VIBRATION PATTERNS AND SOUND ANALYSIS OF THE VIENNESE TIMPANI

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Abstract
Orchestras in Vienna traditionally use kettledrums with goatskin and a hand-tuning mechanism (so-called 'Hochrainer' timpani) and not modern pedal timpani that are international standard, which are equipped with Mylar membranes or calfskin. The 'Hochrainer' timpani sound is preferred in spite of the drum's disadvantages: the inhomogeneous skin is harder to tune and much more sensitive to moisture and temperature than plastic membranes. The objective of this study is to document the properties of the Vienna timpani and to compare the acoustic characteristics with international timpani. Studies using LASER interferometry and digital sound analysis of recordings (made in the anechoic chamber in the IWK) have been made with Viennese timpani and with standard timpani. Findings show similar mode frequency ratios with international timpani but the 'quasiharmonic' modes 11 and 31 have higher amplitudes in the membrane displacement and the resulting sound spectra, which provide more tonality. The laser study also allowed an animated documentation of the vibration patterns of the membranes.

INTRODUCTION

Vienna Tradition. While almost all international top orchestras in the world use rather similar and standardized sets of 'Dresden-type' pedal timpani, orchestra in Vienna still play mainly the old-fashioned 'Hochrainer' timpani with a hand-tuning mechanism. Schnellar and his heirs Hochrainer and Schuster were principal timpanists in the Vienna Philharmonic Orchestra and teachers at the University for music in Vienna. Hochrainer modified the 'Schnellar' Timpani (e.g. aluminum feet without rollers, instead the heavy tripods). This ideal circumstance, where the instrument maker himself is principal player of the Philharmonic Orchestra and teacher at the Music University, is unique within the development of a musical instrument, because the Vienna timpani tradition is not only based on the instrument but also on the playing-technique. It is said that Viennese timpanists 'play' the timpani, rather than 'hit' them, and that the sound never sounds vulgar, even if played forte.
Construction. The construction and properties of the Vienna timpani (VT) differ in many ways from the internationally used 'standard' pedal timpani (IT). Standard timpani change the tension of the membrane by means of a pedal. The membrane is held against a counterhoop that is pressed down via tension rods. The note of the resulted tension can (roughly) be seen at a tuning gauge. The Viennese timpani has no counterhoop and no pedal. These instruments have a single master screw to change the pitch. By means of the hand-tuning mechanism the whole kettle is lifted up and pressed against the membrane. 6 struts connected with the casters hold the membrane.
Membrane Material. Viennese Timpani only use goat skin (from Edlauer Enns, Austria) while other Timpani are either equipped with calfskin or with a plastic membrane (Mylar). The goatskin is thicker than calfskin, but both share many characteristics of natural skins, which have besides their unique sound qualities many disadvantages in handling. Natural skins are more sensitive to moisture and temperature and therefore more difficult to tune. Further, the material is not reproducible, harder to prepare and more expensive.
Kettle. The kettle of Viennese timpani is- like other fine timpani -a hammered copper bowl (0.8mm in thickness), its shape is slightly different and equals one part of an ellipse. The hole in the bottom (slightly off centered) is without acoustic importance.
Setup. The setup of Viennese timpani is the 'German configuration'. Both lower timpani are stand-

Fig. 1. Vienna „Hochrainer“ Timpano manufactured by Schuster

ing at right side, a pair of smaller timpani on the left side of the player. This configuration equals the historical setup when timpani were played by musicians mounted on horses. Other orchestras outside Germany and Austria usually have the larger, lower timpani at the left side, like at a keyboard. The range of the large 76 cm timpani is from 'E2' (82.4 Hz) to 'c3' (131.8 Hz). The range of the smaller 69 cm timpani is from'Bb2' (116.5 Hz) to 'f3' (174.6 Hz). Besides these, a 59 cm soprano timpano is set up with a range from 'f3' (174.6 Hz) to 'a3' (220 Hz).

