A Study into the Acoustic and Vibrational Effects of Carbon Fiber Reinforced Plastic as a Sole Manufacturing Material for Acoustic Guitars

Jimmy O'Donnell[1*], Graeme McRobbie[1]
1.University of the West of Scotland, High Street, Paisley, Scotland, PA1 2BE
Corresponding Author: jimmy.odonnell@uws.ac.uk

Introduction: This poster details the use of COMSOL Multiphysics when carrying out an Eigenfrequency analysis on a 3D model of the soundboard of an acoustic guitar constructed solely from Carbon Fiber Reinforced Plastic (CFRP). The guitar has been provided by Alistair Hay of Emerald Guitars, a company based in Ireland who specialise in custom built, high end guitars and who deviate from the traditional inclusion of wood.

Previous work in the area has included the initial investigation of a CFRP plate [1]. This study detailed the physical characteristics of the carbon lay-up used in the manufacturing process through experimental methods. The model of the plate, constructed in COMSOL had, to a high degree of accuracy, an almost identical acoustic response to that which was collected experimentally.

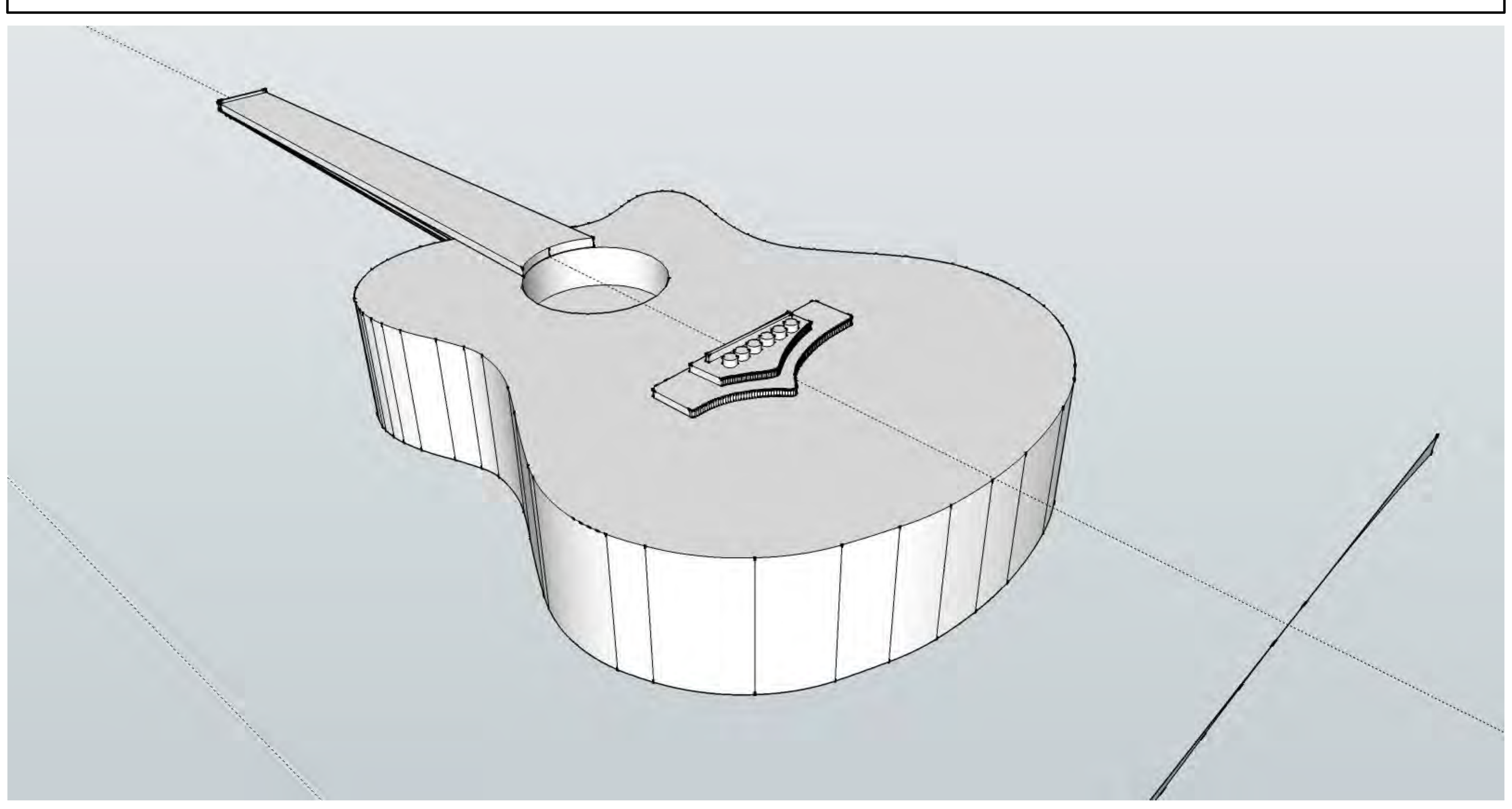

Figure 1: Rendered image of the acoustic guitar from AutoCAD

Model Design: A guitar model [Figure1] has been constructed using AutoCAD. The dimensions of the guitar have been obtained by accurately measuring the outside of the body with a set of large 'outside callipers' through a series of points along the edges and across the length and breadth of the guitar body. Complex curves on the body have been measured with the use of a 255mm profile gauge. The model was saved as a .dwg file and imported into Rhinoceros where the CAD model was then split into 3 separate volumes; soundboard, back and sides. The soundboard