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(Article begins on next page)

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Preliminary study for the preservation of two natural horns from the end of the 17th century

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Abstract – **A recent finding at the Castello Sforzesco in Milan of two brass natural horns of the end of the 17th century and assigned to the Haas family from Nuremberg, brought to light new information about this class of objects. The instruments were heavily damaged, but their historical value is great. A multidisciplinary collaboration supported by a scientific non-invasive approach, including stereomicroscopic observations of the surface, X-ray radiography and 3D scanning followed by 3D model creation, was employed to discuss numerous issues concerning the knowledge of the artefacts and their preservation: i) executive techniques for archaeometric purposes; ii) study of the shapes with the aim to reconstruct the original model of the instruments; iii) identification and mapping of the damages and the alterations of the structure and the surface**.

I. INTRODUCTION

In this work, two brass natural horns held in the ethnic collection section of the storage of the Museum of Castello Sforzesco in Milan were investigated. One of the reasons of the extraordinary importance of these objects is due to the makers: two of the most important components of the Haas family which is with no doubt among the most influential one from Nuremberg in Germany, between the 17th and the 18th century. In fact, during this period, the city was the capital of the brass instrument making. Here, several families organized into guilds were exporting the instruments throughout Europe, thus dominating the field for several generations [1-2].

This study tries to demonstrate the strength of using non-invasive techniques for the documentation and the evaluation of the conservation state of historical horns, and in general of brass instruments, held in museum collections. It is also a tool able to offer an essential support to the definition of the best preservation and maintenance practices [3-6]. Although, modern makers tackle to reproduce early brass wind musical instruments with the aim to find their original sound and style; for this purpose, they need to access and measure the executive and decorative details as accurately as possible (e.g. diameters of tubes, depths of sleeve joints or jointing methods) [7]. Moreover, the information regarding the chemical characterization of the material like the composition of the employed metal alloy is also crucial in this perspective since in the brass instruments the alloy can affects the timbre [8-9]. The non-invasive methodology seems to be the most suitable for these purposes, also enabling the documentation to be carried out in the preventive conservation approach and to retrieve plenty of information to be read in the archaeometric frame of reference [10-11].

A preliminary diagnostic campaign was accomplished by the photographic documentation, the stereoscopic observation of the surface details and the X-ray radiography. The campaign analysis has been complemented with the production of two 3D models acquired by a laser scanner. This approach was aimed at (i) investigating the executive techniques, for archaeometric purposes, (ii) documenting dimension and shapes of both musical instruments, (iii) characterizing the damages and the alterations of the structure and the surface.

II. MATERIALS AND METHODS

The instruments involved in the project are shown in Fig. 1. The oldest one (Fig. 1a), cataloguing number *inv.878,* was made by Johann Wilhelm Haas (1649-1723) who represents the most important member of the family; for what concerns the model, it attests the early construction of this horn-type in Nuremberg and it is probably dated back to the late 17th century. The second one (Fig. 1b), cataloguing number *inv.877,* was made by Wolf Wilhelm Haas (1681-1760), the son of Johann, is datable to the '20s of the 18th century.

The photographic documentation under visible light was acquired with a Nikon D4 full-frame digital camera equipped with a 50 mm f.1.4 Nikkor objective using a softbox LED lamp.

The magnification of the surface details was performed with an Olympus stereomicroscope equipped with an Olympus HD DP73 camera. The images were recorded through Stream Essentials software.

To explore the structural features highlighting the joint and the reparations, X-Ray radiographic investigation was carried out by means of an X-Ray generating Industrial Control Machines CP 120B (settings: 110 kV, 1 µA of 100 s exposure time) and a photosensitive radiographic plate Dürr NDT GmbH & Co. scanned with CR35NDT Dürr NDT.

As laser scanner we employed the RS3 Integrated Scanner (a linear laser scanner with a stated accuracy of 30 µm) mounted on a mobile arm with 7 degrees of freedom (Romer Absolute Arm 7-Axis "SI") both produced by Hexagon Metrology. All the 3D data acquisition and elaboration were performed with the PolyWorks Suite and Blender, while the measurements were taken with FreeCad.

III. RESULTS AND DISCUSSION

The horn made by Wolf bears the inscription "MACHT / JOHANN / HAAS / NURNBERG" and the initials "IWH" above a leaping hare turning backwards its head, while the other one by the father Johann, bears the hare keeping its face forwards [12]. The bells and the tubes were detached, some parts were lacking, and the surface suffered from different kinds of alteration.

