Accuracy of Prediction Methods for Sound Insulation of Homogeneous Single Baffles

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Abstract

The article presents a comparative analysis of determined spectral responses of the airborne sound insulation of single homogeneous baffles using computational and experimental methods. Calculations using theoretical models, such as mass law, the Sharp and Davy models, SoundFlow software and laboratory tests concerned nine plates made of plastic, steel, aluminium and rubber, which are homogeneous materials. These materials are used in the construction of walls in vibroacoustic protection, such as acoustic barriers, machine operating field shields and sound insulating enclosures. Apart from analysing the spectral responses of the sound insulation of the plates, the weighted single-number sound reduction indices R_w, calculated by using prediction methods and laboratory measurements, were compared. Research has shown computational errors of about 6-7 dB for mass law and the Sharp model and about 3 dB for the Davy and Davy-Sharp models and SoundFlow software.

Keywords: sound insulation, homogeneous single baffles, calculation models

1. Introduction

The article focuses on the sound insulating properties of homogeneous single baffles, of different material and thickness. The tested materials are used in the construction of walls in vibroacoustic protection, such as acoustic barriers (plastic plates), and sound insulating enclosures (steel, aluminium and rubber plates). Plastic plates, including plexiglass, may be used in the construction of shields protecting the operational field of the technological process. The basic parameter of materials used in constructional solutions of anti-noise protections, is sound insulation, which can be determined in laboratory, in situ conditions and also using theoretical models. The main aim of the study was to check which calculation model best approximates the spectral responses of sound insulation of baffles obtained from laboratory tests.

2. Calculation of sound insulation

The calculations of sound insulation by single baffles using theoretical models have been analysed in numerous works [2-7, 10]. Among the best-known calculation models for the sound insulation of homogeneous single baffles, it is worth mentioning mass law [3] and the Sharp [10] and Davy [4] models. In [5], a model that is a combination of the Davy model for lower frequencies and Sharp for higher frequencies (Davy-Sharp) was proposed.

The validation of sound insulation calculations of the plates carried out with the use of the mentioned models and commercial SoundFlow software [1] was performed in relation to the results obtained from laboratory tests, which were carried out in the Reverberation Room Unit at the Department of Mechanics and Vibroacoustics of the AGH UST in Krakow. The laboratory meets most of the guidelines contained in the standard ISO 10140-2:2011 [9], except for the reduced dimensions of the measuring window (the required area is 10 m^2) [11]. The measurement method, described in [8,11], uses the difference in sound pressure levels between the transmission and receiving rooms, assuming that the acoustic fields in both rooms are diffuse and the acoustic energy is transferred only through the tested baffle.

The physical properties of the tested baffles are presented in Table 1 [3].

Table 1. Physical properties of the tested baffles [3]

	Plate thickness, h, [m]	Young's modulus, E, [GPa]	Density, ρ, [kg/m^3]	Poisson's ratio, ν	Loss factor, η
Plexiglass	0.003 0.005 0.015	3.5	1150	0.35	0.02
Polycarbonate	0.06	2.3	1190	0.35	0.003
Polyethylene	0.01	1.4	950	0.44	0.03
Polypropylene	0.01	1.4	920	0.4	0.09
Steel	0.001	207	7850	0.3	0.01
Aluminium	0.002	70	2800	0.35	0.01
Rubber	0.003	0.006	1825	0.48	0.00075

Figures 1-3 show the results of the calculation and calculated errors (RMSE), which were the root mean square of differences between the R values calculated from the models (software) and those obtained from laboratory tests for plates with different thickness, for 21 centre frequencies of 1/3 octave bands from 50 to 5000 Hz.