and back were then extruded by 3mm and the sides were transferred to polylines joined together so to create only one curve and not a series of lines. This was then extruded by 3mm creating a solid object. The solid was then exported as a .stp and .iges file to ensure the 3D compatibility when importing to COMSOL.

Use of COMSOL: The physical, material characteristics used in this model are the same as those detailed previously by O'Donnell & McRobbie (2011) [1]. Tables 1 and 2 detail these for clarification:

Left: Table 1; Material Contents

Variable	Value	Units
Young's Modulus	1.01e9	Pa
Density	1015	kg/m^3
Poisson's Ratio	0.28	

Below: Table 2;Linear Elastic Material Model

Variable	Value
Anisotropic Loss Factor	0.02

Results: As the purpose of this study is only concerned with the soundboard of the guitar, the boundary settings have been set accordingly. That is, the edges of the soundboard have been fixed in position while only the top and bottom plates of the soundboard are free to vibrate representing a true to life soundboard.

The study has analysed the first 10 Eigen-frequencies of the soundboard and the study settings were 10 desired eigenfrequencies around 100Hz. The relative tolerance of 1.0e-6 has been defined in the general eigenvalue solver configurations and it is felt that this will provide enough detail for this initial study.

Results have been compared to an eigenfrequency analysis carried out on a CFRP rectangular plate of similar dimensions the results are as expected with small discrepancies. Figures 2 - 3 compare the first modes between the soundboard and CFRP plate.

A free tetrahedral mesh was used with a normal element size. The mesh consisted of 14264 elements with a total of 87900 degrees of freedom was used for this study.

