ARCHIVES OF ACOUSTICS
27, 1, 55–63 (2002)

ACOUSTICAL INVESTIGATIONS OF THE INFLUENCE OF MOISTURE CONTENTS IN OAK WOOD ON THE DAMPING OF ITS FREE VIBRATIONS

T. ZIELIŃSKI

Institute of Paper Managing and Art of Printing
Technical University of Łódź
(90-924 Łódź, Wólczańska 223, Poland)
e-mail: tadziel@ck-sg.p.lodz.pl, fax: (+48-42) 631-38-01

This paper presents some results of acoustical investigations of the influence of moisture contents in oak wood on the damping coefficient of its free vibrations. It has been found out that a change of the damping coefficient is observed only in the range of the inhibition water, but not in that of the capillary one. The values of the damping coefficient versus moisture content in oak wood were found out to be different during the adsorption (chemical, physical) process of water and the desorption one. This diversity is similar in shape to a hysteresis loop which upper curve corresponds to the moistening process and the lower one to the drying process.

1. Introduction

The results presented in this paper is a part of the larger problem of noise abatement of debarking drums applied in the paper industry. The Sound Pressure Level (SPL) of noise emitted by them achieves 130 dB. The main source of noise emission of a debarking drum are vibrations of the rotating steel shell of the drum caused by the impacts on the raw material (wood). As a result of the experimental tests of different kinds of models of debarking drums, some solutions that can be applied for decreasing the noise level have been found.

In Figs. 1a and 1b there are shown some examples of noise spectra of a debarking drum model made of a cylindrical steel shell (1 mm thick). They have been achieved during tests at rotational speeds of 20, 31.3 and 60 rev/min and the fulfilment degree $\varphi = 0.5$ using dry wood logs (Fig. 1a) or wet ones (Fig. 1b) [2]. As one can see from these figures, the rotational speed and moisture content in the wood logs affect the noise emitted by the tested drum model. As a result one can conclude that the change of the moisture content in the raw material (wood) affects free vibrations of the cylindrical shell of the drum model and, in consequence, its SPL.

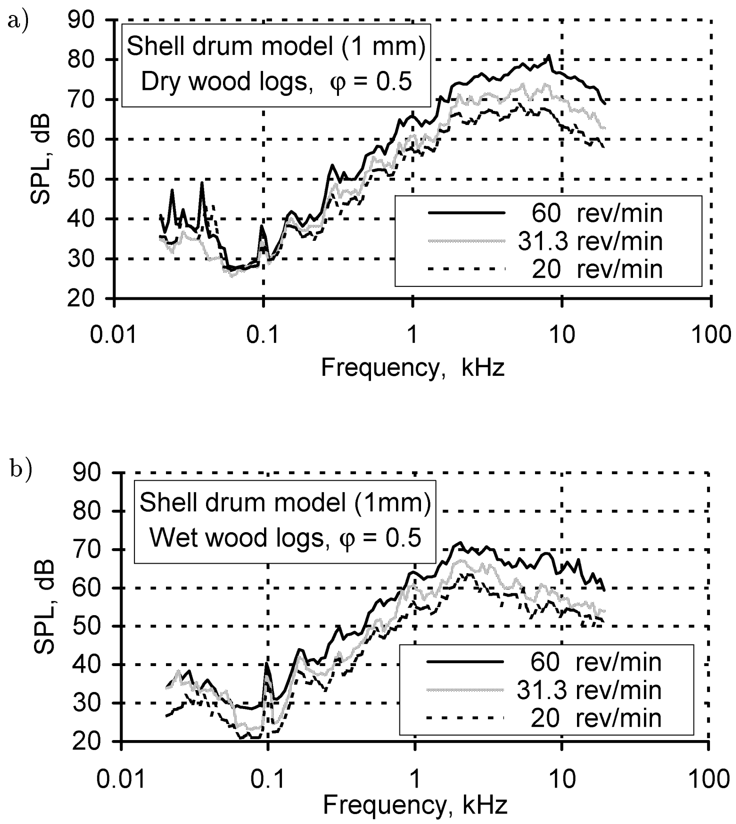

Fig. 1. Noise spectra of the drum model made of a cylindrical steel shell (1 mm thick) at rotational speeds: 20, 31.3, 60 rev/min; a) filled up with dry wood logs; b) filled up with wet wood logs. Fulfilment degree $\varphi = 0.5$.

