Some aspects of the research in the Laboratory of the Musée de la Musique, Paris Cité de la musique

by Stéphane Vaiedelich

Art and technology meet at the Musée de la Musique à Paris. The paper covers some aspects of the research carried out in the laboratory of the museum and focuses on the work of the science team for the study and conservation of musical instruments, both in terms of preventive and curative conservation of the collection museum.

The Musée de la Musique houses a collection of close to 5000 instruments covering a time period stretching over about four centuries and coming from all continents. It has a research and restoration laboratory that combines applied research dedicated to the study and conservation of musical instruments while also providing services linked to the collection. The activity of the laboratory falls within the scope of the study of the material and cultural object represented by the musical instrument and the values its legacy is leaving.

The research conducted there has a concrete application in the conception and implementation of the conservation choices regarding the Musée's collection: pre-emptive or curative conservation, presentation of works of art as part of different exhibitions, and obviously the maintenance of their working order.

A material commodity as much as a sonorous object, the musical instrument is both a piece of art and an everyday object, a complex compound of several materials, which has a musical functionality. This immaterial dimension of past and present music conveyed by the actual objects is what makes them singular works of art and inspires research directly connected to the study or conservation of their functionality.

The scientific team of the Musée consists of 9 people, some of whom work part time. Three of them carry out the responsibilities of curators. The laboratory's team includes a doctor of chemistry, a doctor of physics, a scientific and technical expert, and three curator-restorers, one of whom is exclusively assigned to maintaining keyboard instruments in working order. The team possesses investigation and analytical equipment that allows it to conduct in situ exams in terms of observation (microscope, ultraviolet) as well as elementary analysis (X-ray fluorescence) or mechanical characterisation (modal analysis in real time). Today, this team is part of networks made up of national and international partners with which it carries out numerous research projects.

The collection generates daily tasks related to its legacy and intended to ensure the conservation to satisfactory standards of the works of art exhibited in the museum as items in reserve: monitoring the climate, providing technical loan management and pro-active involvement in campaigns for the semi-annual temporary exhibitions.

The monitoring of the exhibition condition conducted by the laboratory particularly focuses on controlling the climate and dust level of the work of arts, which is favoured by the urban environment in which the Cité de la Musique was built. A large part of the collection of keyboard instruments and harps, some of which are maintained in working condition, is on public display. This calls for particular attention as monitoring the hygrometric conditions is of utmost importance.

Fig. 1 - Permanent collection, 18th century space, Musée de la musique.
The J. Couchet E.2003.6.1 harpsichord from the permanent collection of the Musée de la musique is not displayed in a glass case. This attractive presentation is appreciated by the public, though it requires great care in climate and dust control.
Photo : A. Borel, © Cité de la Musique

The laboratory also provides for control of the collection's sanitary state. If the presence of mushrooms and mould is not really a concern considering the general condition of conservation, the presence of wood-boring insects is a permanent threat particularly in the exhibition areas. As soon as a suspicion of infestation is detected by the presence of insects in the traps throughout the museum, active anoxic debugging campaigns ensue. In order to use these treatments wisely, the laboratory has recently developed a technique using ultrasonic methods of identification of insects inside the wood, which is in the process of being patented. Efficient and suited for these objects of national value because it is completely non-invasive, this new technique allows us to detect the actual presence of larvae from all wood-boring insect species inside the material.

Fig. 2 - In situ detection of an infestation
The ATAX System (Analyse des Traces Acoustiques de Xylophages - analyses of acoustical traces of xylophage) can easily be adapted to several types of wooden objects. The micro sensor is fixed by a completely reversible interface. Signal processing can be performed post-acquisition. The data analysis can be performed in the laboratory, easing the intervention on the object.
Photo : S. Leconte© Cité de la Musique

In addition to its pre-emptive conservation action, the laboratory is responsible for the interventions performed on the works of art. It thus conducts numerous restorations on the entire corpus each year. These interventions are founded on a deontology that is now widely accepted and relayed on the international level through the setting up of CIMCIM, a committee of ICOM (International Council of Museums) that includes the majority of the most prestigious museums of musical instruments worldwide. These restoration campaigns are often correlated to temporary exhibitions or the renewing of permanent ones.
When creating a display is their goal, their main features