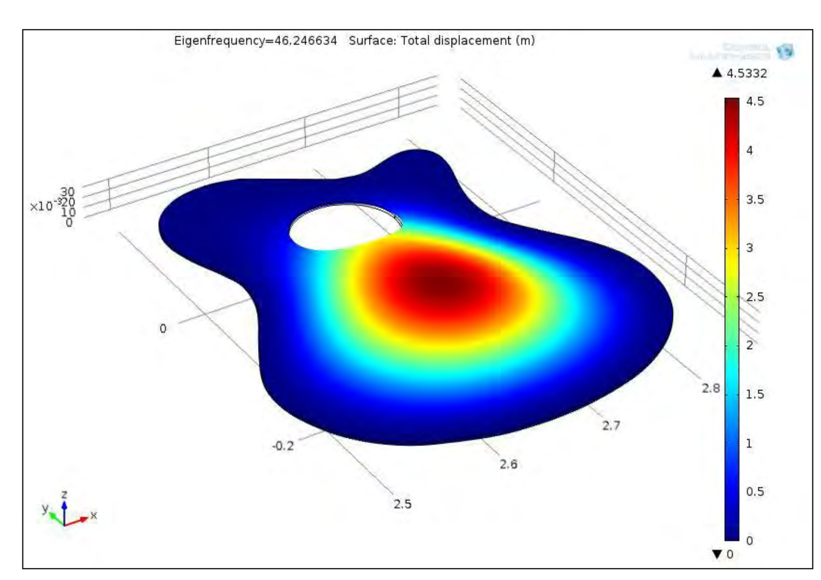

Figure 2: First Eigenfrequency; 1:1 mode.

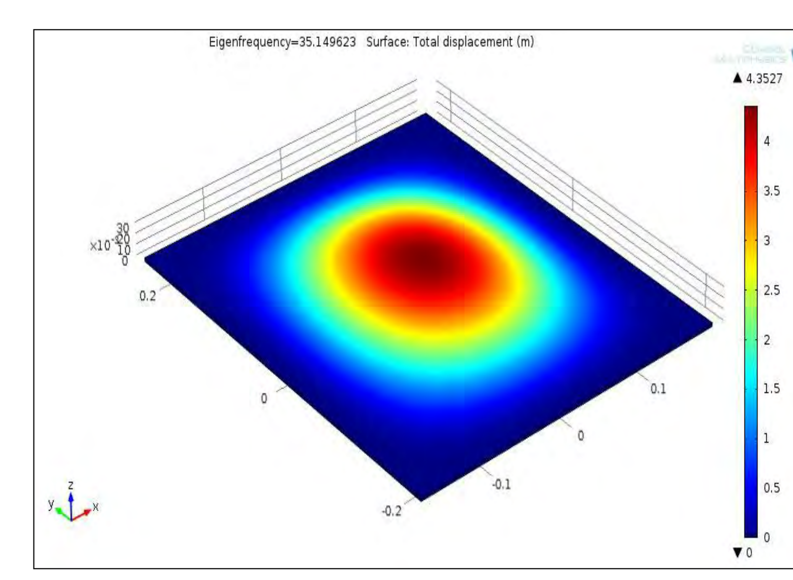

Figure 3: First Plate Eigenfrequency; 1:1 mode.

Conclusion: While the study has only considered the soundboard of the guitar in this instance, more work will be carried out on the impact of the coupling between the remainder of the guitar body, neck and bridge and the effect these have on the modal properties and frequencies at which these occur.

The results have shown that there is a consistent match between early and current studies for each individual Eigenmode. The data gives the author full confidence to carry out further research in this area and to develop and refine techniques.

References:
1. O'Donnell, J.; McRobbie, G, A Study of the Acoustic Response of Carbon Fiber Reinforced Plastic Plates, *Proceedings of the COMSOL Users Conference, Stuttgart* (2011).
2. Caldersmith, G. Guitar as a reflex enclosure. *Journal of the Acoustical Society of America*. **63(5)**, p1566-1575 (1978).
3. Richardson, B. Mode Studies of Plucked Stringed Instruments: Application of Holographic Interferometry. *Proceedings of the Second Vienna Talk, Sept. 19-21, 2010, University of Music and Performing Arts Vienna, Austria*. p129-132 (2010).
4. Sumi, T.; Ono, T. Classical guitar top board design by finite element method modal analysis based on acoustic measurements of guitars of different quality. *Acoustical Science and Technology*. 29 (6), p381-383, (2008).
5. Gorrostiea-Hurtado et al, Vibration analysis in the Design and Construction of an Acoustic Guitar, *International Journal of Physical Sciences*, **7(13)**, 1986-1997, (2012).

COMSOL CONFERENCE BOSTON 2012