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VIBROACOUSTIC INVESTIGATION OF A BATTER HEAD OF A SNARE DRUM

E. B. SKRODZKA, E. HOJAN, R. PROKSZA

Adam Mickiewicz University
Institute of Acoustics
Umultowska 85, 61-614 Poznań, Poland
e-mail: hojanaku@interia.pl

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The modal analysis of a batter head of a snare drum and measurements of the instrument's sound spectrum have been performed. The modal analysis results is comparable to the scarce literature reports. The analysis of the frequency maxima of the sound spectrum revealed significant discrepancies between the modal frequencies and those of the spectral peaks. It has been shown that the lowest mode (0, 1) is the strongest mode of radiation only for central excitation. For non-central excitation, the frequencies of spectral peaks differ significantly from the modal frequencies. It has been found that the batter head was not necessary the most strongly radiating element of the drum system and that the influence of other elements (the snare drum, the shell, the snares) are also very important as far as sound impression is concerned.

Key words: snare drum, modal analysis, sound spectrum.

1. Introduction

Snare drums belong to the family of untuned membranophones. A typical snare drum is a two-headed instrument about 35 cm in diameter and 13–20 cm deep. When the batter head (upper membrane) is excited by a drum stick, the snare head (lower membrane) vibrates against steel springs (the snares). A significant coupling between the two heads is expected, especially at the low frequency range. This coupling can take place acoustically, through the air enclosed, or mechanically through of the drum shell.

The dynamic and acoustical properties of a snare drum are defined by its physical properties such as: size, shape and material of both the membranes; the membrane's tension, mass density, propagation velocity; the membrane's inhomogeneities; the drum shell and the snares [1]. The dynamic properties of an ideal membrane can be studied applying numerical modeling, but for a real musical instrument they should be measured experimentally due to the complexity of the problem. The sound radiation from the two coupled air-loaded membranes is difficult to calculate, too, and what is more, existing reports on the vibroacoustics of snare drums are very scarce and are based on measurements performed on a single instrument and by the same team [4–6]. Taking these facts into account, we decided to perform a modal analysis (to investigate the dynamic behavior) and an acoustic analysis of the sound produced by the instrument in order to check the relation (if any) between the spectral component frequencies of the sound produced by the complete instrument and the modal frequencies of the batter head. In our opinion these results enable a better understanding of the snare drums mechanics and sounding.

2. Modal analysis

The term *modal analysis* refers to a process of characterising the dynamic response of a structure by describing its vibrational motion by means of a set of mathematical relationships, generally referred to as the modal properties. Vibrational modes of a structure can be obtained by means of one of the two different approaches: mathematical models or experimental analysis.

The experimental modal analysis starts from a set of the measured Frequency Response Functions (FRFs) of a structure. The FRF are defined as a ratio of the response signal spectrum (measured at point i) to the excitation signal spectrum (measured at point j). Thus, the measured set of FRFs forms a matrix. Basing on these functions, the modal properties (i.e. the modal frequencies, modal damping and mode shapes) are calculated without any specific assumptions concerning the distribution of mass and stiffness of the structure. The modal model, that consists of the modal properties, is obtained by analytical curve fitting of one or more FRFs. The main assumption of the modal analysis, i.e. the linearity of the investigated object, implies that only a single complete row/column of the FRF matrix may be measured. Thus, the majority of modal experiments are performed either with a fixed response point or with a fixed excitation point [2, 7].

The experimental modal analysis with a fixed response point was performed on the batter head of the steel snare drum. The snare drum, the shell, the snares and the membrane's tension have not been investigated. The snare has not been damped. The diameter of the drum was 36 cm. The REMO Weatherking Coated Powerstroke 3 heads have been used. The batter head was not a new one and had visible trails of attrition in its central part. Both the heads were tuned before measurements. 352 measuring points were chosen on the batter head (Fig. 1). The drum was mounted on a steel tripod.