The structural features help to access the manufacturing processes and to identify the damages and eventually the presence of some reparation or restoration action. X-ray radiography (Fig. 2) showed up, for both the instruments, numerous patches, and cracks: a magnification of some of their visible traces on the external surface have been documented by stereoscopy and showed in Fig. 3a. Moreover, brazing, jointing, and in some cases the accretions found agglomerated on the inner surface of tubes have been highlighted as well. The investigation suggested that the *inv.878* (Fig. 2a) was characterized by a

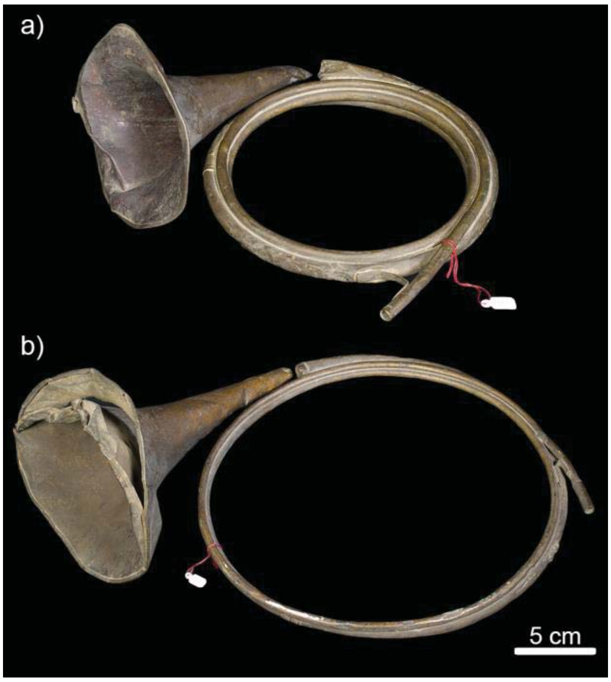

Fig. 1. a) inv.878 by Johann Wilhelm Haas (1649-1723); b) inv.877 by Wolf Wilhelm Haas (1681-1760).

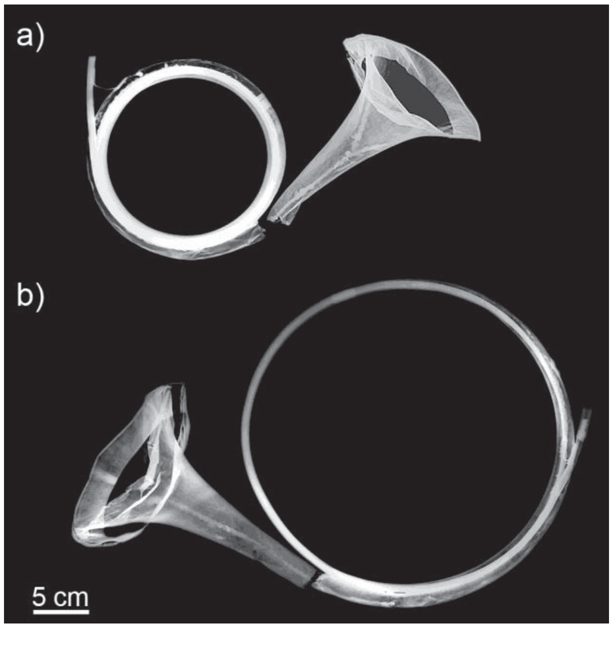

Fig. 2. X-Ray radiography respectively of the inv.878 by Johann Wilhelm Haas (a) and on the inv.877 by Wolf Wilhelm Haas (b).

uniform thickness and by a nipped tooth joint between the edges of the lamina (Fig. 3b).

Two important elements referred to the peculiar executive technique were highlighted for this instrument

by X-Ray radiography: the presence of the "gusset" which is a "V" shaped lamina inserted with a nipped tooth joint generally added to prevent too much stretching of the edge during the hammering and in order to produce a larger bell (Fig. 2a); the difference in the optical density around the ring that divide the tube and that seems to join two laminas of two different thickness. The bell of the *inv.877* could be made of a uniform lamina, thinner than the one of the other bell, characterized by numerous cracks and it recognizable by the unique metal joint (Fig. 2b).
Moreover, the detail of the metal thread shown in Fig. 3c, confirmed a traditional building of the garland that was the standard bell finishing method of early brasses before the industrial revolution. Sheets of brass were cut in a "Y" shape, folded, brazed, and hammered over a mandrel. The garland was then fitted over the edge without soldering. On the outside of the bell, the position of an original support between the bell and the tube is proven by a leftover part [13].