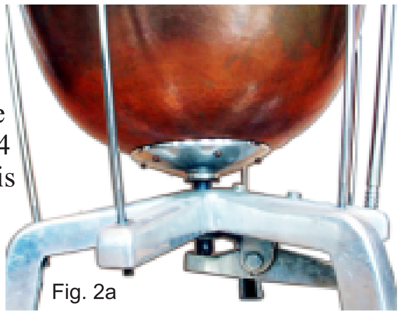


Fig. 2a

Fig. 2b: Hand tuning mechanism of the Viennese Timpani (left) and the "standard timpani" (right) with a pedal

METHODS

Literature. The acoustics of timpani have been studied in various investigations. In several publications the research results of the Northern Illinois University group were published by Rossing [1]. Besides the documentation of the 'normal modes', the influence of tension and diameter of membrane and the effect of air loading was demonstrated. Fleischer [2] made several studies using various methods (measurements, calculations, psychoacoustics experiments, modal analysis). Together with Fastl [3] they studied the influence of the air volume in the kettle and the influence on the membrane material. They found significant differences between synthetic skins and calfskin. Their focuses have been the sound and the position of the membrane modes. They also made a study on the clarity of pitches on timpani [4]. By means of psychoacoustics studies they found that the sound of a calfskin head is clearer than that of synthetic Mylar membranes and that for one timpano there are differences depending the tension of the head. Sullivan [5] made several measurements on timpani concerning an accurate frequency tracking of timpani spectral lines. He found that the most important factors appear to be the ability to produce a clear, focused pitch and the ability to achieve a good resonant sound, where partials such as a fifth or octave decay slowly.

Sound recordings. In 1999 a set of two Viennese Timpani (Schuster) and a set of two international pedal timpani (Premiere) were recorded in the anechoic chamber of our Institute. The excitation was realized by means of an electronically controlled machine (FIG 3) on both timpani sets with three mallet types (hard, medium and soft) and three tensions (high, medium and low tensions). An additional recording in 2000 was made with one pedal timpano (Aehnelt) to compare a plastic membrane (REMO Weatherking) and a goatskin membrane. The excitation was played by a professional timpani player.

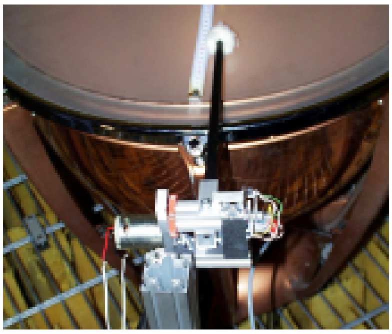


FIG. 3: An electronic controlled machine was used for a reproducable stroke.

Laservibrometry. The same instruments were measured both times with the Polytec Scanning Vibrometer PSV (scanning head: OFV 050; software vers. PSV 6.0 and controller OFV 3001S) that is owned by the technical Museum Vienna. PSV is a complete area vibration measurement and analysis system. PSV automatically collects complete vibration data from up to thousands of individual points on a user-defined area. (See FIG.4) The laser beam moves quickly, so PSV produces graphical, easily understood results. The setup 1999 included a chirp excitation with speaker, shaker (Oscillator: HP 33120) and with the electronic controlled machine; the 2000 setup was realized with a manual excitation (medium flannel mallet, mezzoforte)

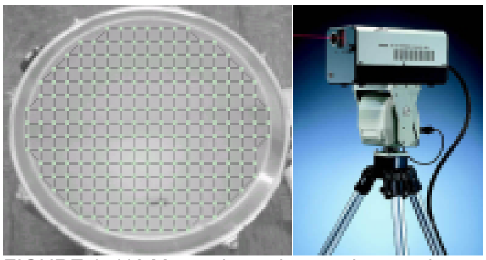


FIGURE 4: 110 Measuring points on the membrane (left) and the scanning head of the PSV system.

