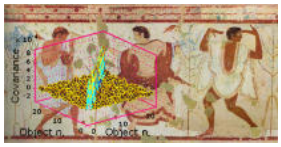

Identification of Precious Artefacts and Stones: The Sonic Imprint

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Abstract

This paper presents a new non-invasive methodology useful to univocally identify 3D rigid and elastic objects, particularly lapideous and ceramic artefacts and stones, by means of retrieving their capabilities to vibrate when stressed by artificial sources. A new instrument has been arranged to apply the methodology to large pieces in situ; it is provided with 16 piezotite sensors (Murata pads, Piezotite non-resonant type, 6CC-10-3R9-1000), while another instrument is being prepared to test the vibrations of small stones, using a triggered tweeter as source and a small laser remote sensor to measure the vibrations of the stones.

Introduction

A new non-invasive test has been already developed for the unique identification and the integrity monitoring of precious artefacts (potteries, statues and, generally, object made of stone, metal or wood) [1, 2]. This test meets the more and more urgent need, in the museum management, of cataloguing that includes the identification of the artefacts and the establishment of their integrity. The trend of the management of cultural heritage towards national or international loan of precious artefacts involves many risks for the artworks (damages, substitutions, physical deterioration, etc.). Furthermore, by now many art exhibitions are itinerant, and consequently the artefacts are constantly subjected to transport and/or displacement.

The general characteristics for the identification of an object, such as its shape, dimension, aspect and texture of the surface, colours of the surface, etc. nowadays using laser technologies, are cloneable: it is possible to obtain quasi-perfect copies of an artefact. Nevertheless, other physical parameters, dependent on internal non-observable properties (chemical composition, atomic structure, internal defects, etc.), are practically impossible to be cloned: for instance the distribution of resistivity, permittivity, dielectric constant, hydraulic permeability, etc. However, the mechanical parameters (density, elastic moduli, damping parameters) are suitable for both the identification of the objects and the monitoring of their integrity: the study of the propagation of the elastic waves in the artefacts allows then the construction of a sort of DNA, called "sonic imprint", that identifies the objects and, eventually, establishes their mechanical consistency (or integrity).

The methodology and tests

For studying the resonance frequencies of an artefact one can generate in it elastic waves by means of a suitable source and then measure the induced free damped oscillations. When the artefacts are large, a source like a gummed hammer or a driven loudspeaker can be used, the measuring devices being small piezoelectric transducers tightly coupled to the surface of the object. When the objects are small or very small (like precious stones) the source can be given by a sonic or ultrasonic emitter (tweeter) and the sensor by a laser sonic remote detector. In every case, the vibrations are closely linked to the geometry of the artefacts and the spatial distribution of their elastic parameters, as well as to the number and distribution of their internal defects. So, the sonic imprint (i.e. the set of main resonance frequencies of the artefact) presents more or less significant changes even in presence of small structural modifications of the object. Actually, any object is characterized by a continuous distribution of vibrational modes and decay times, and then oscillates with an overlap of vibrational modes of different frequencies: the distribution of the frequencies shows resonance picks linked to many parameters (shape, dimensions, elasticity) of the object itself.

A possible deterioration of an handmade artefact, caused by cracks or damages, generates significant variations in its vibrational modes: these variations are simply checkable comparing the sonic imprints acquired before and after the deterioration.

The artworks studied until now are: the Eleonora D'Aragona bust (F. Laurana, 1471), the San Michele Arcangelo statue (Gagini's apprentices, XVI century), the Niobidi Crater (V century b.C.), the pottery Vessel representing Bes, the Bes pottery (IV century b.C., fig. 1), some bronze pieces of A. Ugo and other antique plates and vessels. More recently, some pieces of modern art have been analyzed, e. g. the statues Venus (Portugal pink marble, Sajeva 1994, fig. 2).

The instrument for small size stones is being developed and the very first tests seem to be very encouraging, especially because a large application basin can be opened.

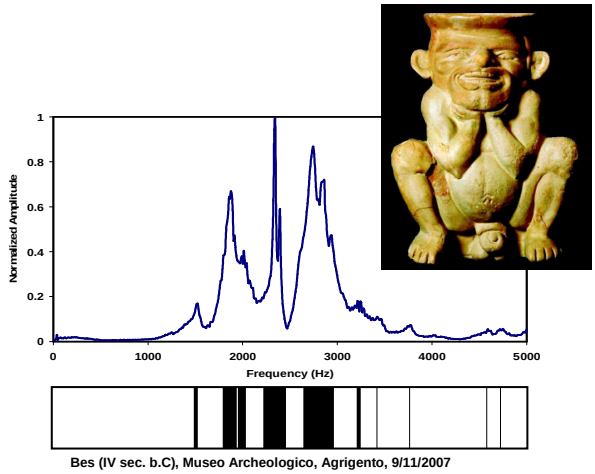

Fig. 1; From top to bottom: Vessel of the Bes God, vibrational spectrum and sonic imprint bar-code.

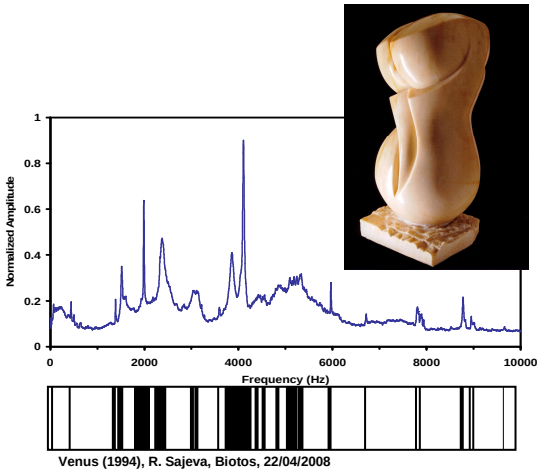

Fig. 2; From top to bottom: Venus of Sajeva, vibrational spectrum and sonic imprint bar-code.

Results and conclusions

The target of the study on handmade and industrial objects was to validate and to standardise the acquisition technique and, in particular, to verify: 1. The repeatability of measurements, in spite of the problems of coupling between sensors and object, the repositioning of the sensors and the small differences in their response; 2. The influence of the support of the object; 3. The capability to discriminate different objects with the same shape, dimensions and constitutive materials; 4. The capability to distinguish the response of an object before and after a crack; 5. The real non-invasivity of the method. Compared analyses of entire and cracked vessels has verified all the above mentioned points. Univocally determinable vibration modes in every point of the surface of the artefacts have been confirmed, though characterized by minor differences depending on the positions of the source and the sensors.

The set of main frequencies of vibrational modes is determined by means of a simple statistical analysis finalized both to delete possible outliers and find robust averaged responses. This give also information about the overall physical-mechanical status of the studied objects.

Preliminary results of the tests, conducted on small stones, are still being studied and they will be hopefully discussed during the oral presentation.

References

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