The drum was excited by an impact hammer with a piezoelectric force transducer to provide a broad-band excitation. The response signal (acceleration) was measured by a small accelerometer that mass equaled 0.5 g. The accelerometer was glued by bee wax at a point distant 12 cm from the center of the head (point no. 67 in Fig. 1). Thus, two signals were always measured: the excitation signal and the response signal. Basing on these signals, the Frequency Response Functions, FRFs, were calculated for all the pairs of measuring points. All the FRFs were measured within the frequency

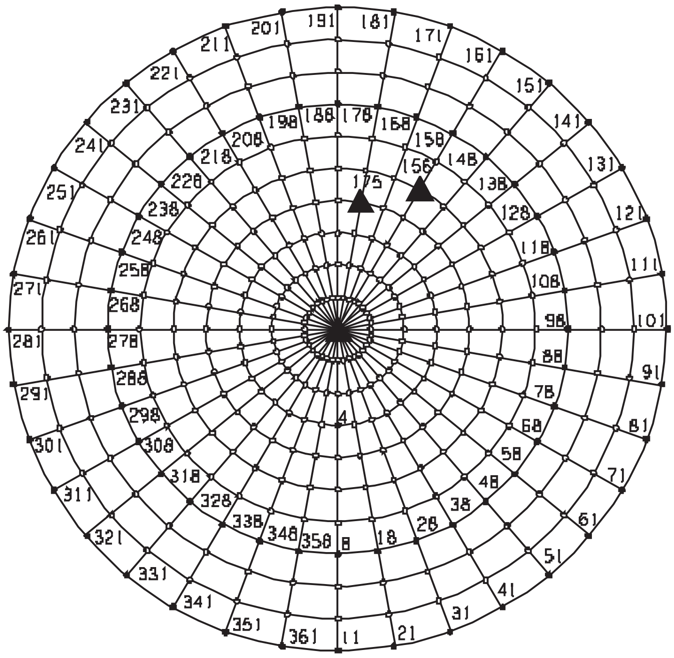


Fig. 1. Distribution of measuring points on the snare drum's batter head for modal analysis. Black triangles show the excitation points for acoustic measurements.

range 0–800 Hz. 10 time averages were used. The frequency resolution of the analysis was 1 Hz. The frequency range, resolution, position of the accelerometer were established from preliminary measurements. An example of the measured FRFs is shown in Fig. 2.

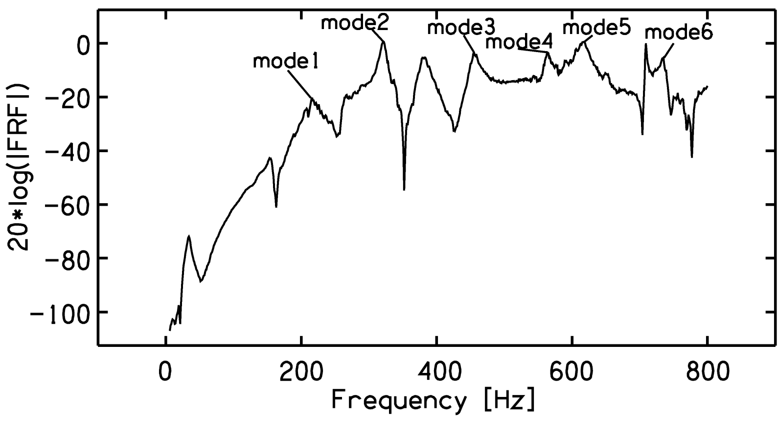
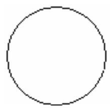
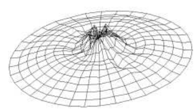
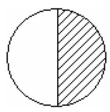
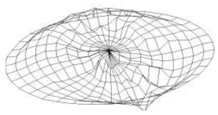
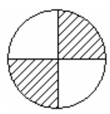
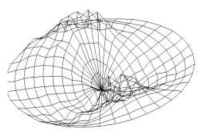
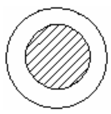
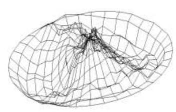
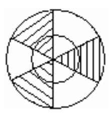
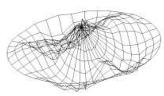
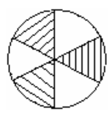
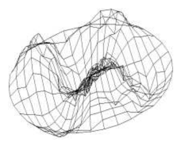


Fig. 2. Example of the measured FRF (point no. 167 is an excitation point, point no. 67 is a response point, see Fig. 1).

Modal parameters were calculated by means of the program package SMS STAR*Modal*® [9]. An Advanced Curve Fitting method was used for the modal parameters estimation [10]. The results of the modal analysis are listed in Table 1. In the first column, the mode number and mode description is given in brackets. The first number gives the number of the nodal diameters and the second one – the number of nodal circles (including that one at the circumference). For each modal frequency, the value of the percentage of modal damping, expressed as a percentage of the critical damping, [8–10] is listed, as well as well the ratio of the current modal frequency and the fre-

Table 1. Modal analysis results of the snare drum batter (upper) membrane.