RESULTS

The Laservibrometry study 1999 provided a good documentation of the vibration patterns of the membranes. FIGURE 5 shows examples of some modes in two and three-dimensional representations. The Laservibrometry images of these modes from an international timpano with plastic head (IT) and from a Viennese Timpano (VT) look similar, (only the other representation is different.) The software also made it possible to create animated images of the following Modes: M01 (=Mode 01), M11, M21, M31, M41, M51, M02, M12, M22, M03 and M32. These modes have been found as peaks in an FFT of

the membrane displacement.
The positions of these peaks have been compared between the IT , VT and with reference values from the literature (Rossing et al) [1]. The frequencies of the peaks have been related to the main mode M11. FIGURE 6 shows this comparison for two measurements of the small timpani of both types (note B and D) and with both larger timpani, also with two different tensions (note G and B). All these measurements agree with measured and calculated values of the literature: M11, M21, M31, M41, M51 have a 'quasiharmonic' relation (1):(1,5):(2):(2,4):(2,9). FIG.4 also shows the relation of the other mode. Remarkable is that M01 changes its position depending on the tension.
Differences between VT and IT could be found in the magnitude of the peaks in the membrane displacement FFT.

FIGURE 7 shows the absolute maximum displacement for each measured mode in nanometers. The values for Mode 11 on the large timpani are 4000nm measured at VT and 3000nm for IT (both tensions) and 2800nm versus 1400nm and 5000nm versus 2200nm with the smaller timpani. Also Mode 21 and Mode 31 (fifth and octave of the Mode 11) have a higher magnitude with the Viennese Timpani (VT).

Analysis of the recorded sounds of the same sounds agrees with these findings. FIGURE 8 shows a 3D-FFT of 5 second tone D, played with medium mallets on IT and VT. The position of mode M11, M21 and M31 are indicated by a small circle. The amplitudes of the corresponding partials are higher at the VT. Higher partials in the radiated sound are stronger on the IT. This explains why the sound of VT has a more tonal and a less percussive characteristic than IT. This agrees with studies of Fleischer and Fastl on calfskin.

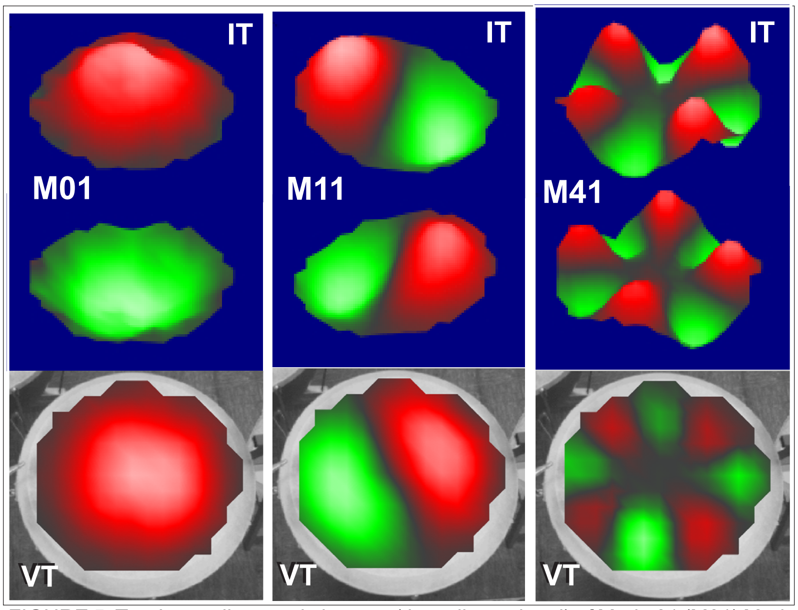


FIGURE 5: Two Laservibrometrie images (threedimensional) of Mode 01 (M01) Mode 11 (M11) and Mode 41 (M41) from international timpani with plastic head (IT) and the colormap images of a viennese Timpano (VT) below show similar characteristics.

