the need for specialy equipement or specialists training. This make the aircraft's production attractive to a number of subcontractors, especially those in the woodworking industry which were having difficulty in finding war production contracts [7].

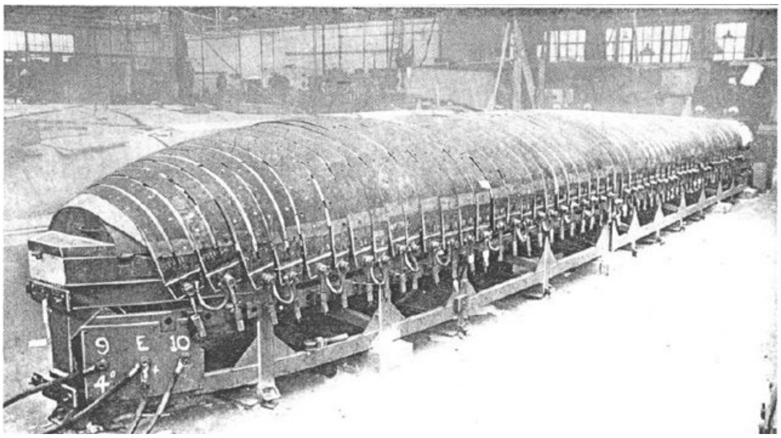


Figure 3. A jig for the fuselage mould of a Mosquito aircraft. Thin layers of wood would be moulded to the form of the jig. The metal strips would then be placed over the wood to hold it in place as it was shaped to the form of the aircraft.

It was noted in an article from the *Times* in 1942 that de Havilland had over 400 furniture and woodworking factories, large and small, working as subcontractors making parts for the bombers [8]. Piano makers had experience in constructing multiple ply components as well as bending wood. The firms had factory space and workman ready trained in woodworking. In addition, many piano firms did not have primary war production contracts and were in need of work. Becoming a subcontractor for the supply of airplane parts was of mutual benefit for both the piano firms and for de Havilland.

Figure 4. Mosquito Bomber. Courtesy of the National Archives. AIR 20/2284

One company that received extensive war contracts was Kemble pianos. According to Denzil Jacobs, former manager of Kemble, the company was the largest manufacturer of pianos in Britain at the time and employed over 150 men at the start of the war, most of whom were wood workers and polishers. At the start of the war Kemble approached the aircraft industry for contracts and was granted a trial order from de Havillian Company for wooden parts. The trial order was deemed satisfactory and production increased. By 1941 the entire factory had been converted to airplane production.

6. Reconversion and resumption of the piano trade

When the war finally ended, piano manufacturing slowly returned. Stalling the process was the reconversion process. Factories taken over by other companies had to be put back together and often repaired from war damage. In addition, material restrictions and taxes continued to have a negative impact on the industry. In the post war years piano manufacturers had to content with the 100% Purchase Tax for new instrument sold within England. Interestingly, instruments sold outside of England, were not subject to this tax, so piano manufacturers exported all new pianos. They were generally sent to the imperial preference locations such Australia, India, and South Africa, but also sold to the Netherlands, Thailand and Scotland. In England, second hand pianos were only available. The restriction on domestic sales continued until July 1949. At this time, companies were allowed to sell 15% of their total production at home at a fixed price which was approved by the Board of Trade.

In general, the piano companies that received extensive war contracts such as Kemble were able to recover from the war more quickly. These companies had maintained their factory space during the war and were in a more stable position than companies which had to completely stop production. That said, the post war years were incredibly difficult on the entire industry and some companies, such as Marshall and Sons Ltd., decided not to re-start production and instead sold their business.

After the last restrictions ended in 1949, the British piano industry was able to resumed full production. Although government restrictions had been lifted, the industry never fully recovered from the impact of the war. Many companies were not able compete with the growing global market, particularly imports from Japan, while others were so crippled by having to close their factories during the war years that they never fully recovered. After the war the British piano industry continued to decline, and it never regained a prominent place in the piano market.

Acknowledgements

The authors gratefully acknowledges the staff at the National Archives, Surrey History Centre, and Hackney archives for their assistance in sourcing documentary evidence, the organizers of WoodMusICK COST Action FP1302, the staff of the Museu de la Música of Barcelona, MIMEd, and Jonathan Santa Maria Bouquet.

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WoodMusICK (WOODen MUSical Instrument Conservation and Knowledge) FP1302 COST Action aims to combine forces and to foster research on wooden musical instruments in order to preserve and develop the dissemination of knowledge on musical instruments in Europe through inter disciplinary research. This program involves curators and conservators on the one side, wood scientists, chemists and acousticians on the other side, and finally, researchers in organology and making of instruments.

The main objective of this COST Action is to improve the conservation of our wooden musical instruments heritage by increasing interaction and synergy between wood scientists and other professionals (including instrument makers) applying wood science, curator, organologists and makers towards the study, conservation and restoration of wooden instrument collections of artistic or historic interest, and to offer a novel and reliable, independent and global knowledge on these collections.

This Conference aims to enhance the cooperation among makers, museums, scholars, and scientists to increase the basic and general knowledge of how wooden musical instruments work, and also how working together can improve this knowledge.

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