Mode no. and description	Frequency [Hz]	f_i/f_1	Modal damping [%]	Schematic mode shape	Mode shape	ROSSING *et al.*, [6]	
						Frequency [Hz]	f_i/f_1
1 (0, 1)	$f_1 = 224$	1	5.07			$f_1 = 224$	1
2 (1, 1)	$f_2 = 322$	1.44	1.10			$f_2 = 280$	1.25
3 (2, 1)	$f_3 = 457$	2.24	1.07			$f_3 = 403$	1.80
4 (0, 2)	$f_4 = 566$	2.32	1.16			$f_4 = 445$	1.99
5 (3, 2)	$f_5 = 616$	2.75	1.24			$f_5 = 801$	3.58
6 (3, 1)	$f_6 = 734$	3.28	0.77			$f_6 = 512$	2.29

quency of the first mode, f_i/f_1. Moreover, the number and positions of nodal circles and diameters are shown in a schematic manner. The outlined areas show parts of the head which move in antiphase to the white areas. In this paper, only the most distinctive and best-pronounced modes are presented. For comparison the results obtained by ROSSING *et al.* [6] are shown in the last two columns of Table 1.

As can be seen in Table 1, the modal frequencies are not harmonically related. The mode shapes 1–4 occur in the same frequency sequence as that reported by ROSSING *et al.* [6]) although the modal frequencies and the f_i/f_1 values are different. The frequencies and sequence of modes (3, 2) and (3, 1) differ significantly from those reported by ROSSING *et al.* [6].

The batter head vibrating in its lowest mode (0, 1) acts as an ideal membrane as all its points move in phase. This mode is relatively highly damped (5.07%) due to the coupling between the two heads. This mode is also a strongly radiated mode for the central excitation (see later). The mode (1, 1), which is an antisymmetric mode, is much less damped. Contrary to kettledrums, this mode is not a strongly radiated mode [3]. The modes with higher frequencies are slightly damped (about 1%) as the coupling between the two heads (being a decreasing function of frequency) is much smaller.

3. Sound spectrum of the snare drum

Sound spectra produced by the snare drum excited manually by the drum stick at three different points placed on the batter head are shown in Figs. 3–5 as well as the spectral positions of modal frequencies. The spectra have been normalized to their maximum value.

The position of the excitation points (no. 1, 166, 175) is shown by black triangles in Fig. 1. The excitation point no. 1 is a central head's point. Additionally, we excited the head at two different points (no. 166 and 175), which were not positioned on the same circle and on the same radius, to avoid excitation in a nodal point. Moreover, the points 166 and 175 are approximately the points usually excited by the drum stick by a player. The spectra were measured using a condenser microphone (Studio Project B3) with omnidirectional characteristics. The microphone was placed either along the drum's main axis of symmetry, 1 meter above the head, or 1.5 meter distant from the main axis of symmetry and 1 m above the drum's head. The latter microphone positioning seems to be more similar to sound perception. The audio interface RME HDSP Digiface and the Behrniger A/C transducer were used (44.1 kHz, 16 bit). The spectra have been recorded in an anechoic chamber of the Institute of Acoustics of the Adam Mickiewicz University, Poznań, Poland. The spectra have been stored on a computer hard disc after 10 averages.

There are some striking features of the measured spectra:

- none modal frequency is exactly equal to the frequency of the highest spectral maximum,
- only a few modal frequencies coincide with spectral peaks,
- for the measurements performed with the microphone placed along the main axis of symmetry, the highest spectral maximum occurs at a frequency close (but not equal) to the frequency of mode (0, 1),
- for the measurements performed with the microphone placed away from the main axis of symmetry, the highest spectral maximum occurs at different frequencies that are much higher than the first modal frequency,
- no harmonic relation between sound spectrum maxima is observed.

