# *Normal modes of a Gamelan Gong*

1st EAA – EuroRegio 2010
Congress on Sound and Vibration
15 - 18 September 2010, Ljubljana, Slovenia
With Summer School for Young Researchers from 13 - 15 September 2010

European Acoustics Association EAA
Alps Adria Acoustics Association
Slovenian Acoustical Society

# Normal Modes of a Gamelan Gong

Nick HERINGTON[a], Daniel P. ELFORD[a], Gerry M. SWALLOWE[a], Luke CHALMERS[a], Robert PERRIN[b] and Thomas R. MOORE[c]

[a] Department of Physics, Loughborough University, Loughborough, LE11 3TU, UK.
e-mail: G.M.Swallowe@lboro.ac.uk
[b] Institute of Fundamental Sciences, Massey University, Palmerston North, New Zealand
[c] Department of Physics, Rollins College, Winter Park, FL, 32789, USA

## ABSTRACT

A gamelan is an ensemble of traditional musical instruments from Indonesia and surrounding countries. The backbone of a gamelan is a selection of gongs with a wide range of sizes but a characteristic general shape. Compared with many other percussion instruments these gongs have been incompletely investigated. In the present work we report a study of the normal modes of one particular small gamelan gong originating in Sarawak. A finite-element model of the gong has been constructed and used to calculate the forms and frequencies of its normal modes. These are compared with experimental ESPI results. Agreement is reasonable in view of the lack of precision in the manufacture of the instrument. They show exactly what one would expect of an axially symmetric system subject to reasonably small symmetry breaking. A comparison with the acoustical power spectrum enables us to identify the small number of modes mainly responsible for sound output.

# 1. INTRODUCTION

The predominant musical ensemble of Indonesia and Borneo is the gamelan. This consists mainly of metalophones and gongs. The latter form the backbone of the gamelan and come in a wide range of sizes but are all of similar general structure.

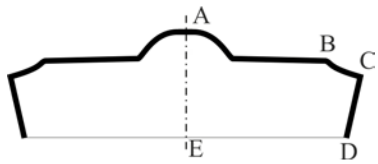


**Figure 1.** Vertical cross-section of a gamelan gong.

In Fig. 1 we show a vertical cross-section through the centre of a small gamelan gong placed on a horizontal surface. It consists of a central dome *A* on top of a flat plate which is terminated by a flat shoulder *BC* and then a deep, flat, inward sloping rim *CD*. The vertical line *AE* is the axis of symmetry. These gongs are rung by being struck on the central dome with some kind of mallet. They are suspended in various ways depending on size. In the present study we used one of a set of relatively small gongs from Sarawak which would normally be supported horizontally by strings from underneath.

Since a "perfect" gong has axial symmetry one can conclude [1] that the normal modes must have nodal patterns consisting of $m$ equally spaced "diameters" and $n$ circles parallel to the rim's edge. Modes with $m > 0$ will occur in degenerate pairs with the diameters of one bisecting those of its partner. In practice geometric and metallurgical imperfections will usually cause most of the doublets to split and produce some distortions of the nodal patterns. Modes can be identified by label ($m$, $n$).

# 2. METHODOLOGY

An ESPI facility previously described [2] was employed to visualize the normal modes of the gong, which was mounted on a vibration-isolated optical table inside an anechoic chamber. The gong was driven by a speaker placed about 50cm from it. A high quality function generator produced a sinusoidal signal which drove the speaker. This was carefully monitored to avoid introducing harmonic or sub-harmonic signals. Unfortunately the optical system did not permit the gong to be supported horizontally, as it is during normal playing. Instead it was hung vertically from a clamp attached to the top of the rim. This would certainly have influenced some of the modes and had to be taken into account when constructing the finite-element model and when interpreting results.

The structural mechanics module of Comsol Multiphysics was used to calculate the normal modes of the gong. The inner and outer profiles of the gong along a specific "diameter" were measured using a Metric Coordinate Measurement Machine. These profiles were fed into Comsol as geometric data and used to generate a 3-dimensional model with perfect axial symmetry. The material properties were taken as those of standard steel and a constraint was imposed on the top of the rim to mimic the clamp.

