Toward a New Method for the Evaluation of the Tonal Colouring of the Japanese Koto using COMSOL Multiphysics.

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ABSTRACT
This paper investigates the potential for a multidisciplinary approach using finite element models of COMSOL Multiphysics for the evaluation of the tonal colouring of the Japanese koto (13-stringed zither). It uses Ando’s classic acoustic studies (1986; 1996) as a benchmark for the analyses of the natural resonant frequencies and design of the sounding board of the koto. It reports on the development of the model and initial results of simulations. It concludes that COMSOL Multiphysics and finite element analysis can contribute to a multidisciplinary approach to an investigation of the tonal colouring of the koto and that further development of the model is warranted.

INTRODUCTION
The koto is classified as a 13-stringed plucked zither. The instrument has strings stretched the length of the sounding body. The sounding body of the koto is a rectangular box which is 186 cm, by 25 cm and 7 cm. It is composed of several types of wood. The box is typically made of paulownia, with the neck of koto being made of several species of bamboo. The neck of koto has a long, hard neck with string support at its base. The strings are tightly tensioned in order to maintain a fixed length and pitch during playing. The koto is played with a plectrum, which is a small, thin piece of wood or plastic that is plucked with a pick. The sound is produced when the plectrum strikes the string. The koto is a versatile instrument that can produce a wide range of tones and textures. It is widely used in Japanese music, particularly in classical and traditional forms.

RESEARCH PROBLEM AND METHODOLOGY

1. RESEARCH PROBLEM and METHODOLOGY

The koto is an ancient instrument that has been used in Japanese music for centuries. It is a plucked zither with a rectangular body and 13 strings. The koto is made of wood and has a rectangular body, which is typically 186 cm long, 25 cm wide, and 7 cm deep. The strings are made of silk or nylon and are stretched across the body of the instrument. The koto is played by plucking the strings with a plectrum, which is a small, thin piece of wood or plastic. The strings resonate and produce sound when the plectrum strikes them. The sound produced by the koto is characterized by a rich, complex tone that is unique to this instrument. The koto is an important instrument in Japanese music, and it has been used in a variety of traditional and contemporary music styles.

Methodology

The methodology developed for this study involves three stages:

1. Creating a Heuristic Model using Ando (1986): The creation of a heuristic model in the COMSOL Multiphysics Acoustic module to examine general concepts and make discoveries about the sound and tonal colouring of the koto. The model is informed by knowledge of Japanese musical culture and traditional practice. Simulation of the Ando (1986) koto and its performance using the model is then undertaken. This stage acts as a test and calibration of the method.

2. Creating a Heuristic Model using Coaldrake’s koto: The identification of discoveries from Ando (1986) is used to develop a more sophisticated understanding of tonal colouring of a koto of known provenance, sound qualities and dimensions.

3. Refinement of the Model: Results of Stage 2 highlight points for refining the model and direct attention to key areas for further study.

A. Q. Does the curvature of the instrument really make a difference?
B. Q. Does the curvature of the instrument really make a difference?
C. Q. Does the curvature of the instrument really make a difference?
D. Q. Does the curvature of the instrument really make a difference?

Fig. 5.1 Comparison of Eigenfrequencies and Tuning Frequencies


Fig. 5.2 Comparison of Eigenfrequencies and Tuning Frequencies


Fig. 5.3 The 12 frequencies of the standard koto tuned in each of three dimensions (top, side and end)

The koto is placed in a sphere of air (Fig. 5.1) and a point power source (10 W) is then played for each of the 12 frequencies of the standard koto. The sound at a point that approximates where the performer plucks the string. The standard tuning results are compared with the eigenfrequencies of the instrument (Fig. 5.2). It shows that the tuning of the instrument does not correspond with the eigenfrequencies. The pitch of the standard tuning are simulated and top, side and end views compare. The wave length (L) is included in each diagram. (Fig. 5.3). The results highlights the intensity activity taking place within the resonant cavity of the instrument with standing wave like formations along spacing waves with the wave length of the frequency in Air. At higher frequencies very marked banding is observed (Fig. 5.4a and 5.4b).

Fig. 5.4a and 5.4b: Marked banding at high frequencies

6. Conclusions

COMSOL Multiphysics and finite element analysis can contribute to a multidisciplinary approach to the investigation of the tonal colouring of the koto and its musical characteristics.

1. Further development of the model is warranted.

REFERENCES

Koto. Koto: Its Tonal Colour: Total colour (13-string), also known as tenori, is a defining characteristic of Japanese music: The koto is a 13-stringed plucked zither. It uses Ando’s classic acoustic studies (1986; 1996) as a benchmark for the analyses of the natural resonant frequencies and design of the sounding body of the koto. It reports on the development of the model and initial results of simulations. It concludes that COMSOL Multiphysics and finite element analysis can contribute to a multidisciplinary approach to the investigation of the tonal colouring of the koto and that further development of the model is warranted.

ADDITIONAL RESEARCH INSTRUMENTS

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