By radiography (Fig.2b), the tube appeared as a single folded element as expected in the traditional executive technique [13]. Also, in this case numerous deformations of the lamina, macroscopic cracks, and areas of soldering and reparations were highlighted. Part of the soldering showed a coarse aspect that could be correlated to later restorations (Fig, 3d).

The stereoscopic examination revealed many chromatic and morphological alterations of the surface. Most of them could be the products of the chemical reaction of the materials with the environment. The deposition of the white dusty and adherent deposits inside the engravings and the punching (Fig. 3e and f) could be the consequences of an inappropriate cleaning of the surface. Finally, the documentation of a superimposed layer characterized by red particles suggests the presence of a surface pigmented treatment (Fig, 3g). In fact, in many cases as a common practice, a varnish was applied to give shine and protection to the metal alloy after polishing the surface [8]. A peculiar aspect of both horns, and more evident in the *inv.878* by J. W. Haas, is also the reddish surface inside the bell, (Fig. 3h) that could be due to a peculiar finishing. In fact, the finishing the inner side of the bell with dull coating or a fine decoration was a common practice as well.

To assist the conservator in the choice of the best preservation and exhibition strategies, faithful 3D models were acquired. It allowed the documentation of the current state of the instruments and also to take non-in contact and repeated measurements without the risk to damage the original pieces, thus opening the opportunity of building replicas that could be used to retrieve the original pitch and sound. The 3D models were acquired adapting to this specific case the protocol defined in our laboratory [14,15]. Due to the specific material and the peculiar surface morphology, this application also gave us the opportunity to highlight some advantages and drawbacks of the technique applied to this specific kind of

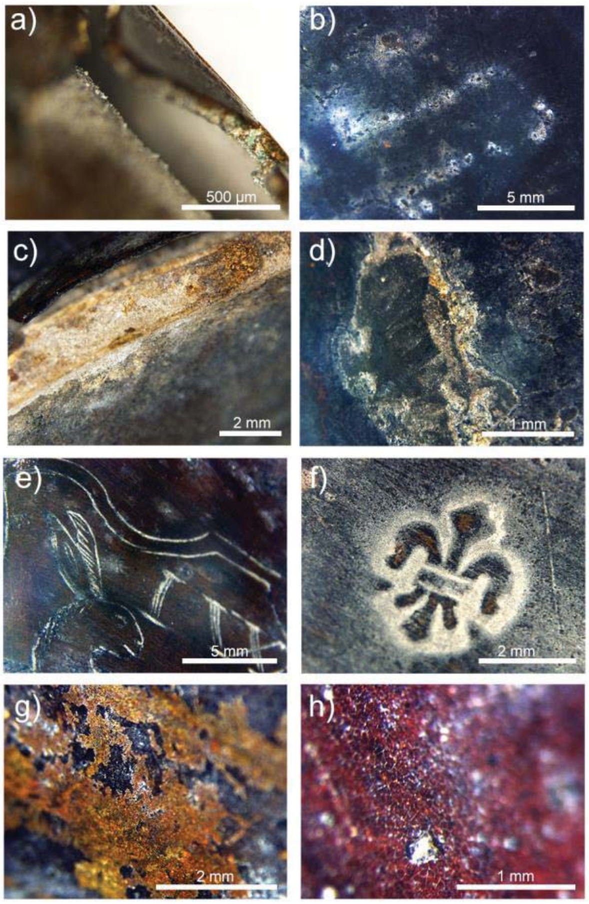

Fig. 3. Details magnification by stereomicroscope: a) crack on the tube (inv. 877); b) nipped tooth joint (inv. 878); c) metal thread in the garland (inv.877); d) reparation (inv.878); e) and f) white dusty leftovers inside the engravings and the punching (inv.877); g) possible leftover treatment on the surface (inv.878); h) reddish surface inside the bell (inv.878).

instruments. The main problems during the acquisition have been represented by the dark areas along the conjunctions of the pipes and the surface deformations. It was observed that these issues can limit the acquisition capabilities of the laser scanner: the first one was the less critical, since the geometries of the pipes are relatively regular and the missing areas could be reconstructed with a high accuracy; the second problem, instead, severely limited the capability of the laser scanner to reach the areas under the deformations. In this case, a manual reconstruction of the partially acquired areas, has been performed. The highly deformed areas did not undergo to the reconstruction process because of the too few data acquired.