2. Method of investigations

The tests were made in order to find out the influence of the moisture content on the damping (due to internal friction) coefficient of free vibrations of the logs (ϕ 10×60 mm) made of oak wood. The tested wood logs of various moisture contents were struck into a big steel log and the decreasing acoustic pressure (mPa) versus time, observed after an impact, was recorded. Three records have been made for two situations of the wood log defined by the fibre layers in its transversal section. The measurements were done separately for the moistening process and the drying one. The results obtained in a Vibration Analyser (suitable for the changing acoustic pressure versus time) were sent to a computer and transformed in order to get time graphs in dB. From envelopes of the latters shaped as straight lines the coefficients of inclination of the slopes in dB/ms have been read. Thus, a logarithmic decrement of damping, defined as $h = \ln(a_n/a_{n+2})$ [4] (where a_n, a_{n+2} — successive amplitudes of the decreasing acoustic pressure on the same slope), was found. The tests were made for vibrations of the wood log in the directions perpendicular and parallel with reference to the layers of fibres. In Figs. 5 – 8 some expected values (EV) of the damping coefficient h, defined in distributive series from 6 measurement values for a given moisture, are given. The length of the class interval was equal to 0.3 dB/ms and the lower threshold of the variability interval was 2.6 dB/ms. Approaching them the regression curves have been presumed to be exponential functions with coefficients defined separately for each of the measurement series [3].

3. Test equipment

The main part of the stand (Fig. 2) where the tests were conducted, was a short steel log (ϕ 50 × 50 mm) placed on a soft base (polyurethane's boiling 10 cm thick). The main axis of the steel log was deviated from the impact direction (coinciding with the wood log axis) by about 4 deg. Its natural frequency of vibrations (calculated) was beyond the

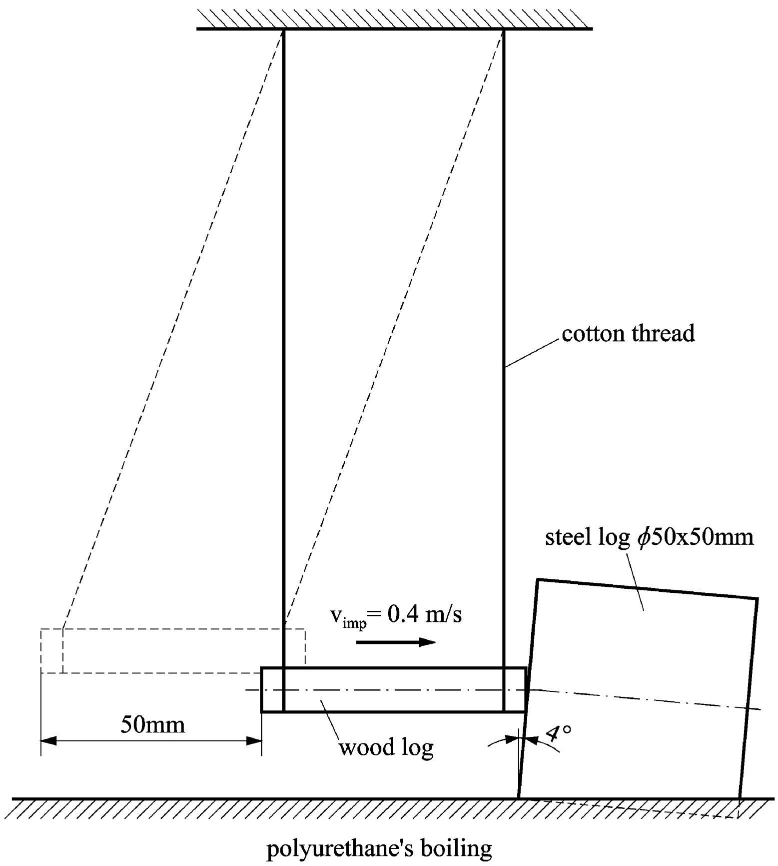

Fig. 2. Scheme of the stand for investigations of the influence of moisture contents in oak wood on the damping of its free vibrations.

measurement range. The impact velocity of the wood log, hung up on two elastic and very thin (about 0.2 – 0.3 mm) cotton threads, was constant ($v_{\text{imp}} = 0.4$ m/s). The tests were made in an anechoic chamber. For the measurements a B&K Impulse Precision Sound Level Meter type 2209, a Vibration Analyser type 2515 and a computer IBM with a GPIB interface system have been used. The microphone was situated in the impact direction at a distance of 0.5 m from the source of noise.