## 3. RESULTS AND DISCUSSION

A preliminary study of the modal forms suggested that they might divide into two types: "rim" modes and "plate" modes. However, a comparison with results previously obtained for cymbals [3] shows that the "rim" modes are really just *n=0* cases for the complete system where the region of evanescence extends from the gong's centre to a position ever closer to the rim's edge as *m* increases.

Example interferograms obtained by ESPI are shown in Figure 2 together with the corresponding Comsol results. Clearly the modal forms are in good agreement. The selection made in the first row is to show a "rim" mode plus an orthogonal pair of "plate" modes.

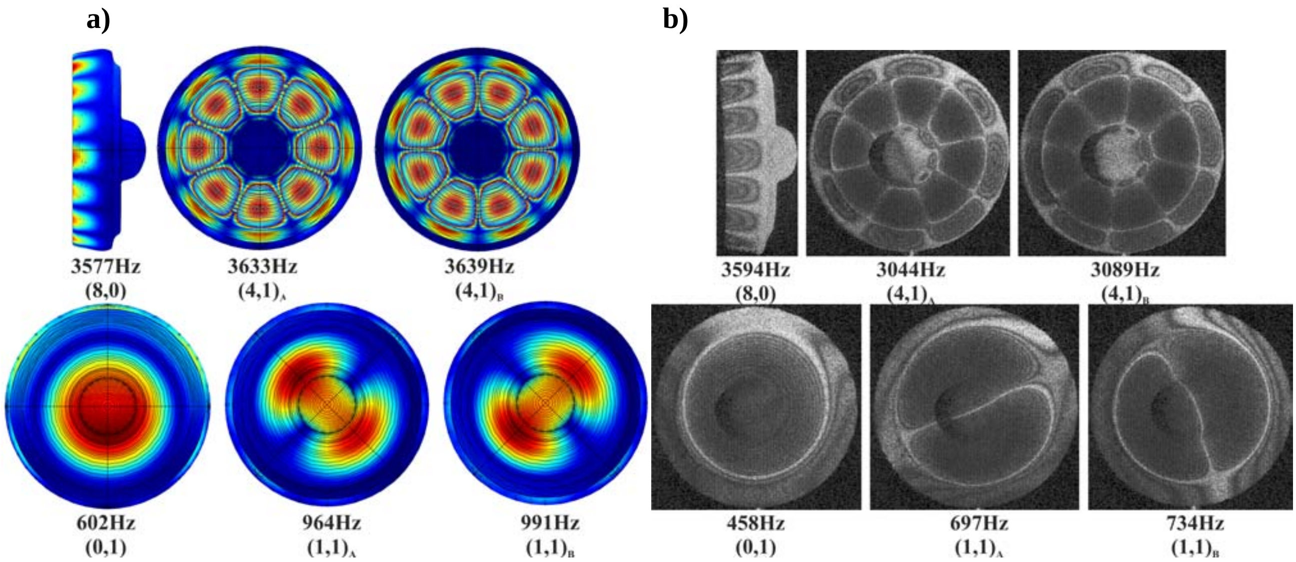


**Figure 2.** a) Finite Element modes predicted by Comsol Multiphysics and b) the corresponding Interferograms obtained using ESPI.

Taking a time-averaged acoustic power spectrum of the gong, after being struck on the dome, reveals, not surprisingly, that the singlet (0,1) mode is by far the most important. The orthogonal pair of (1,1) modes also prove significant. These are shown in the second row of Figure 2. It should be noted that the doublets are somewhat split, as expected.

