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EXPERIMENTAL AND NUMERICAL ANALYSIS OF THE MUSICAL BEHAVIOR OF TRIANGLE INSTRUMENTS

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The history of musical instruments dates back nearly as long as the humanity itself. During the last centuries the development of the quality as well as of the play of musical instruments was pushed empirically and experimentally by instrument makers and players. This development can hardly be surpassed. Therefore, at first sight, the scientific study of instruments does not seem to allow any further significant improvement. It is, however, very important to gain an understanding for these complex systems and to provide numerical models to illustrate the behavior of sound.

The characteristics of the sound of an instrument significantly depends on the overtones. These overtones originate from the structural behavior, e.g. the string of a bow instrument oscillates with the full length, the half length, the third length and so on. The frequency series of the overtones f_n can be described by

$$f_i = f_0(i+1)c_i$$

in dependency of the fundamental frequency f_0. The constant c_i is an indicator for the brightness of the sound. The less c_i deviates from an average value $\bar{c}$, the more pleasant the sound appears. The deviation can be described by the root mean square deviation.

Another criterion is the consonance or dissonance of the overtones. Dissonance occurs if the difference of two frequencies f_i and f_{i+1} of a sound is within a specific range. There is a critical frequency band around the average frequency $\overline{f_i} = (f_i + f_{i+1})/2$ where the listener is not able to distinguish between two frequencies. The bandwidth depends on $\overline{f_i}$. This band can be split into the dissonant area and the area of beat frequency which is actually not dissonant because the listener only hears one tone with a time depending amplitude [Pierce85].

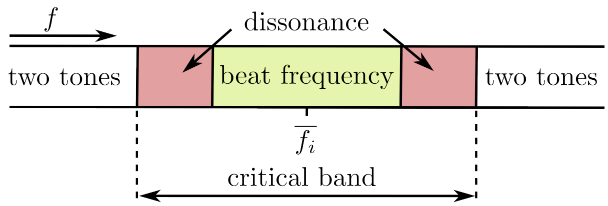

Figure 1: Dissonance in the critical bandwidth of two frequencies

The topic of this work is the investigation of two different triangle instruments using experimental modal analysis. These triangles differ significantly in price. The two main differences the listener notices are the time length and the harmony or disharmony of the sound. The length of the sound is justified in the damping behavior of the material. Much more interesting, however, is their characteristics in terms of harmony or disharmony, and the reason for it.

The results of the experimental modal analysis using a scanning Laser-Doppler-Vibrometer and the measurement using a microphone, provide the structural eigenforms and the eigenfrequencies. With the above-mentioned criterion for disharmony, it can be shown that more overtones of the less expensive triangle are dissonant than for the higher-priced triangle. Furthermore, the root mean square deviation of the factors c_i for the overtone series of the cheaper triangle is six times higher than that of the expensive one.

Further numerical investigations shall give answer to the questions on how the geometrical differences between the triangles affect their sound, and whether there is a possibility to achieve a more harmonious sound by conduction of well-directed geometrical changes.

REFERENCES

[1] Pierce, J.R.: Klang, Musik mit den Ohren der Physik (in German). Spektrum der Wissenschaft, Heidelberg, 1985.