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CULHER-3064; No. of Pages 9
ARTICLE IN PRESS
Journal of Cultural Heritage xxx (2016) xxx–xxx

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Wooden Musical Instruments Special Issue

Experimental assessment of the effect of an eventual non-invasive intervention on a Torres guitar through vibration testing

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ARTICLE INFO

Article history:
Received 12 March 2015
Accepted 27 April 2016
Available online xxx

Keywords:
Wooden musical instrument
Guitar
Tornavoz
Vibration testing
Frequency domain correlation

ABSTRACT

Guitar FE09 – MDMB 626 is one of the best-known Antonio de Torres instruments and is an excellent sounding example of a guitar with tornavoz. Although the instrument is in playable conditions, the back plate has a deformation and cracks which are undoubtedly the result of the pressure exerted by the tornavoz supports. Over the last hundred years experts have chosen not to have the cracks repaired as it might result in a change in the sound. Recently, professionals stated that the guitar sounded different with strips of masking tape covering the cracks. Although subjective evaluations and claims abound, no quantitative data is available to determine the effect of this modification. This paper provides the results of an experimental campaign aimed at assessing the effect upon the vibration response of this eventual non-invasive intervention. Vibration testing was performed on the top and back plates before and after adhering strips of masking tape along the cracks. The influence of tensioning the strings is also examined. Correlations were done in both modal and frequency domains. The results allow conclusions to be drawn regarding the influence of this simple non-invasive intervention that can lead to audible changes, proving the feasibility of using vibration-based NDT methods for damage or structural modification assessment of musical instruments.

1. Aim

The historical Torres guitar FE09 – MDMB 626 is currently in playable condition, but it presents important deformations and cracks on the back plate. Several experts suggest that the instrument sounds different with a simple non-invasive modification. This work is aimed at assessing the effect upon the vibration response of this eventual intervention by using a vibration-based nondestructive testing method.

2. Introduction

Musical instrument construction is characterised by a great respect towards craftsman heritage and traditional techniques. Indeed, builders of musical instruments are one of the few groups of artisans who are able to resist the move towards automation and serial production. The Industrial Revolution and its accompanying social changes were influential in the demise of guilds and the strict controls over how the artisans operated. This was definitely a time for new ideas and changes, and instrument making was not an exception.

The Spanish guitar suffered significant changes between 1780 and 1850: the sixth string, wound bass strings and fixed metal frets, among others innovations, were introduced, but then has been very resistant to change since that time. As an instrument becomes fixed in its canons and aesthetics, radical changes are less likely to be accepted.

A significant invention in the mid-19th century was the so-called tornavoz, a sound-hole tube[1] for lowering the first mode to improve the low-frequency response of the instrument.[2] Besides

[1] Generally made of brass, but wood or heavy paper are also employed [1].
[2] Invention of the tornavoz is generally attributed to the Spanish guitar-maker Antonio de Torres (1817–1892) since he made the oldest surviving example of a guitar with tornavoz [2,3]. Other authors state that an earlier example made by José Pernas exists [4].

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http://dx.doi.org/10.1016/j.culher.2016.04.011
1296-2074/

Please cite this article in press as: M.A. Pérez, et al., Experimental assessment of the effect of an eventual non-invasive intervention on a Torres guitar through vibration testing, Journal of Cultural Heritage (2016), http://dx.doi.org/10.1016/j.culher.2016.04.011

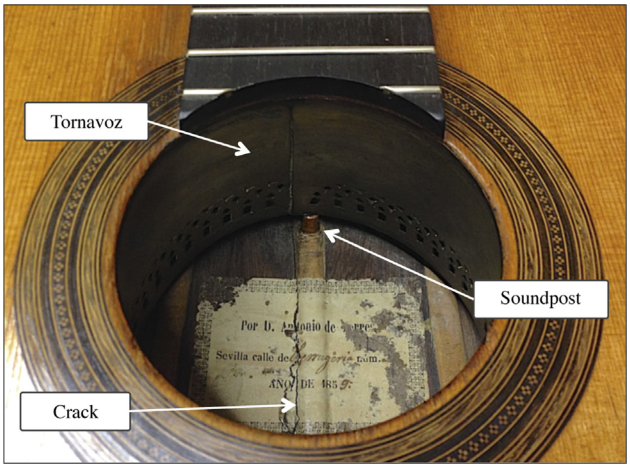

Fig. 1. Detail of the sound-hole of the guitar FE09 – MDMB 626. The tornavoz is supported by wooden soundposts resting on the back. Label: *Por D. Antonio de Torres // Sevilla calle de la Cerragería, núm. 32 // AÑO DE 1859.*

the acoustical purpose, it is known that the tornavoz could have a structural function. In some of conserved the Torres' tornavoz guitars the tornavoz is supported on small blocks which rest on the back (see Fig. 1). A transverse bar which is free of the top or the complete lack of that bar indicates that the tornavoz and its support soundposts were intended to take the place of that supporting bar thereby allowing a larger area of the top to vibrate.

