Transient Finite-Difference Modelling of geometrical nonlinearities of a Balinese Gender dasa Plate

Rolf Bader[1]

[1] *University of Hamburg, Institute of Musicology, Neue Rabenstr. 13, 20354 Hamburg, R_Bader@t-onine.de*

Introduction

The Indonesian, especially Javanese and Balinese traditional musical orchestra is the Gamelan orchestra. It consists mostly of metallophones made out of bronze, like gongs or plate instruments [Rossing and Peterson 1982]. The music of the islamic island Java differs considerable to that of Bali. While Javanese music is mostly very slow and tender, the music of Bali and most popular the Gong Kebyar is very fast, loud and lively [Tenzer 2000]. Indonesian instrument builders are known to carve their instruments very precise in terms of their acoustical properties [Rossing 2000]. I.e. the large gong gede is a not shaped perfectly round, the diameter of one side is a little longer than that of the orthogonal side. This results in two frequencies being very close to each other and so producing a musical beating of about 2 Hz. The exact frequency of this beating is considered of great importance by listeners and craftsmen in terms of the instrument quality [Schneider 1992] [Schneider 1997]. With the plate metallophone instruments, we have a difference between Java and Bali, too. Balinese plates are mostly struck by a wooden hammer as the gender dasa investigated here and show a trapezoidal shape. The Javanese plate metallophones which are also played with a wooden hammer are round (i.e. and most prominent the saron) and show much less overtone structures, and so do have much less brilliance than the Balinese gender. The Javanese gender on the other side also showing a trapezoid shape is not played with a wooden hammer but with one being covered by soft tissues and so is very low in terms of overtone structure, too. This investigation shall show, if the trapezoid shape of the gender dasa of Bali is just an ornamentation or if acoustical reasons can be found for this special shape.

Method

The plate was recorded several times while being struck with the original wooden hammer. The frequencies found in the spectrum were compared to the frequencies possible with a plate by solution of the differential equations and by a 3D Finite-Element calculation taking the trapezoid shape and the slight curvature of the plate into consideration. Then a Finite-Difference calculation was performed with four conditions. The plate was calculated being 1) flat and 2) trapezoid and being a) of free and b) of fixed boundary conditions. Both boundary conditions were not perfect, as the plate is held by cords put through holes in the geometry of the plate and so the boundary conditions can be considered to be more of a damping at the hole and not being exactly free or fixed. But as this does not effect the overall results, we use the free condition of the Finite-Difference calculation here. Then a Wavelet-Transformation was performed with the sounds showing the different amounts of frequencies present with the flat and the trapezoid case. A complex Morlet-Wavelet was used to produce a plot of amplitude in frequency and time.

Measured vs. calculated vs. FEM-solution

The theoretially calculated frequencies consisted of bending, longitudinal and torsional waves along the sides of the plate [Fletcher and Rossing 1999]. The fundamental frequency of 288 Hz was close to the measured one of 273, while the FEM solution for the free case was 280 Hz and of the fixed case of 277 Hz. The calculated modes show much less frequencies than the list of the strongest spectral peaks present in the measured sound. This situation is getting better with the FEM results. Here the free case is much better in frequency precision than the fixed FEM solution. Abbildung 1 shows the mode shapes of the FEM calculation for the mode (3,0) for a) the free and b) the fixed case. Only the free mode frequency of 763.9 Hz, not the fixed frequency of 450.9 Hz comes close to the measured value of 751 Hz.

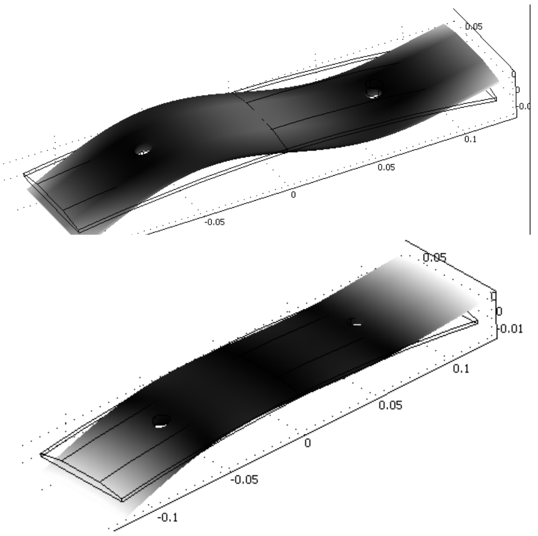
Still modes are missing even as we do only consider the most prominent peaks during the initial transient. The FEM solutions of higher modes can clearly be associated with the mode shapes, where i.e. the mode (6,0) with 3624 Hz still comes very close to 3606 Hz, the 6th bending mode.

To get all possible modes during the initial transient, we calculated the Finite-Difference model as a transient cauculation.