4. Results

Figure 3 shows some auxiliary curves attained from the measurements; they display the dependence of the moisture content on time for the tested wood log during both the moistening process and the drying one. Measurements of the mass of the tested wood log, needed for finding the relation between its moisture content and the drying/moistening time, were done with a laboratory balance of 0.1 mg precision.

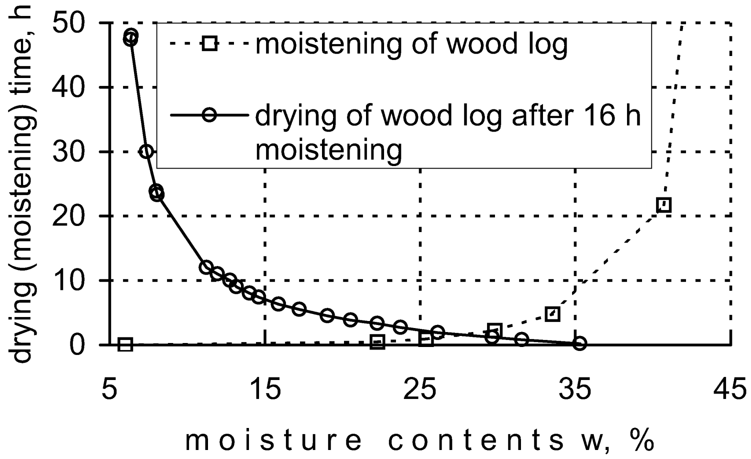

Fig. 3. Dependence of the moisture contents (in %) on time (in hours) of the tested wood log in the moistening and/or drying process.

Figures 4 and 5 show two example records of the decreasing acoustic pressure (suitable to flexural free vibrations of the tested wood log in the direction perpendicular to the layers of its fibres) versus time observed after an impact on the wood log marked out as "30". Figure 4 shows the decreasing acoustic pressure for a dry wood log (moisture content $w = 8\%$). Figure 5 shows the same for a wet wood log ($w = 26.5\%$).

The results obtained from the tests are presented in the following figures. A change of the values of the damping coefficient versus moisture content in the tested wood log is shown in Figs. 6–9. Figure 6 shows a change of the damping coefficient in the moistening process for vibrations in the direction perpendicular to the layers of fibres. Figure 7 shows (continuous line) a change of the damping coefficient for vibrations in the same direction perpendicular to the layers of fibres, but in the drying process. Figures 8

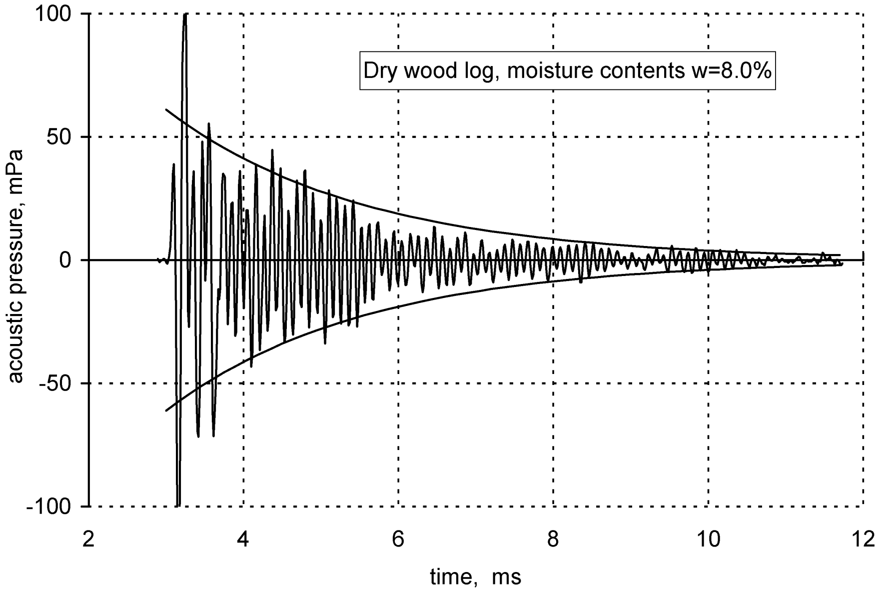

Fig. 4. Decreasing acoustic pressure, suitable to flexural free vibrations of the dry wood log in the direction perpendicular to the layers of its fibres, versus time; Envelope: $|p| = 66.2 \cdot 10^{-3.60(t-3.125)/20}$.

