Application of Model Updating on the Numerical Model of a Classical Guitar with Identified Parameters from Experimental Modal Analysis

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Abstract

The classical guitar is a popular string instrument in which the sound results from a coupled mechanical process. The oscillation of the plucked strings is transferred through the bridge to the body which acts as an amplifier to radiate the sound of the guitar. In this contribution, a numerical finite element (FE) model of a classical guitar is presented. Alongside the numerical modeling, an experimental modal analysis of the particular modeled guitar is carried out and the identified modal parameters are used in a model updating scheme. The goal of this paper is to present a numerical FE model that approximates the modal behavior of a real guitar well although the material properties are only coarsely known due to the natural variation of wood. The numerical model might be used as virtual prototype to simulate the influence of varying parameters like different bracing patterns or new geometries or to compare different guitars and, thus, give guitar makers better insights in the design process of guitars.

The numerical modeling of a classical guitar yields several challenges. Firstly, the geometry of a classical guitar contains many details that influence the sound and, therefore, have to be modeled with high fidelity. Consequently, the numerical finite element model of the guitar consists not only of the guitar body and the neck of the guitar, but also of the struts to reinforce the soundboard and the back of the guitar are included. The geometry of the FE model is visible in Figure 1.

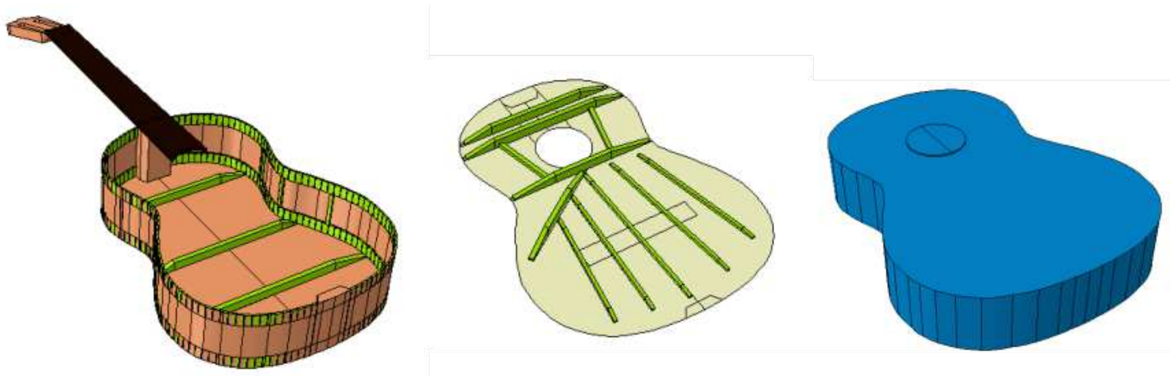

Figure 1: Finite element model of the guitar. The colors visualize the different materials of the guitar and the most right picture displays the simplified air volume inside the guitar.

Secondly, the air volume inside the guitar body influences the oscillation of the structural parts by a significant amount and, therefore, has to be taken into account in a physically precise model [2]. In the presented the model, the air volume inside the guitar is modeled with acoustic finite elements and fluid structure interaction is taken into account. The radiating boundary condition on the soundhole surface is approximated by acoustic infinite elements.

Thirdly, the choice of wood is a crucial part of a guitar makers' work as the sound of the guitar is influenced highly by the material properties and the different parts of a guitar are made of different kinds of wood to create a desired sound [3]. The particular examined guitar is made of five different kinds of wood. Moreover, the material properties of wood are not only anisotropic, but also vary significantly even when comparing multiple trays from the same tree.

In this contribution, the material properties of the examined guitar are taken from literature in a first step and then updated in a model updating scheme making use of experimentally identified modal parameters. Experimentally, the vibration of the guitar is examined by means of an experimental modal analysis. An experimental setup being capable of determining eigenmodes and eigenfrequencies in a high spatial

resolution is presented. For the measurements a scanning laser Doppler vibrometer is used and the guitar is excited via impulses using an electrodynamical shaker.
The experimental modal analysis is carried out using the complex mode indicator function (CMIF) in combination with the enhanced frequency response function (EFRF) and a peak fitting algorithm due to its advantage of making use of the fine spatial resolution of the measurements [1]. This approach yields very good results for the parameter identification as can be seen in Figure 2. The measured mobility and the with the identified modal parameters reconstructed mobility are in very good agreement for a singular point below the bridge on the soundboard. The deviation in the frequency range below 50 Hz is owing to the approximately free support in the experiment and the corresponding rigid body movement of the guitar which is not included in the identified modal model.
Finally, the identified modal parameters are used in a model updating scheme where the material properties are identified through numerical optimization. In an objective function, the eigenfrequencies and eigenmodes of the experimentally examined guitar and the numerical model are compared and the material properties of the numerical model are updated. This procedure makes it possible to identify the only coarsely known material parameters of the different woods used to create the guitar resulting in a good approximation of the experimentally identified eigenmodes and eigenfrequencies by the numerical FE model.

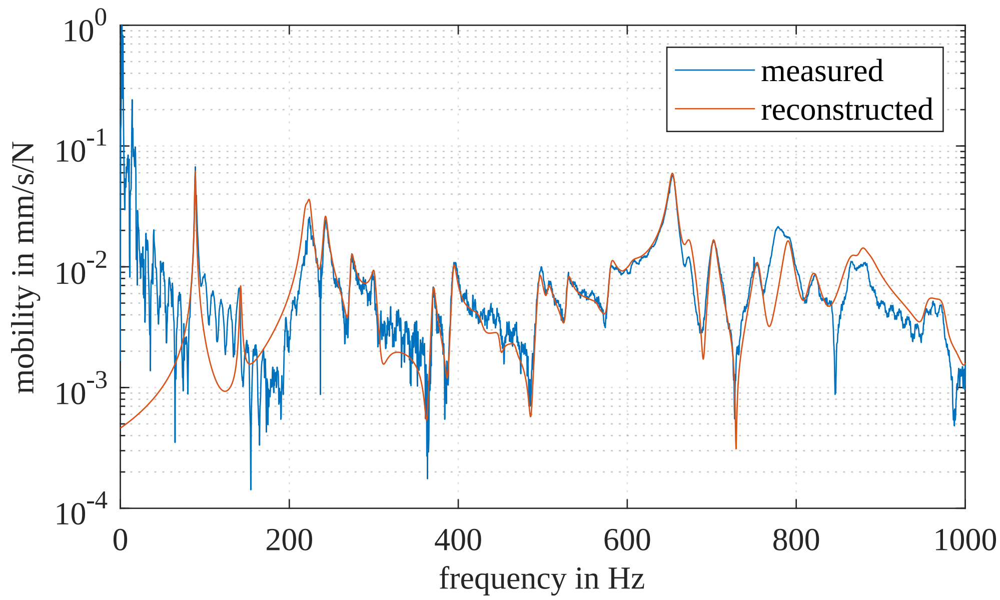

Figure 2: Comparison of measured mobility and mobility reconstructed from an experimental modal analysis for a point on the soundboard below the bridge.

References

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