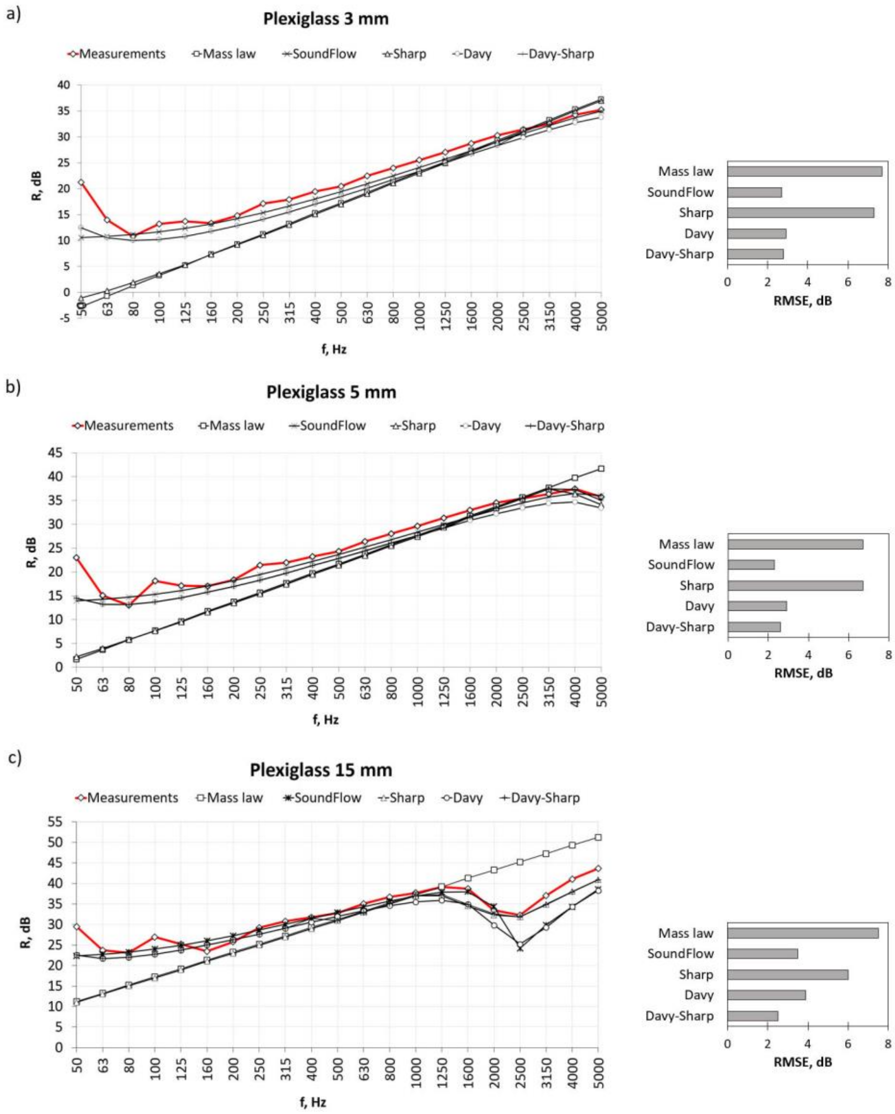

Figure 1. Spectral responses of the sound insulation obtained from laboratory tests and using the following models: mass law, Sharp, Davy, Davy-Sharp, and SoundFlow software for plexiglass plates with the thickness: a) 3 mm, b) 5 mm and c) 15 mm, with the root mean square errors