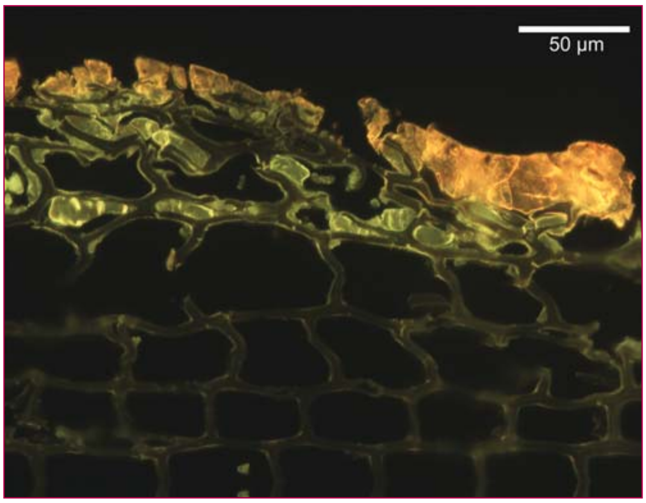

Fig. 3 - Stratigraphy of a varnish
Stratigraphy of a varnish and top wood cells from the soundboard of A.Stradivarys' "Proviginy" violin, 1716, Cremona E.1730.1 collection of the Musée de la musique, Paris.
From bottom to top: cellular structure of the wood, typical of conifers; first (white) oil-based layer impregnated in the wood; upper layer (yellow-orange), a mixture of oil and pine resin containing red pigments.
Photo : J.-P. Echard © Cité de la Musique

are connected to the composite character represented by the musical instruments. Indeed, it is not rare to see, within the same instrument, animal matters (glue, ivory, gelatine, viscera, horn, etc), vegetal matters (wood, liana, resin and natural rubber) or mineral matters such as stones or metals combined. This complex assembling often provides favourable conditions for the rapid deterioration of some materials. This is particularly true of some metals, as soon as they are in contact with wood. This is what happens to the weights added to the keys of keyboard instruments in order to tune them. Confined in an environment with an acid pH, it decomposes rapidly while creating sulphates in the process. Occupying a greater volume than the metal from which they come from, they cause irreversible cracks in the parts that require a conservation intervention.
Beyond these tasks related to the conservation of this cultural heritage, the laboratory also conducts several research projects seeking a better understanding of the musical instruments in a systemic approach that associates matters, structures, and historical contexts.

STUDYING VARNISHES AND COATING

The question of the coating of musical instruments is a vast issue because almost all instruments' bodies are covered with protective coatings. Considering the stakes and myths attached to them, the quartet instruments and especially the violin family take on a singular character. Until the end of the 18th century, there is no known historical source, whether from stringed-instrument makers or observers who had direct access to their craftsmanship, that precisely describe the materials, tools and processes used to varnish instruments. However, a sketch of the technical context of the coating practices in Europe during that era, particularly the coating composition, can be drawn from indirect bibliographic sources. From a general point of view, it seems that the development of alcohol- and petrol-based coating and the abandonment of oil-based coating constituted a technical rupture in the middle of the 18th century. From the early 19th century onwards, many stringed-instrument makers and research workers are forced to speculate regarding the coating technique of ancient Italian stringed-instrument makers, whose instruments are perceived as far better than the contemporary production at the time.
Faced with the stakes of the conservation and restoration of these bodies, the laboratory makes it a point to define a methodology of physical-chemical analysis dedicated to the most comprehensive characterisation of ancient varnish of musical instruments[1]. We have offered a sequence of analytical techniques that maximises the quantity of data obtained (both on the stratigraphic structure and the organic and inorganic composition) and that appropriately matches the thickness scale of the varnishes and the quantities of matter available for this analysis. We were able to apply this methodology to a wide corpus rather than to one instrument at a time. Directed by the Musée de la Musique[2], a multi-disciplinary team was brought together to work on this issue. Minuscule fragments of varnish have been taken from these instruments in order to be analysed with infrared microspectrometry at the LC2RMF (Laboratoire du Centre de Recherche et de Restauration des Musées de France) and on the SMIS beamline of the Synchrotron SOLEIL, with Raman microspectrometry at the LADIR (Laboratoire de Dynamique, Interactions et Réactivité, sous la tutelle de l'Université Pierre et Marie Curie et du CNRS), with scanning electron microscopy at the Institute for Analytical Sciences in Dortmund, and with gas chromatography coupled to mass spectrometry at the CRCC (Centre de Recherche sur la Conservation des Collections).