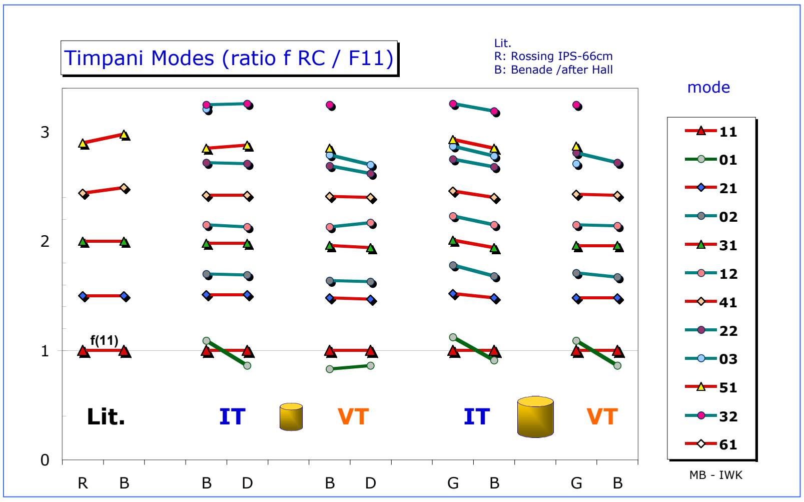
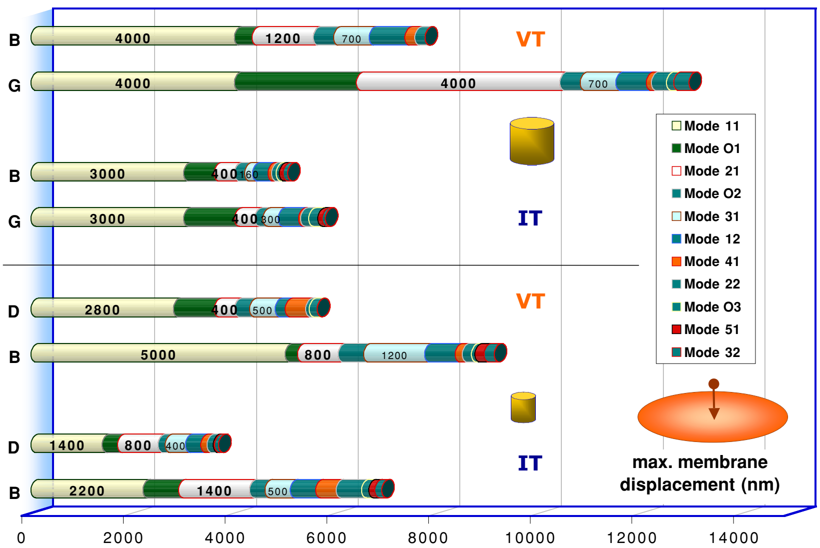
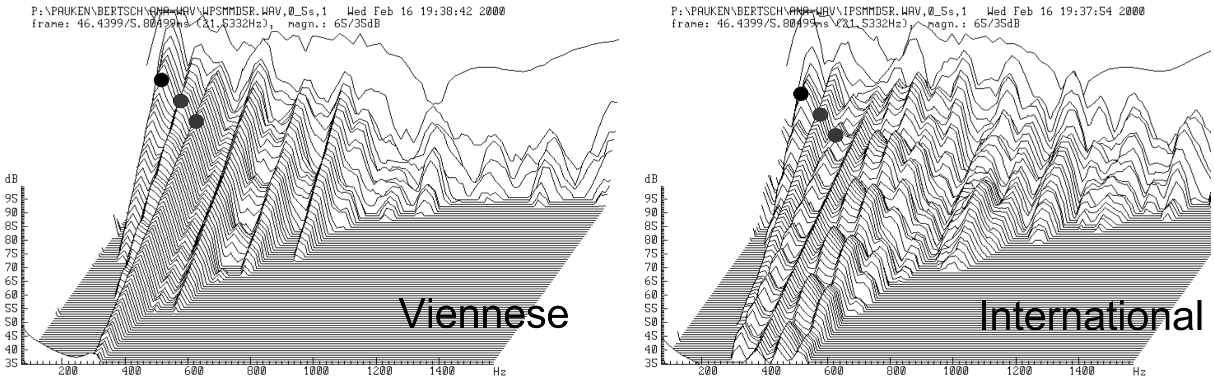


FIGURE 6 (above) : comparison of the mode ratios found in the laservibrometrie images compared to the normal modes found in the literature (Lit). The mode ratios of the Viennese timpani (VT) and the pedal timpani with plastic membrane (IT) are very similar. This could be found for both tensions (note B und D on the small timpani and note G and B on the large timpani). Mode 01 changes its position depending on the tension. FIGURE 7 (below): the correspinding magnitudes of membrane displacement for all modes in nanometer.

