Split guitar :
Calculation of the sound pressure field by Boundary Element Method (BEM)

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Summary

How to make a good guitar ? This question has always perplex the makers. That is why musical acoustics tries to help luthiers to make more powerful and pleasant hearing instruments. As one of the first, Antonio de TORRES, in the nineteenth century, thought about adding some pieces of wood under the soundboard of the guitar disposed like a symmetric fan, called bracing, and having a bigger soundbox. The goal was to make guitars more powerful and have better sound qualities. Years after years luthiers developed different ideas to make guitar (and other instruments) always better.

But those guitars were almost the same. They had a full soundboard excited by strings via the bridge and a sound box opened with the soundhole.

1 Introduction

Some scientists [1] have had an idea : "why not cutting the soundboard in two parts in order to make vibration of the board more asymmetric and, so, more radiative ?"

A numerical method is known, but not so used, to calculate a sound pressure field : The Boundary Element Method. As its name says, only the boundary of the domain (here, only the guitar form) have to be meshed. And moreover, the mesh don't have to be very thin unlike the Finite Element Method (FEM) where the meshing of the entire of the domain of study is necessary. Also, for a good precision, the size of elements must be very tight for high frequencies.

The aim of this paper is to prove (numerically, with the BEM) that splitting the soundboard in the length make it more powerful than a classical one.

2 Methods

In order to be precise and focus only on the profit of splitting the board we will consider non-braced and non-preloaded guitar soundboards. We will take the results of a colleague [3] which has calculated modal deformation of a non-split (or full) guitar and a split one with the FEM. We will implement those results in our *OpenBEM* code (developed with Matlab by V. C. Henríquez and P. M. Juhl [4]). To be sure that our results won't be indisputable we first have to validate our BEM calculation code.

The validation have been done with two simple cases witch we have analytic results known from a long time : the rectangular and the circular baffled piston. We have created these meshes with Cast3M, a FEM calculation software, because *in fine* the guitar mesh and vibration calculation will be picked out from it. A big challenge have been to export those mesh to Matlab (guitar mesh in figure 2).

We took the analytic expression of C. LESUEUR [5] for the rectangular piston and the one of A. CHAIGNE [2] for the circular piston. We have compared our results calculated by BEM to the analytic pressure on a curve above the mesh. The convergence test seems to show that for elements under 6 centimetres long, the BEM results are very close to the analytic predictions, at least directly above the piston, a beat less above the baffle. As it is shown in figure 1.

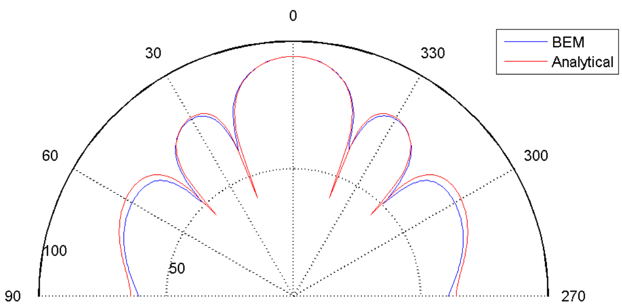


Figure 1: Comparison of analitical and numerical calculation of the normalised sound pressure field above a rectangular baffled piston - $f = 1000Hz$ - $\delta_x = 7,5cm$

The calculation for the circular piston is quite the same. We decide that we will use less than 6 centimetres size elements. So, we will take about 3 centimetres size elements for meshing the guitar as you can see in figure 2.

Import of the normal speed of the table from Cast3M calculation done, we have then be able to calculate the pressure field above a classic guitar and the *split guitar*.

The BEM Calculation gives us results of sound pres-

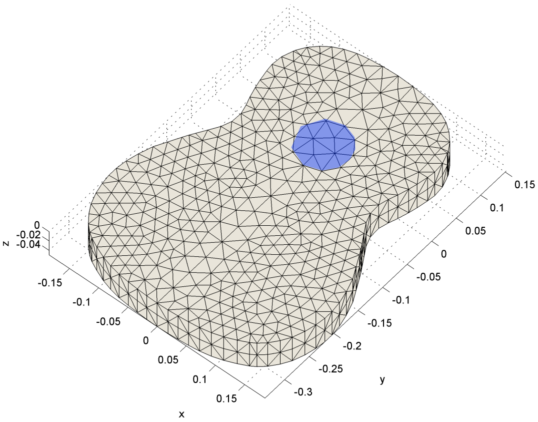


Figure 2: Guitar mesh, witch suits with BEM calculation

sure field calculation such as the one, for the first eigenmode, shown in figure 3.