Beyond the concomitant results and recent development in progress at the museum, this research has shown that the varnish of five of Stradivarius's instruments all have two similar layers of organic composition. The lower layer features drying oil. The upper layer is an oil-based varnish, a mix of drying oil and Pinaceae resin.
A common practice in Europe, adding resin to oil is the basis of numerous varnish recipes used during the period of the instruments under study. Such a varnish is sometimes referred to as "amber varnish."
Moreover, red pigments (iron oxides, vermillion, Cochineal lacquer), also used in easel paints, have been found in the upper layer of the varnish of four instruments. According to their composition and pigment concentration, these varnishes are to be connected to the transparent layer of paint in easel paints. They attest to Antonio Stradivarius's intention to colour his instruments during the varnishing phase and thus to bestow it with a decisive role in the visual appearance of the instrument.
In addition to these works, a systematic analysis of numerous recipes and treaties has been carried out. This documented information is precious for the entire scientific community as well as for contemporary instrument makers, and it has been centralised in a public database hosted on the Cité de la Musique's website. This "VERNIX" database presently includes over four hundred varnish recipes stretching over 2 centuries.

FUNCTIONAL MODALITIES, GESTURES, STRUCTURES

Musical instruments hold a function and the Musée de la Musique when it is both technically feasible and ethically acceptable, maintains the collection's instruments in working order. This conservation choice does not apply to all corpuses. Thus, woodwind instruments, clarinets, oboes and snake flutes for example, will not be affected. Indeed, the breath of the musician, whose average temperature is 30° C and which is loaded with nearly 100% relative humidity, causes an internal constraint that is incompatible with sustainable conservation. Indeed, wood, a mechanical sorbent material, if there ever was one, strongly expands under the effect of a hot and humid breath. The inside hygroscopic gradient causes irreparable cracks in the tube, permanently ruining the instrument and preventing us from any subsequent interpretation and analysis of its functional qualities. To overcome this difficulty and offer the best possible approach to the instrument's functional and musical qualities, the laboratory has recently developed non-destructive and non-invasive, acoustic impedance experiments providing understanding of and documentation on a large part of these corpuses' acoustic properties without having to play them.

Fig. 4 - Acoustic impedance experimental setup
Measure of the acoustic impedance of a serpent. The impedance head is placed on the upper extremity of the instrument (on the left of the figure). The acoustic impedance characterizes the "resistance" of the material to the passage of sound. It is defined as the ratio of sound to particle velocity and is frequency dependent.

Offering large quantity of information, these experiments allow us to discover the playing modes, instrument tuning, compatible fingerings, and they also provide information regarding the instrument's state of conservation such as the presence of leaks in the air column for example. In some cases, it is possible to reconstruct the diameters of the instruments' axial canals from the results of these measurements without resorting to direct metrology measurement, which can sometimes be tricky. Essential information that is all at once relevant for musicologists, researchers and makers.
In the case of corpuses of struck, rubbed or plucked string instruments, the main problematic lies in the mechanical constraint that the strings apply on the structure. Indeed, amounting to 30Kg force for a violin whose mass does not exceed 300 grams, this constraint may amount to several hundred kilos or even several tons in the case of pianos. In this case, the laboratory implements several tools and methods of investigation. Of course, prior to applying any pressure to these instruments, a preliminary study is initiated. Among other things, it is based on an external and internal examination of the structure. To do this, the museum uses radiography as a routine examination, which provides invaluable help.
However, visual examination and observation are not sufficient to guarantee the stability of a structure under constraint and the contribution of physics and especially mechanics is essential.
This expertise is properly mastered by the museum and it has multiple applications related to the collection. It provides valuable support in the restoration process. Today, thanks to their high-standard multi-disciplinary training, restorers are attentive to controlling the consequences of their actions on the works from a conservation point of view as much as from their public perception. This essential approach is complex when it comes to measuring the impact of a restoring intervention on the value of this cultural heritage regarding the musical functionality of an instrument. Thus, stabilising fractures in no way guarantees that the structure, the soundboard of a piano or a violin for example, will regain its original vibratory properties. As with any intervention, this one, and particularly its effects on the instrument's vibratory properties, must be documented. Since 2005, the museum has been developing research projects related to this issue and uses calculation and finite element modelling on a regular basis.
Accompanying the restoration of Joannes Couchet's harpsichord, made in Antwerp in 1652, is the first experiment conducted by the museum on this topic. A classified National Treasure acquired in 2001, this harpsichord is in an exceptional organologic state. Originally fitted with a single set of 8 feet, a set of 4 feet and a second keyboard were added in 1701. Interestingly enough, this is the only significant change it has thus far undergone.
This operation, called "restoration implementation," exclusively operated on the instrument's exterior. Therefore, all the structural parts, bars, reinforcements, and the thickness of the soundboard are still well preserved original parts from the 17th century Antwerp workshop. This structural authenticity is one