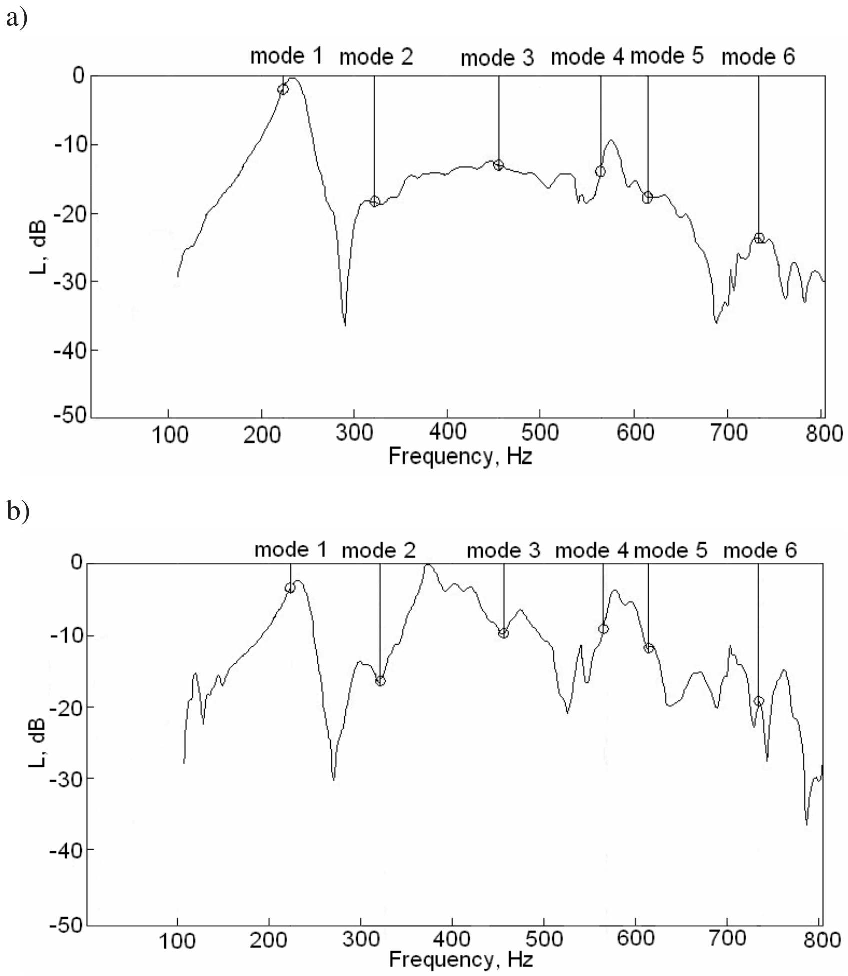
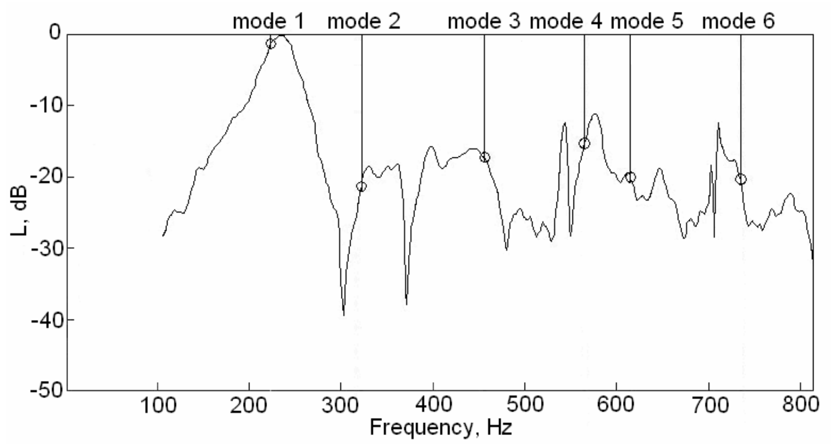


Fig. 3. a) Sound spectrum of the snare drum excited at the central point for the microphone placed along the main axis of symmetry; b) the same, but for the microphone placed out of the main axis of symmetry. The spectral position of modal frequencies is denoted.

These observation have us led to the conclusion that the mode (0, 1) is a strongly radiated mode only in the case of central excitation. For a non-central excitation, this mode excited a relatively high maximum in the sound spectrum but other significant spectral peaks, not related to any modal frequency, appeared too. The source of these other maxima at frequencies different from the modal frequencies was the whole snare drum system: the snare head, the shell and the snares and coupling between these elements. The last conclusion is similar to those of ROSSING *et al.*, [6]. Nonharmonic relation between the sound spectrum maxima as well as those between modal frequencies explain the well known fact of the indefinite pitch of the snare drum sound.

a)



b)