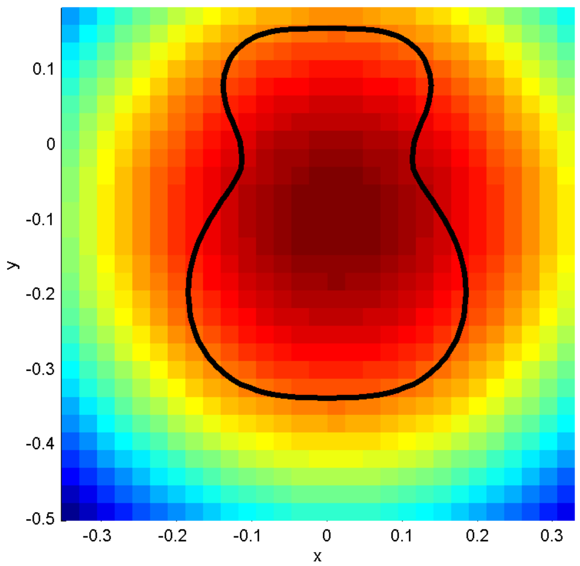


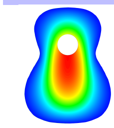
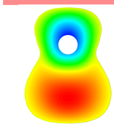
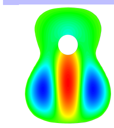
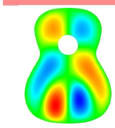
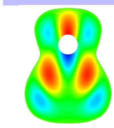
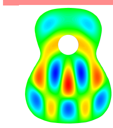
Figure 3: Pressure field above the classic guitar for the first eigenmode one meter above

3 Results

We decided to present our results comparing the maximum pressure level (not always just above the guitar) calculated for the classical and the *split* guitar for some of the first eigenmodes. The results are shown in table 1.

4 Discussion

According to table 1, it is now clear that the benefit of splitting the soundboard can be in the radiation of the so called impair modes. Indeed, it is those eigenmodes that are usually nonradiative. So, although the *split guitar* is less radiant for pair modes, it has an interest for impair modes. Nevertheless, a more exhaustive study shoud be necessary to validate a global increase.

Modal deformation	P 	I 	P 
Frequency full	53 Hz	117 Hz	191 Hz
Frequency *Split*	43 Hz	107 Hz	158 Hz
Full (en dB)	18,5	10*	27,9
Split (en dB)	15,7	16,3	26,2
Δp (en dB)	-3	+6	-1,5
Modal deformation	I 	P 	I 
Frequency full	312 Hz	370 Hz	681 Hz
Frequency *Split*	307 Hz	344 Hz	657 Hz
Full (en dB)	7,7*	22,6	22,4
Split (en dB)	18,8*	22,7	33,5
Δp (en dB)	+11	0	+11

**Maximum level on the sides, on the vertical axis, the radiation is lower.*

Table 1: Comparison of the maximum pressure level 5 meters above guitars for similars modes pair (P) and impair (I)

5 Conclusions

This paper has shown, with an open source BEM calculation software, that it is possible to calculate the pressure field radiated by a guitar in order to make a comparison.

But to prove the increase of 3dB experimentally found by the scientists [1], another study would be needed. Indeed, we would need the vibration of the two soundboards for 'all' frequencies. Only there, a real comparison all over the spectra would prove the general benefit of this guitar.

References

[1] C. Besnainou, J. Frelat et K. Buys – "A new concept for string-instrument sound board : the splitting board".

[2] A. Chaigne – *Ondes acoustiques*, Les éditions de l'école polytechnique, 2003.

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[4] V. C. Henríquez et P. M. Juhl – "OpenBEM - An open source Boundary Element Method software in Acoustics", University of Southern Denmark, 2010.

[5] C. Lesueur – "Rayonnement acoustiques des structures", p. 123 & 124, Editions Eyrolles, 1988.