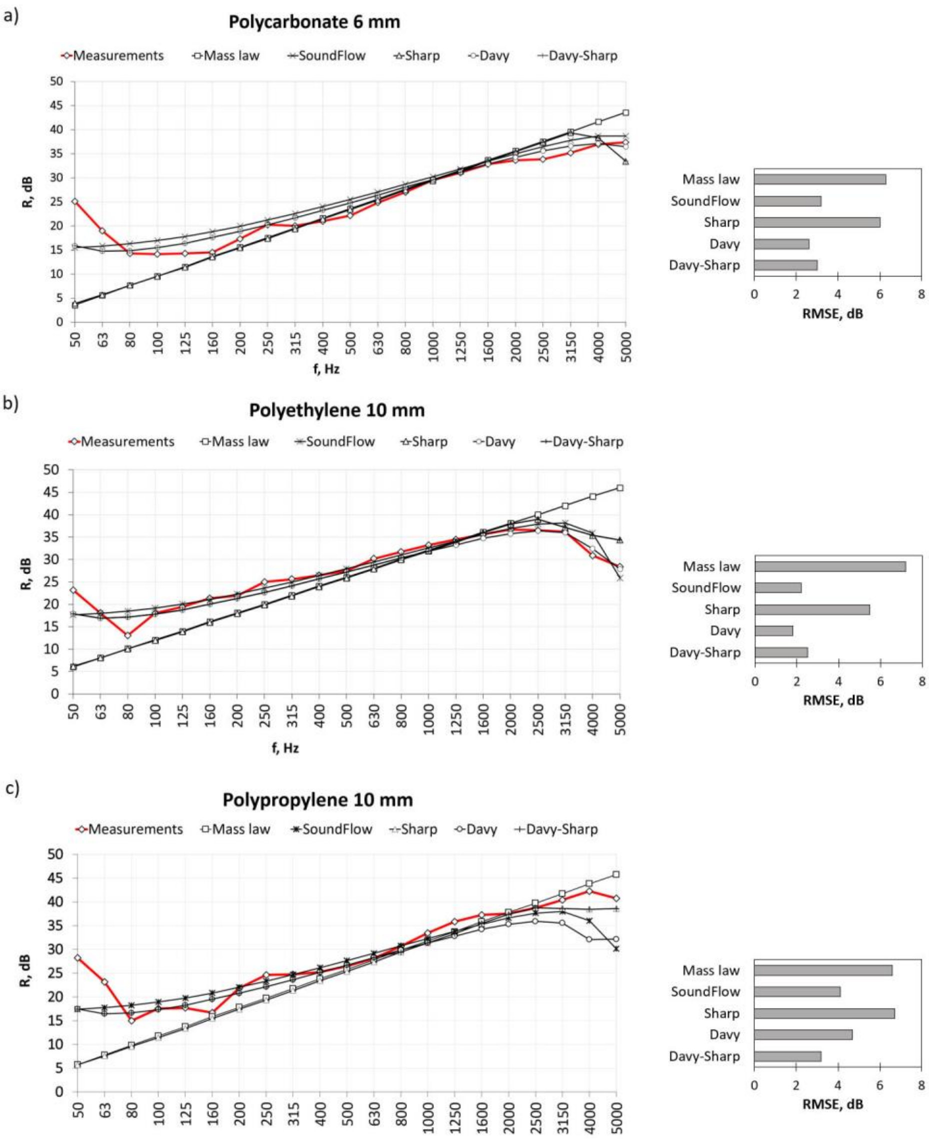

Figure 2. Spectral responses of the sound insulation obtained from laboratory tests and using the following models: mass law, Sharp, Davy, Davy-Sharp, and SoundFlow software for polycarbonate, polyethylene and polypropylene plates with the thickness: 6 mm, 10 mm and 10 mm, with the root mean square errors