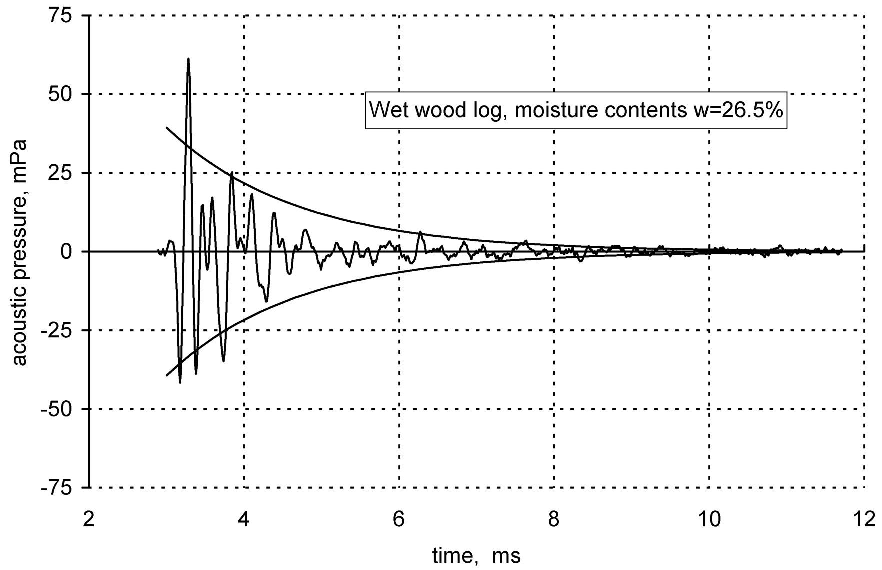

Fig. 5. Decreasing acoustic pressure, suitable to flexural free vibrations of the wet wood log in the direction perpendicular to the layers of its fibres versus time; Envelope: $|p| = 25.1 \cdot 10^{-4.75(t-3.125)/20}$.

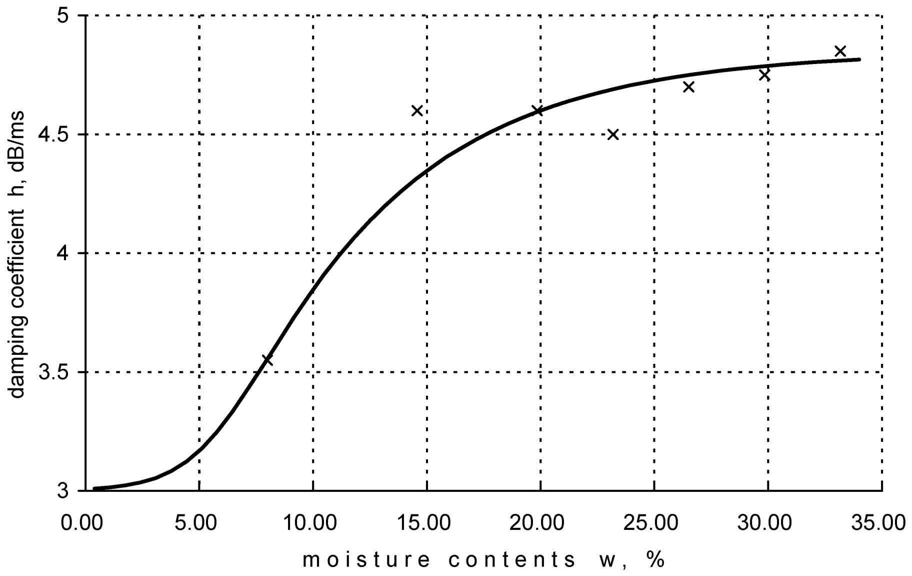

Fig. 6. Change of the damping coefficient in the oak wood log during moistening process versus moisture content for vibrations in the direction perpendicular to the layers of fibres; Approaching curve: $h = 4.85 - 1.85(5e^{0.7(w-8)} + 1)^{-1/5}$.