Luckily, the strongest deformations were mainly focused on the border of the bells and just in the broken connection

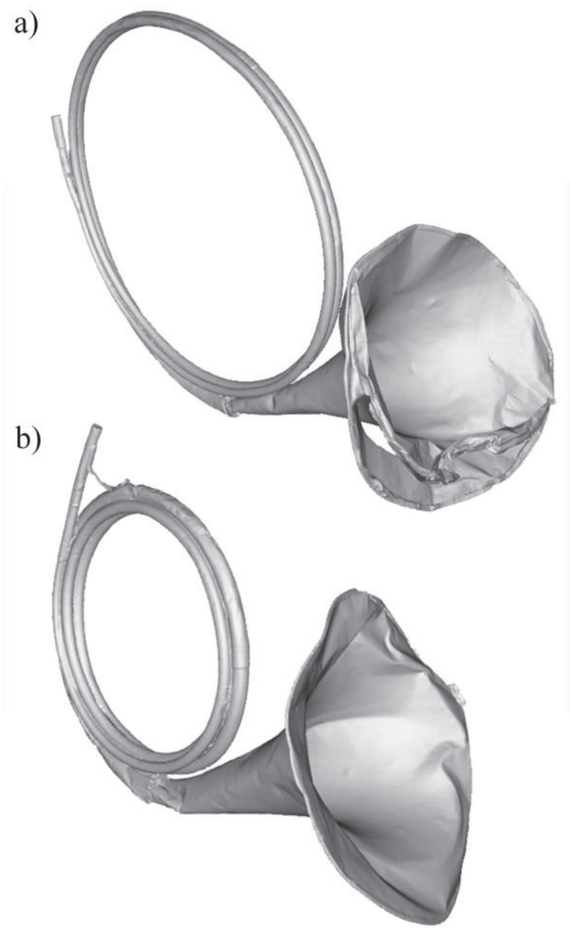

Fig. 4. 3D models of the two horns inv.877 (a) and inv.878 (b).

between the two parts of the horns, while the pipes deformations were not critical for the acquisition. Thus, the 3D models were properly acquired by the laser scanner

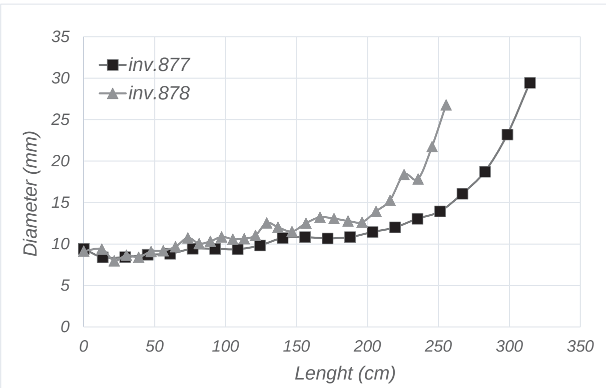

Fig. 5. Plot of the pipe diameters size, from the mouth to the bell, for the two instruments. On the x axis, the length of the tube is reported.

and the comparison to the original horns was useful for taking measurements as distances or diameters (Fig. 4).

Research was primarily focused on the length and the diameter of the pipes. In fact, for the horns the pitch depends on the pipe's length, and the tuning to the shape of the instrument. Tube of *inv.877* is about 3.15 m long and is coiled into two turns. The inside diameter of the pipe coils varies between 378.9 mm and 380.5 mm, while the outside one varies between 398.5 mm and 411.6 mm. The tube of *inv.878* is shorter, only 2.55 m long, but it is characterized by three coils. The internal diameter varies between 199.3 mm and 202.2 mm, while the external one between 240.4 mm and 246.9 mm. Fig. 5 was obtained by the measurements of the diameters along the length of the pipes, acquired by the software, starting from the leadpipe with a regular step of 30 mm. Part of the values are displayed in Table 1. The plot describes a higher variability of the size diameter in the *inv.878* pipe with respect to the pipe of *inv.877*, explained by the presence of greater irregularity and deformations.

Table 1. Main diameters of the tubes (in mm). The showed values have been acquired with a regular step of about 60 mm in length stating by the leadpipe.

Step	*inv877 (mm)*	*inv878 (mm)*
1	8.43	8.66
2	8.84	9.68
3	9.43	10.86
4	9.84	12.55
5	10.83	13.23
6	10.84	13.93
7	12.01	21.74
8	18.73	-
9	29.44	-

As part of the project, we designed an augmented reality (AR) application, for exhibition purposes. The application was developed for Android smartphones, using Unity and the library Vuforia. Augmented and virtual reality (VR) applications are widely known as an effective solution for enhancing the fruition of an exhibition, presenting historical and scientific information in an appealing and interactive way [16]. The current case is particularly suitable to this kind of applications since we have both a faithful 3D models of the instruments and the results of several scientific analyses. To avoid making the application too confusing for the users, we selected a significant sub-sample of data to propose. We used the high-resolution photos acquired for documentation to create the textures to apply to the 3D models. Then, we connected each of them to a specific marker. Fig. 6 shows the graphical user interface of the application as recorded