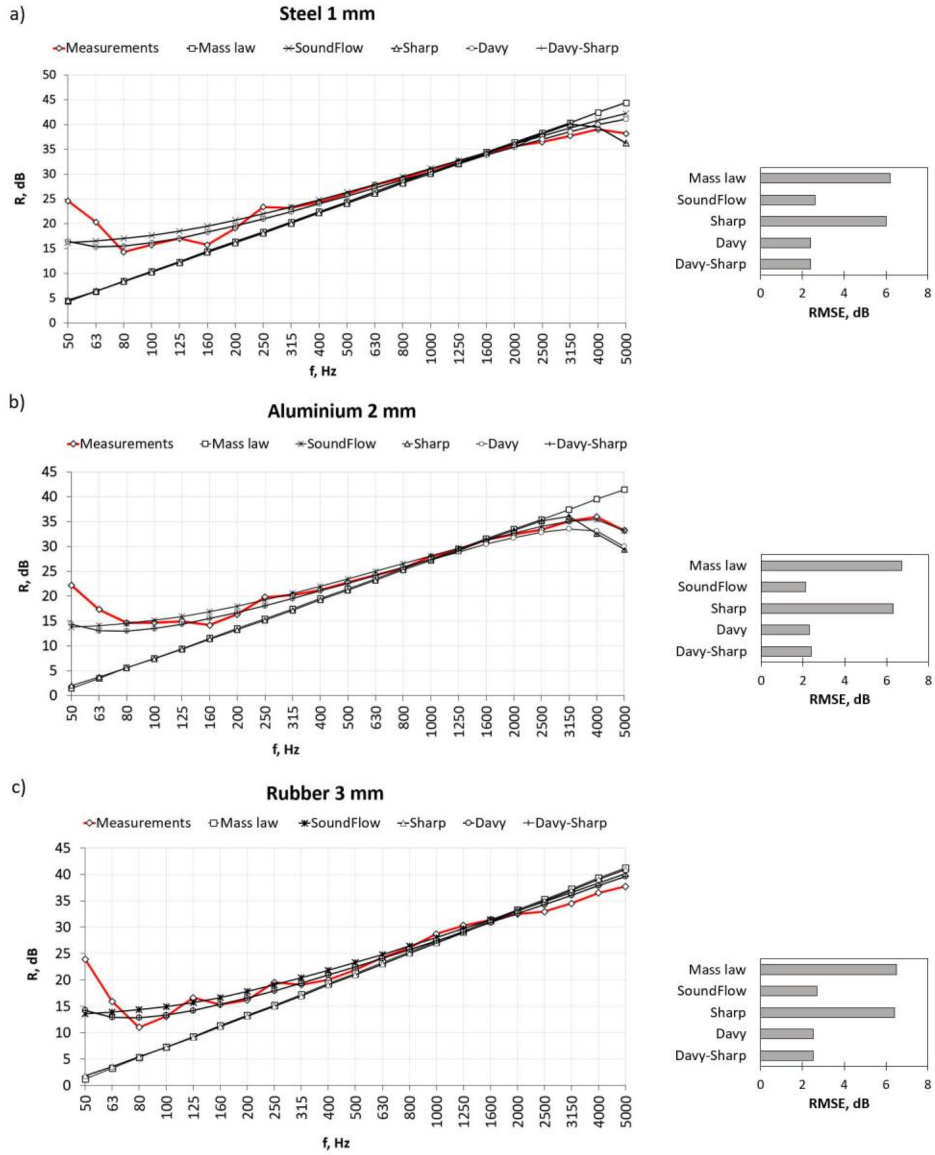

Figure 3. Spectral responses of the sound insulation obtained from laboratory tests and using the following models: mass law, Sharp, Davy, Davy-Sharp, and SoundFlow software for steel, aluminium and rubber plates with the thickness: 1 mm, 2 mm and 3mm, with the root mean square errors

3. Comparative analysis of the accuracy methods for predicting the sound insulation of homogeneous single baffles

Figure 4 shows the root mean square error values for prediction methods, averaged from 9 plates shown in Figures 1-3. RMSEs refer to the spectral responses of sound insulation of baffles obtained from laboratory tests. All the analysed sound insulation prediction methods, such as mass law, the Sharp model, the Davy model, the Davy-Sharp model and SoundFlow software, showed averaged error values from about 3 to 7 dB.

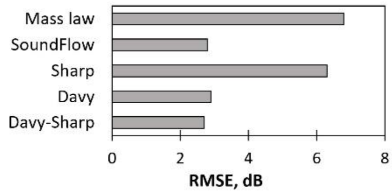

Figure 4. Averaged root mean square error values for prediction methods: mass law, Sharp and Davy models, Davy-Sharp model and SoundFlow software

Higher values of the RMSE (approx. 6 to 7 dB) were given by the mass law and Sharp models. Comparative analysis of the accuracy of other prediction methods, shown in Fig. 4, does not show significant differences between the Davy model, Davy-Sharp model and SoundFlow (RMSE approximately 3 dB).

On the basis of the spectral responses of the sound insulation obtained using calculation models and SoundFlow software, single-number weighted sound reduction indices R_w were determined, which are shown in Table 2 together with the values of this parameter calculated on the basis of laboratory tests of plates.