Transient Finite-Difference calculation results

The Finite-Difference calculation was performed with the flat and the trapezoid shape and with free and fixed boundary conditions. Because of the shortness of this paper we do only consider the free boundary case as the fixed case does not alter the results in terms of the overall results.

In the FDM the trapezoid shape was modelled by a varying thickness of the plate at the sides. A middle node point is displaced modelling the hammer strike. Then the plate is vibrating freely and the velocities are integrated over the upper area of the plate with respect to a virtual



a) b)

Abbildung 1: Comparison between the free and the fixed FEM calculated mode (3,0). a) free, 763.9 Hz, b) fixed 450.9 Hz (751 Hz measured).

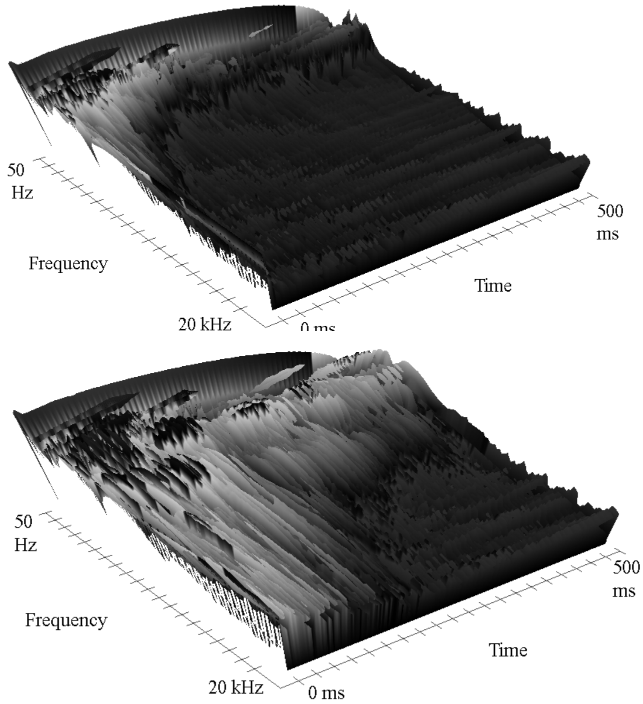
microphone position in the middle of the plate 1 m over its striking point. This method has been well studied in the past [Bader 2005] and results in very accurate and realistic sounds of plates or other structures, like guitars, violins, ect.

Figure II shows the Wavelet-Transforms of the sounds coming out of the Finite-Difference calculation of the gender dasa plate of a) the flat and b) the trapezoid case. The flat case lacks of most of the overtone structure compared to the trapezoid case. The flat geometry has some higher modes within the initial transient phase just at the beginning. The trapezoid shaped geometry has a much more enlarged transient phase with tremendously more overtones and brightness.

The reasons for this could be, that the impulse travelling along the plate is reflected and scattered at the cutting edges of the trapezoid geometry. This would lead to new distances within the geometry and new modes of vibrations. These new modes are unstable of course and damped out quite quickly. So they do not appear after a certain initial transient phase. To test this hypothesis, an acceleration measurement was made at the different parts of the plate, the middle section, right and left.

Association of additional frequencies to plate parts

We lack of giving a complete list of additional frequencies of the plate here because of space restrictions. Within a frequency range of 1 kHz to 3 kHz we have a complete set of 22 modes, while the FEM calculation only has 6 modes. These modes also found in the FEM solution were also present after some time after the strike indicating simple modes. But they also show a distribution in terms of the plate parts being equally distributed over



a) b)

Abbildung 2: Wavelet-Transfomations of the two sounds produced by the Finite-Difference calculation of a) the flat and b) the trapezoid shaped gender dasa plate.

these plate parts. Nearly all other frequencies of the 22 modes are not simple mode frequencies, and did occur only at one side of the plate, either on the right or on the left side or just in the middle. This seems to strengthen the above mentioned reasoning of the trapezoid cutting edged functioning as reflection or scattering zones producing new modes within the initial transient phase.

Literatur

[2] R. Bader, Computational Mechanics of the Classical Guitar,SSpringer, Berlin (2005).

[3] N. H. Fletcher & Th. D. Rossing, The Physics of Musical Instruments,"2. edition, Springer (1999).

[6] Th. Rossing, SScience of Percussion Instruments,"World Scientific, Singapore (2000).

[7] Th. Rossing & R.W. Peterson, "Vibrations of plates, gongs, and cymbals,Persussive Notes **19**(3), 31-41 (1982).

[8] A. Schneider, Notes on the Acoustics and the Tuning of Gamelan Instruments,"B. Arps (ed.) Performance in Java and Bali. Studies in narrative, theatre, music, and dance, London, School of Oriental and African Studies (SOAS) 195-216, (1992).

[9] A. Schneider, Tonhoehe, Skala, Klang,Örpheus, Bonn (1997).

[10] M. Tenzer, "Gamelan Gong Kebyar. The Art of Twentieth-Century Balinese Music,Chicago University Press (2000).