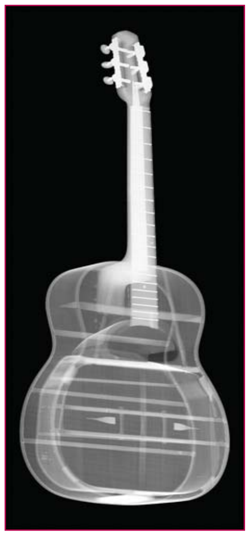

Fig. 5 - Radiography
Radiograph of a "Selmer" jazz guitar. All the internal components are perfectly distinguishable, in particular the double resonator system, patented by Mario Maccaferri who was responsible for the guitar fabrication in the company. A weakness, detached adhesives, or a fracture would be immediately discernible.
Photo : S. Vaidelich© Cité de la Musique

of the reasons why the instrument is still played and recorded today. However, it is also at the origin of the instrument's fragility, and structural reinforcements had to be installed within the harpsichord to enable it to withstand 750 kilograms of pressure applied by the strings. By combining mechanical calculations with the measurements of the vibratory properties through the use of acoustic holographic techniques, it was possible to optimise the number and position of these reinforcements. Thus, the restoration process in respect of deontology is fully reversible.
The reinforcements installed in the structure are not glued together and they maintain the same position simply because of the tension applied by the strings. Stabilising the instrument, the calculation has made it possible to only place three reinforcements in the locations providing the essential mechanical efficiency needed to minimize changes to the vibratory behaviour of the soundboard. Today, it is thus possible to say that the sound produced by the harpsichord is only slightly modified by our intervention.

Fig. 6 - Acoustic holograph of the J. Couchet harpsichord
The microphone grid is placed over the instrument at a precisely known distance. The experimental setup avoids any contact with the instrument and the experimental conditions are easily reproducible. Measures are performed yearly. A difference in the measurements would indicate an evolution of the vibrating structure and would result in a reassessment of the conservation conditions.
Photo: S. Leconte © Cité de la Musique

CONCLUSION

The scientific team of the Musée de la Musique conducts applied research projects that are directly relevant to the field of conservation, knowledge and restoration of musical instruments. The implemented multi-disciplinary perspective applied to musical instruments makes them a unique research focus. Directly applied to the collection of which the museum is responsible, the results and publications of this research are all available online, on the Cité de la Musique's website. Bearing broader issues, this research is often conducted in partnership with other institutions interested in research in the cultural heritage.

NOTE

1 A list of publication related to this topic can be found at www.cite-musique.fr.
2 Under the scientific supervision of Jean-Philippe Echard, Research Engineer at the Musée de la Musique.

ABSTRACT

Experience The Musée de la Musique has a research and restoration laboratory that combines applied research dedicated to the study and conservation of musical instruments while also providing services linked to the collection. The activity of the laboratory falls within the scope of the study of the material and cultural object represented by the musical instrument and the values its legacy is leaving.
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PAROLE CHIAVE

CULTURAL HERITAGE; RESTORATION AND CONSERVATION; X-RAY FLUORESCENCE; RADIOGRAPHY; THE ATAX SYSTEM.

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