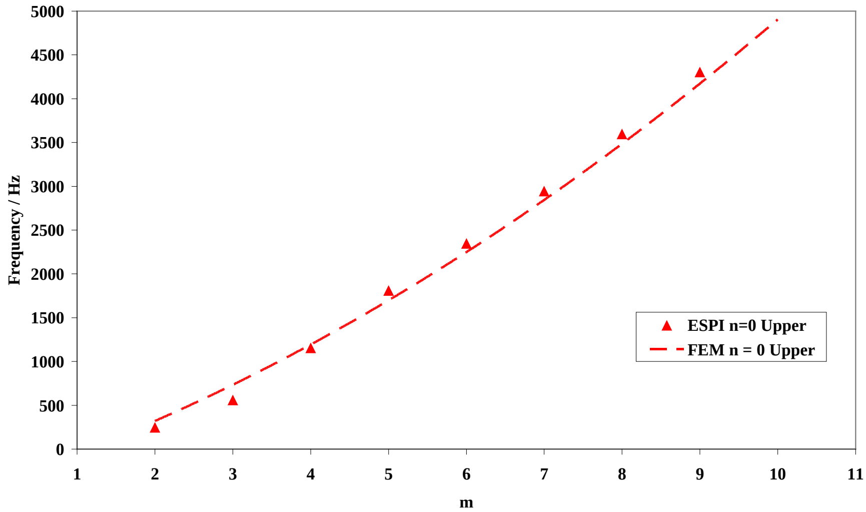


**Figure 3.** FEM vs. ESPI frequencies vs. *m* for *n = 0* upper.

The frequency predictions of the FE model and the corresponding ESPI measurements are shown in Figures 3 and 4. Frequencies above about 5000Hz were excluded because of problems of interpretation of the ESPI forms. Because the *n = 0* "rim" pairs were significantly split, even in the FE model, we show, in Figure 3., the upper frequency components only, for the sake of clarity. Clearly the agreement is excellent. The lower frequency components, not shown, are equally good. In the case of *n=1* modes, shown in Figure 4., the splitting was relatively much smaller, making the components hard to distinguish on the scale of the graph. We therefore again include only the higher frequency components. The agreement is not as good as for *n = 0* but the trends are identical. To emphasize this we have reduced the FE predictions by 20% in the graph. Such a deviation could be due to the assumed uniform thickness of the plate in the model being too crude an approximation. Higher values of *n* have been excluded from the graphs because of problems with identification of their interferograms

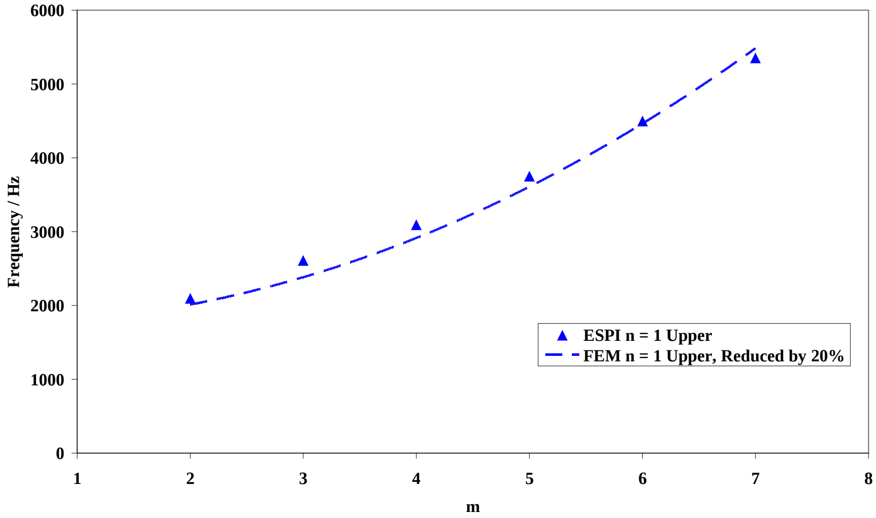


**Figure 4.** FEM vs. ESPI modes vs. *m* , *n = 1* upper.

## 4. CONCLUSIONS

The normal modes of the small gamelan gong are reasonably well understood. The expectations from slightly broken axial symmetry are well satisfied. The similarities with the flat circular plate, the cymbal and other axisymmetric systems are clear. We found little evidence of modes of mixed symmetry types, such as appear in the large crash cymbal. However, this may well occur in larger gamelan gongs.

## 5. REFERENCES

[1] Perrin, R. and Charnley, T., "Group Theory and the Bell", Journal of Sound and Vibration, Vol. 31, 1973, pp. 411-418.

[2] Moore, T. R. and Zietlow, S. A., "Interferometric studies of a piano soundboard", Journal of the Acoustical Society of America, Vol. 119, 2006, pp 1783-1793..

[3] R. Perrin, G. M. Swallowe, T. R. Moore and S. A. Zietlow, "Normal Modes of an 18 Inch Crash Cymbal", Proceedings of the Institute of Acoustics, Vol.28, 2006, pp. 653- 662.