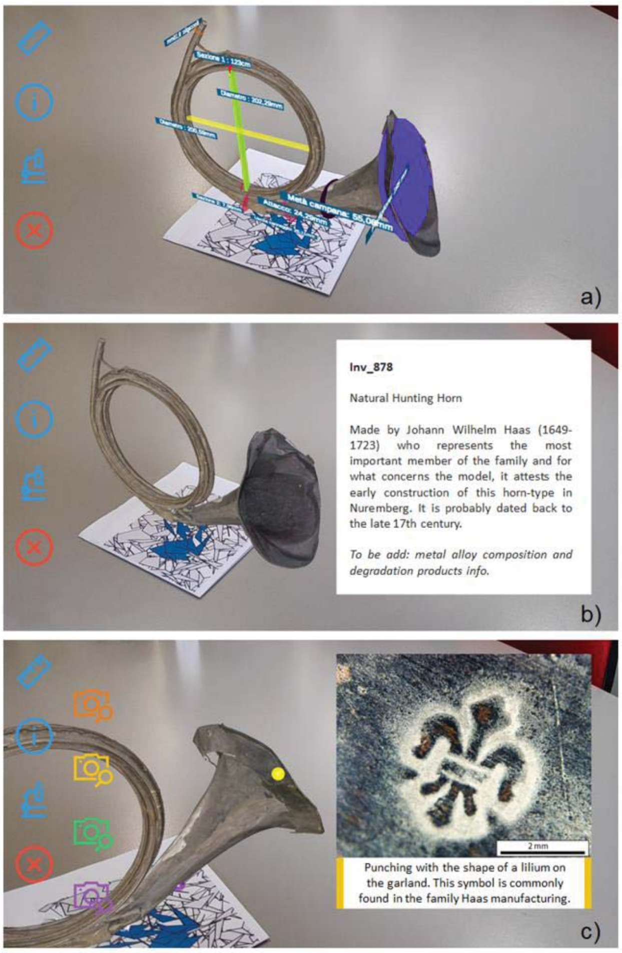

Fig. 6. The AR application: (a) full view of the 3D model of inv878 on its marker, with some significant measures overlapped; (b) information about the chemical composition of the horn; (c) macro with description of a detail of the bell and correspondent position on the 3D model marked by a yellow circle.

on a smartphone. The four controls on the left side of the screen (the ruler, the 'i', the microscope and the 'x') allowed us to show: significant measures on the 3D model (Fig. 6a); historical and chemical information about the horns (Fig. 6b); and macro images of meaningful details (Fig. 6c). In Fig. 6c, a second list of colored icons are shown on the right of the previous one. These camera icons appear after clicking the microscope icon; each of them permits to visualize a specific macro image taken of different spot of the surface of the horn. Moreover, the correspondent areas on the 3D models are marked by small circles of the same color, to be easily identified.

IV. CONCLUSIONS

Starting from the results of the preliminary non-invasive approach, it was possible to map the damages and the fragile areas, besides providing the conservator with some tools to better define the conservation state of the object. At the same time, the investigation of the inner structure and the high magnification of the details allowed for increasing knowledge about the manufacturing of the objects and for giving insight into the traditional practices adopted by one of the most important family of the brass instruments makers with a hint to their evolution during a period of about a century. Furthermore, the high-resolution 3D model enabled us to record and measure the details, the structure, and the morphology in a non-invasive way. The tubes length and diameters were documented with high accuracy to enable the possibility to produce the replicas of the objects. In this way, information about their sound could be retrieved and also new strategies for the exhibition of the instruments and the dissemination of the diagnostic campaign results could be offered. In the perspective in which knowing the object means preserving it for the future, to share the scientific results with the public is an essential step. Now, it is a reliable opportunity thanks to the augmented reality application, able to provide scientific information to the visitors in an appealing and easy way.

To conclude, it is worthy to remember that we are reporting only the results of the preliminary non-invasive campaign showing the valuable information retrieved by this first step. In fact, a non-invasive spectroscopic study is on-going to characterize the metal alloy of the instruments and the traces of the restoration and reparation actions, likewise to answer the questions about the manufacturing, for instance the composition of the reddish surface inside the bells. Moreover, some powder sampled by the corrosion products identified on the surface, will be available for the X-Ray Diffraction (XRD) analysis.

V. ACKNOWLEDGEMENTS

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