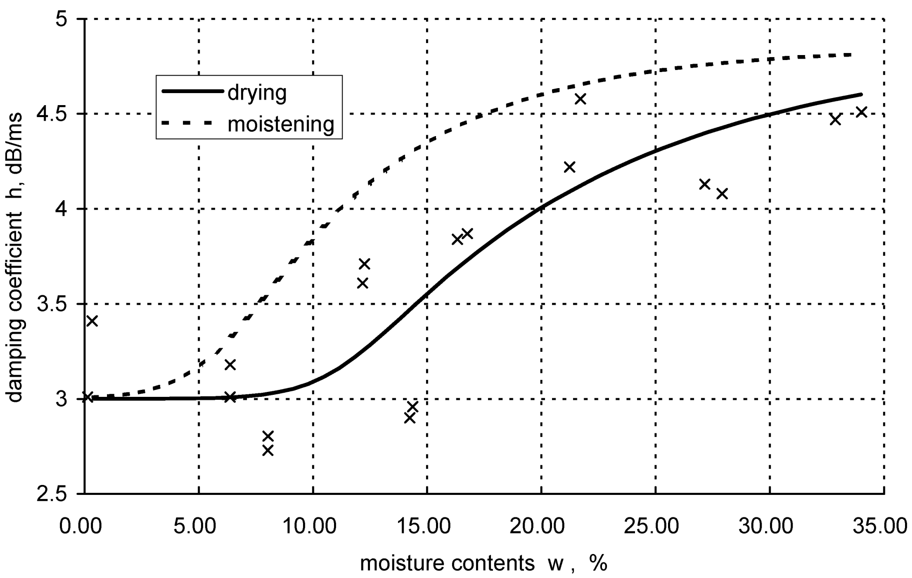

Fig. 7. Change of the damping coefficient in the oak wood log during drying process versus moisture content for vibrations in the direction perpendicular to the layers of fibres; Approaching curve: $h = 4.85 - 1.85(8e^{0.7(w-14)} + 1)^{-1/8}$.

and 9 (continuous lines) show changes of the damping coefficient during vibrations in the direction parallel to the layers of fibres. Figure 8 shows the change of the damping coefficient in the moistening process, and Fig. 9 — in the drying one.

As one can see the characteristic feature of all these graphs (Figs. 6, 7 and 8, 9) is a diversity of the meaning (values) of the damping coefficient versus moisture contents. A hysteresis loop of the damping coefficient for vibrations in the direction perpendicular to the layers of fibres (see Fig. 7) consists of two curves: the first one (Fig. 6) — with bigger values — corresponding to the moistening process, and the second one (continuous line in Fig. 7) — with smaller values — corresponding to the drying process.

Similarly, for vibrations in the direction parallel to the layers of fibres one can create a hysteresis loop (see Fig. 9) using the curves corresponding to the moistening and drying processes (continuous lines from Figs. 8 and 9).

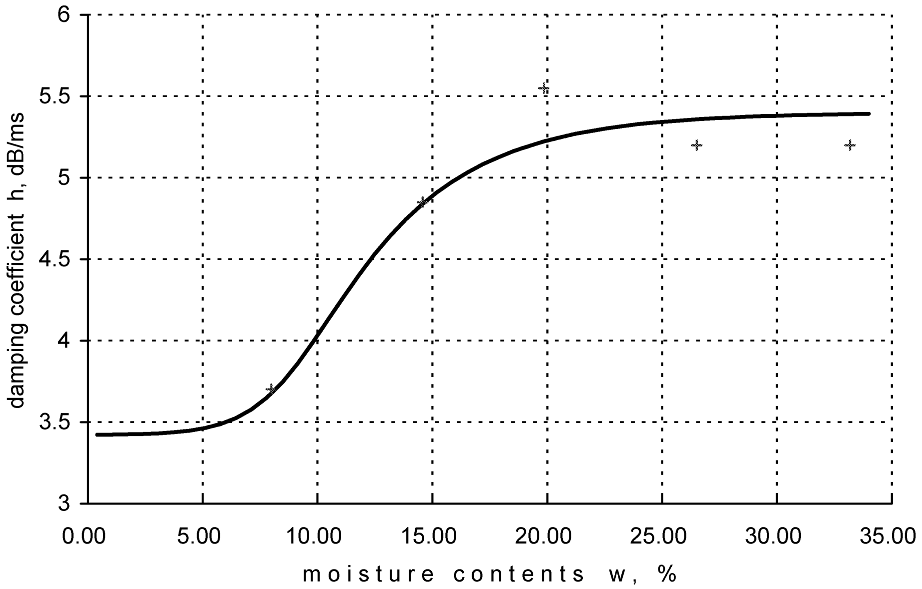

Fig. 8. Change of the damping coefficient in the oak wood log during moistening process versus moisture content for vibrations in the direction parallel to the layers of fibres;
Approaching curve: $h = 5.4 - 1.98(3.2e^{0.7(w-10.5)} + 1)^{-1/3.2}$.