Table 2. Comparison of R_w and RMSE for analysed plates.

Plate designation	R_w, dB					
	Measure ments	Mass law	Sound Flow	Sharp model	Davy model	Davy-Sharp model
Plexiglass 3 mm	25	21	25	21	23	24
Plexiglass 5 mm	29	26	28	26	27	29
Plexiglass 15 mm	35	35	34	33	32	34
Polycarbonate 6 mm	28	28	30	28	29	29
Polypropylene 10 mm	32	30	32	30	31	31
Polyethylene 10 mm	33	30	32	30	31	32
Steel 1mm	30	29	31	28	30	30
Aluminium 2 mm	27	26	28	25	27	27
Rubber 3 mm	27	25	28	25	27	27
RMSE		2.2	1.1	2.4	1.6	0.7

Comparing the values of single-number weighted sound reduction indices R_w (Table 2), the Davy-Sharp model has the smallest root mean square error (0.7 dB). SoundFlow software is also a quite accurate tool for determining R_w (RMSE = 1.1 dB) compared to the Davy (RMSE = 1.6 dB) and Sharp (RMSE = 2.4 dB) models.

Figure 5. shows histograms specifying the frequency (in %) of prediction error, i.e. the difference between the predicted and measured R_w for 9 homogeneous single baffles.

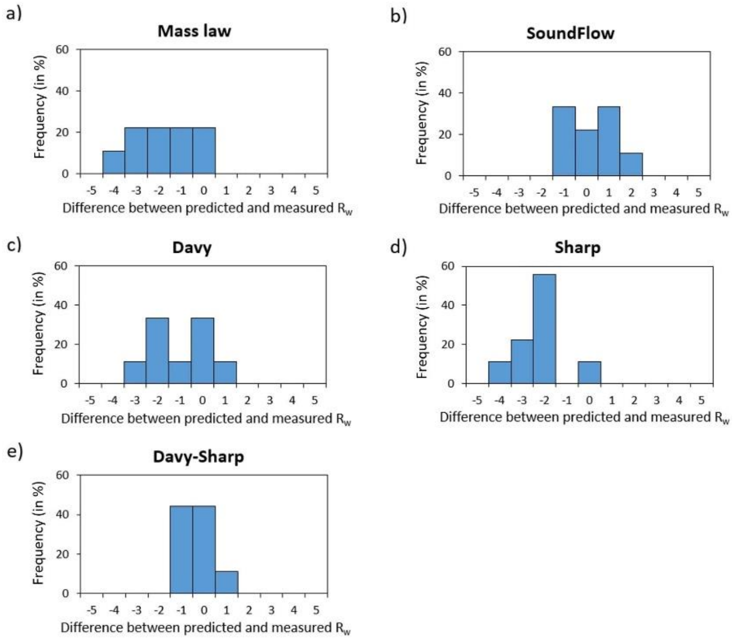

Figure 5. Histograms of the frequency (in %) of prediction error, i.e. difference between the predicted and measured R_w for 9 baffles, using prediction methods: a) mass law, b) SoundFlow software, c) Davy model, d) Sharp model and e) Davy-Sharp model

It can be seen that the use of the Davy-Sharp model showed the smallest prediction error of ±1 dB, among the methods analysed. 44% of observations show no error between the predicted and measured R_w values. Prediction of the R_w parameter using SoundFlow software shows a prediction error of ±1 dB for 89% of observations, while 22% of observations show no error between the predicted and measured R_w values.

4. Conclusions

As part of the article, the spectral responses of sound insulation, along with the single-number weighted sound reduction indices R_w, were determined for homogeneous single baffles using well-known theoretical models. The tests, carried out for nine homogeneous single baffles, showed computational errors of about 6-7 dB for mass law and the Sharp model and about 3 dB for the Davy and Davy-Sharp models and SoundFlow software. The best prediction methods to obtain the R_w parameter are the Davy-Sharp model and, to a lesser extent, SoundFlow software.

Acknowledgments

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