Among the various examples of guitars which have a tornavoz, one of the best-known is the Torres guitar FE09 – MDMB 626 which is the object of study of this paper. This instrument is currently used in concerts and recordings at the Museu de la Música de Barcelona (MDMB). The back of this instrument has a deformation and cracks, which are undoubtedly the result of the pressure exerted by the tornavoz supports (see Fig. 2). If it is accepted that the tornavoz has a positive effect on the acoustics of the instrument, one must also accept that if wedged in between the top and back it has collateral negative effects due to the dilation of metal, the shrinkage of wood and the localised pressure on the supports anchored to the back like the soundpost of a violin. As this particular instrument has great cultural and historical value the priority is obviously the conservation of it. For this reason any decision about its restoration, any change or adjustment which might or might not cause discernible difference in sound should be supported, guided and documented by a reliable and objective test method.

Fig. 2. Back of the Torres guitar FE09 – MDMB 626 with the deformation and cracks as a result of the pressure exerted by the tornavoz supports.

On the occasion of a recent restoration, it was explicitly decided not to repair these cracks for the reasons explained later in the text. However, guitarists and restorers stated that guitar sounded different with strips of masking tape covering the cracks. Although subjective evaluations and claims abound, no comparative data is available to determine the effect of this eventual intervention.

With this in mind, the aim of this research was to experimentally assess the effect upon the vibration response of this eventual non-invasive intervention on the instrument. To that purpose, vibration testing was performed on the top and back plates before and after adhering strips of masking tape covering the cracks. The influence of tensioning the strings was also examined. The results showed that this non-invasive modification causes measurable changes in the vibration response, with different trends between the top and back plate.

In the following section, the mechanical background of the experimental modal analysis performed for modal and frequency domain correlation are briefly presented. Section 4 provides the relevant and available information about the instrument and its historical background. In Section 5 the methodology is described and details and requirements of the experimental test procedures are given. Subsequently, test results are presented, compared and discussed in Section 6. Finally, the conclusions of the study are presented.

3. Modal and frequency domain correlations

Over the years, several nondestructive techniques (NDT) have been used for studying and damage assessment of musical instruments, including electronic holography, laser interferometry, near-field acoustical holography, modal analysis, acoustic radiation, computed tomography and X-ray microtomography, among others, and is still subject of research [5–13]. The principle underlying damage or structural modification assessments using the so-called vibration-based NDT methods, is that vibration response depends on the physical properties of a structure (mass, damping and stiffness); therefore, changes in physical properties due to damage or structural modifications result in detectable variations in the vibration response of the instrument [14–16]. These changes in vibration patterns can be used as an indicator of the degree of affectation.

A considerable number of contributions in the field of vibration-based NDT applied to musical instruments have been made. These methods can be broadly classified into two approaches: model-based methods, i.e., methods that require numerical models [17–22], and response-based methods, i.e., methods that only use experimental data [10,11,23]. The second approach includes methods based on the time domain, frequency domain and modal domain data, the last of which has received the most attention.

Generally these experimental approaches examine modal domain data through modal analysis, in which time domain data are mapped onto the frequency domain. The modal parameters (frequencies, damping and mode shapes) are then extracted from the so-called frequency response functions (FRFs). The structural response $\mathbf{X}(\omega)$ is directly related to the system forcing function $\mathbf{F}(\omega)$ through the quantity $\mathbf{H}(\omega)$ as follows [24]:

$$\mathbf{X}(\omega) = \mathbf{H}(\omega)\mathbf{F}(\omega) \quad (1)$$

where $\mathbf{X}(\omega)$ and $\mathbf{F}(\omega)$ are the N-vectors of Fourier transformed responses and force inputs respectively, ω is the frequency variable and $\mathbf{H}(\omega)$ is the FRFs $N \times N$ matrix, where N is the number of test degrees of freedom (DoFs) of the structure. Due to Maxwell's reciprocity-principle, a row or a column of the $\mathbf{H}(\omega)$ matrix is enough to accurately describe the structural response [24]. In other words, when the response is recorded in a fixed DoF (i.e.

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