There are two possible explanations of this diversity of meaning. As the most probable one we can mention different moisture contents in the wood log following its depth during the adsorption (chemical, physical) and desorption of water. It affects the change of the strength of the wood fibres and other physical and chemical features, and, in consequence, causes an increase or decrease of its natural frequency [1] and the damping coefficient. Another important explanation may be some different physical features of the imbibition water and the capillary one inside of the wood, but this question is not solved yet and is still of interest of the physicists of wood.

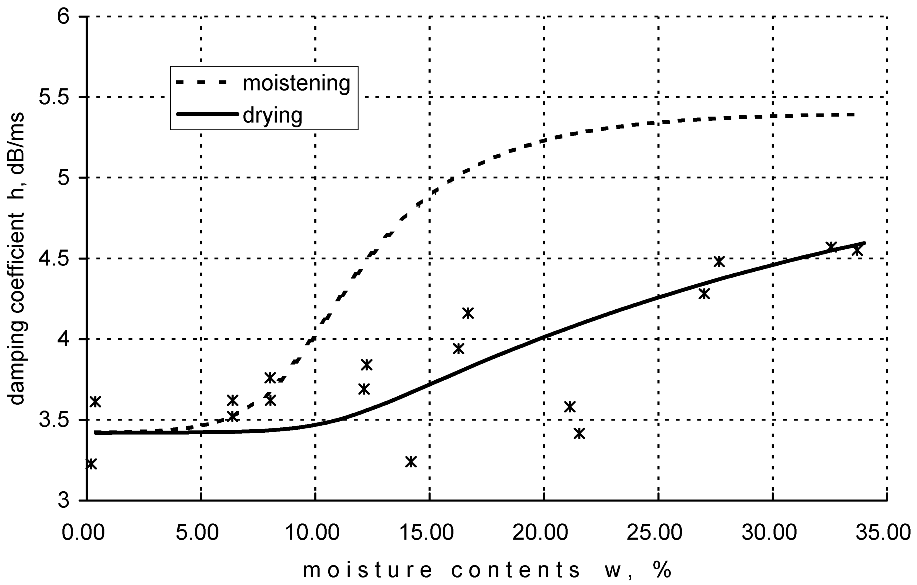

Fig. 9. Change of the damping coefficient in the oak wood log during drying process versus moisture content for vibrations in the direction parallel to the layers of fibres;
Approaching curve: $h = 5.4 - 1.98(18e^{0.7(w-15)} + 1)^{-1/18}$.

5. Conclusions

1. Acoustical methods can be of use in the investigation not only of the structure of materials (in particular so strongly nonhomogeneous as wood) [1], but also of the coefficient of damping of its free vibrations.

2. A strong influence of the moisture content in wood on the damping of its free vibrations is observed only in the range of the imbibition water, but not in that of the capillary one, i.e. up to 33% of moisture contents.

3. There is a diversity of the meaning of the damping coefficient of the wood log versus its moisture content in the range up to 33%. This diversity of values can be expressed by the hysteresis loop which upper curve corresponds to moistening process and lower one to drying process.

4. The values of the damping coefficient depend on the direction of vibrations. Bigger ones are observed in the direction parallel to the layers of fibres, while the smaller ones in the perpendicular one.

References

[1] T. Zieliński, *Influence of moisture of oak wood on its natural frequency of vibrations — Results of the experimental tests*, Proceedings of the Fourth International Congress on Sound and Vibration, pp. 1077–1082, St. Petersburg 1996.

[2] T. Zieliński, *Some results of acoustical investigations on scale models of barking drums*, Proceedings of the Third International Congress On Air — and Structure — Borne Sound and Vibration, **1**, pp. 589–596, Montreal 1994.

[3] T. Zieliński, *Dependence of Damping Coefficient of Vibrations of Oak Wood on its Moisture Contents — Results of the Experimental Tests*, Proceedings of the 7th International Congress On Sound and Vibration, Garmisch-Partenkirchen 2000.

[4] Z. Osiński, *Tłumienie drgań*, PWN, Warszawa 1997.