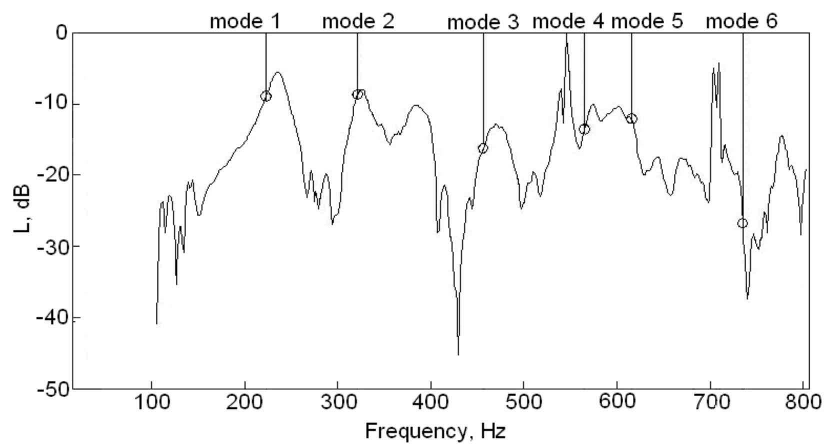
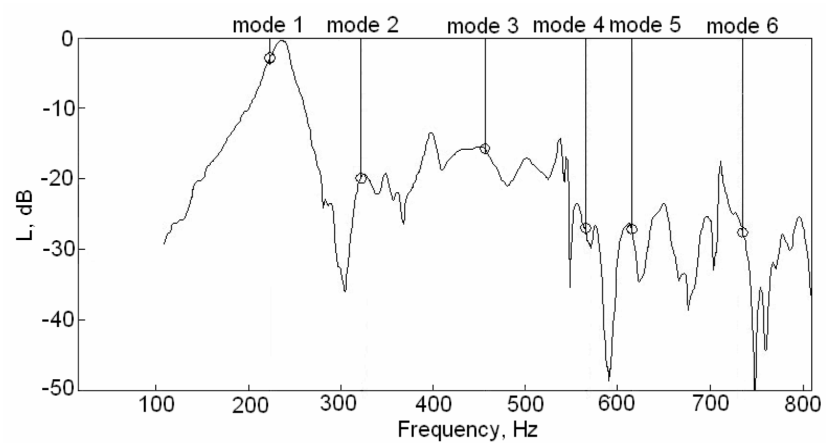


Fig. 4. a) Sound spectrum of the snare drum excited at the point no. 166 for microphone placed along the main axis of symmetry; b) the same but, for the microphone placed out of the main axis of symmetry. The spectral position of modal frequencies is denoted.

a)



b)

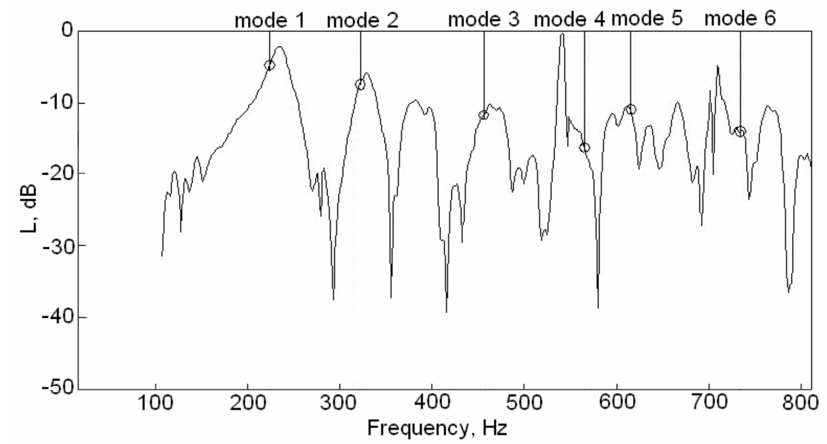


Fig. 5. a) Sound spectrum of the snare drum excitedat the point no. 175 for microphone placed along the main axis of symmetry; b) the same but for the microphone placed out of the main axis of symmetry. The spectral position of modal frequencies is denoted.

4. Conclusions

The general conclusions of our work are as follows:

- The modes of vibration of the snare drum were generally similar to those reported in the literature. The modal frequencies and f_i/f_1 ratios found for particular mode shapes were different from those reported in the literature.
- The modal frequencies were not directly related to the frequencies of the sound spectrum peaks.
- The mode (0, 1) was a strongly radiated mode only in the case of central excitation.

- The indefinite pitch of the snare drum sound resulted from the nonharmonic relation of its spectral maxima and the lack of a single strong component in its spectrum.
- Total auditory impression generated by the snare drum resulted from the radiation of the whole drum's system.

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