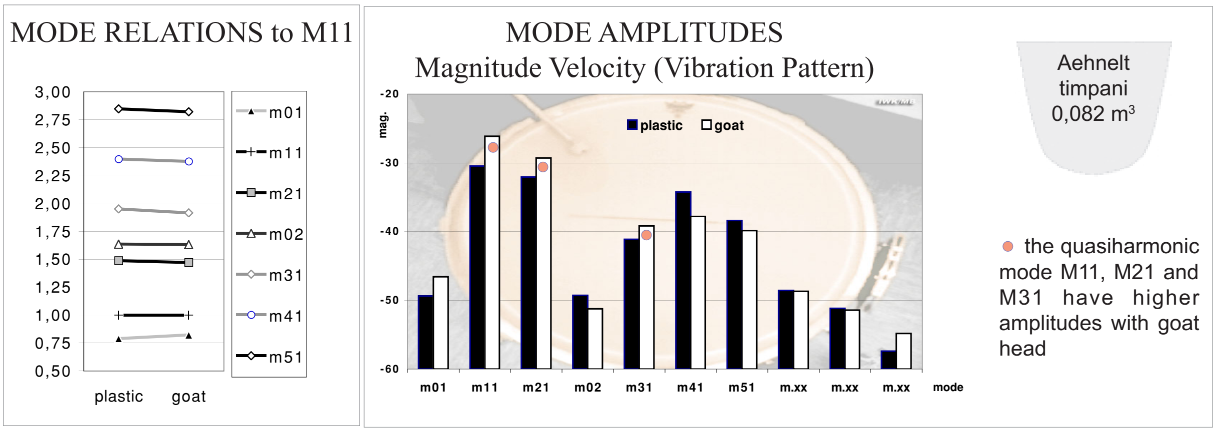




FIGURES 8: 5 sec. 3D-FFT of the recorded sounds of a small VT and IT. M11, M21 and M31 have a higher amplitdes in the VT sample.

Since the reason for this difference of VT could be the membrane or the other part (kettle) of the instrument, a follow up study was made (setup 2000) with only one pedal timpano and two different membranes. A goatskin and a plastic head. Again, sound recordings and Laservibrometry studies have been made, and the results of a similar analysis can be seen in FIGURE 9. The result of these measurements shows also similar mode relations for plastic and goat heads, but differences in the amplitudes. The important modes M11, M21 and M31 have higher magnitudes in the membrane displacement. This could be caused by the inhomogeneous skin structure of natural heads, in particular by the reinforcement of the skin from along the backbone of the animal (that can be seen as diagonal line over the membrane in FIG 1). Further studies could be focused on different natural membrane materials.

The analysis of the recorded sounds in the setup-2000 indicated also fewer higher harmonics with the



FIGURES 9: Laservibrometry results from the setup 2000: a plastic and a goatskin head on the same Aehnelt timpano.

VT, but the stronger lower 'quasiharmonic' partials could not be found. Since this setup derived from a human player, many reasons for the variation of sound quality could be assumed.

CONCLUSIONS

Viennese 'Hochrainer' Timpani are different since they use goatskin and a different tuning mechanism. The LASER interferometry and sound analysis results show similar mode ratios to the International Timpani but different mode amplitudes. Mode 11 (fundamental) and 31 (octave) are stronger, especially at higher tensions. This results in a different sound and more tonality. The 'Hochrainer' timpani are preferred by Viennese players despite of their sensitivity to moisture and temperature because of their unique sound qualities.

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