ACOUSTIC PARAMETERS OF DIFFERENT SHAPES OF MAPLE WOOD LOUDSPEAKER ENCLOSURES

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Abstract: This paper deals about the sound performance of loudspeakers and their influence by the design of the enclosures. Both enclosures were made of maple wood. Acoustic filling was also installed in both baffles, if it could improve the acoustic properties. Both speaker systems were subsequently tested in an anechoic room using the "sine sweep" method to compare their resonance characteristics and sound pressure level.

Keywords: Loudspeaker enclosure, Sound pressure level, resonance characteristics, maple

1. INTRODUCTION

When discussing speaker cabinets or baffles, it is essential to consider the significant presence of wood and wood-based materials in the industry. Agglomerated materials are frequently utilized due to their homogeneous properties; however, the unique qualities of solid wood should not be overlooked [1]. Solid wood stands out not only for its distinctive appearance but also for its purely natural character, which holds particular importance in modern times.

The sound performance of loudspeakers can be heavily influenced by the design of the enclosures, including factors such as the chosen shape and the material used, along with its inherent properties. While loudspeakers of conventional shapes crafted from commonly used materials are prevalent, they may not always yield the optimal effects on sound output. This study aims to address this crucial aspect by examining how different design elements impact the audio performance of loudspeakers.

2. MATERIALS AND METHODS

The maple wood used for the production of both shapes of enclosures had a density of 602 ± 18 kg/m^3. This wood was chosen as a representative of wood with good acoustic properties used, among other things, for the production of acoustic musical instruments.

At the beginning, a design proposal was created, which was based on the already known resonance characteristics of basic geometric shapes. According to previous studies, the spherical shape of the baffle shows the smoothest curve and a block with beveled front edges with an eccentric speaker behaves well [2]. However, the spherical shape of the baffle is very complicated to manufacture. The goal was to create a new design that would stand out among several loudspeaker baffles with its uniqueness. We decided on an interesting combination of already known shapes and the result is a new baffle in the shape of a teardrop.

2.1. Production of enclosures

This study focused on the development of two distinct types of baffles. The first type, illustrated in Figure 1, is a handcrafted baffle created according to the proposed design. It was made on a lathe using naturally dried maple wood. The second type, shown in Figure 2, is a traditional cubic sound box manufactured using CNC technology from the same maple trunk. Using identical wood allowed for a direct comparison between the innovative drop-shaped sound box and the conventional block-shaped design. Each enclosure type was produced three times, and frequency characteristics were measured across all six to minimize the impact of potential manufacturing variations on the r

Figure 1. Drop-shape enclosure.

Figure 2. Cuboid-shape enclosure.

Speaker driver that was used to measure the characteristics of the individual enclosures was the same each time to make the results comparable. It was specifically a Dayton RS 75-4 converter. The inverter characteristics are described in Table 1 below.

Impedance	4 Ω	Sd	12 cm^2
Re	3.1 Ω	Vd	1.31 cm^3
Le	0.72 mH 1 kHz	BL	2.01 Tm
Fs	177 Hz	Vas	0.14 l
Qms	5.76	Xmax	1.1 mm
Qes	0.97	VC Diameter	16 mm
Qts	0.83	SPL	85.2 dB
Mms	1.1 g	RMS Power Handling	15 W
Cms	0.72 mm/N	Usable Frequency Range (Hz)	170 - 20 000 Hz

Table 1. Speaker driver characteristics.

Where is ***Re***: DC resistance, ***Le***: Voice coil inductance, ***Fs:*** Resonant frequency, ***Qms***: Mechanical quality factor, ***Qes***: Electrical quality factor, ***Qts***: Total quality factor, ***Mms:*** Moving mass, ***Cms***: Mechanical compliance of the suspension, ***Sd***: Effective piston area, ***Vd***: Displacement Volume, ***BL***: Force factor, ***Vas***: Equivalent volume, ***Xmax***: Maximum excursion, ***VC Diameter***: Voice coil diameter, ***SPL***: Sound Pressure Level, ***RMS Power Handling***: The amount of electrical power a speaker can handle before damage.

2.2. Software measurements

Utilizing the Room EQ Wizard (REW) software for room acoustics and audio analysis we measured Sound Pressure Level (SPL) [3]. This is a crucial metric in audio engineering, as it quantifies how loud a sound is perceived and is essential for evaluating the performance of audio equipment, including loudspeakers.

In this study, we employed the retuned harmonic signal method, commonly referred to as “retuned sine” or “Sine Sweep,”. This technique was implemented to accurately measure the loudspeaker’s impulse response. The methodology involves exciting the system with a harmonic signal whose frequency increases over time in an exponential manner, specific to our case. The system's response to this signal is recorded, enabling the extraction of the impulse response through subsequent processing. This can be achieved either by filtering the recorded signal with an inverse filter or by performing division in the spectral domain, though the latter method does have certain limitations [4].

One of the significant advantages of using the retuned harmonic signal method is its ability to separate harmonic distortions from the primary response, thereby providing a clearer and more accurate measurement of the loudspeaker's performance. For this study, the measurements were conducted at a high sampling frequency of 192 kHz with a 16-bit depth, ensuring a detailed capture of the audio signal. The duration of the sine sweep was set to 512,000 samples, equivalent to 2.7 seconds [5]. This duration was deliberately chosen to be longer than the room's reverberation time to avoid any adverse effects on the measurement accuracy. To ensure reliability, each measurement was repeated four times.

The timing reference for the measurements was maintained using the feedback connection of the sound card, ensuring precise synchronization. The loudspeaker system was strategically positioned at a height of approximately 1.5 meters. The microphone, essential for capturing the audio response, was placed at a distance of 0.5 meters from the loudspeaker, as illustrated in Figure 1. This setup was designed to optimize the accuracy and reliability of the measurements, thereby facilitating a comprehensive analysis of the loudspeaker's impulse response.

3. FINDINGS AND ARGUMENT

As the differences between the wood species were not so significant during the production of speaker enclosures, the following Figure 3 shows a comparison of both shapes of the maple enclosure. In this case, without internal filling [6].

In Figure 3, the differences between the curves are distinctly visible, particularly from frequencies above approximately 400 Hz. Significant deviations occur between 1 and 2 kHz, where the teardrop-shaped enclosure exhibits a greater drop in sound pressure level, about 6 dB lower than that of the cuboidal enclosure. Additionally, a deviation occurs around 200 Hz higher in the cuboidal enclosure compared to the teardrop shape. Notably, a pronounced peak is observed in the teardrop shape between 4 and 5 kHz, where the curve rises by approximately 4 dB compared to the cuboidal enclosure. Thus, it can be concluded that a block-shaped enclosure without damping exhibits a slightly smoother and more balanced frequency response compared to a teardrop-shaped enclosure.

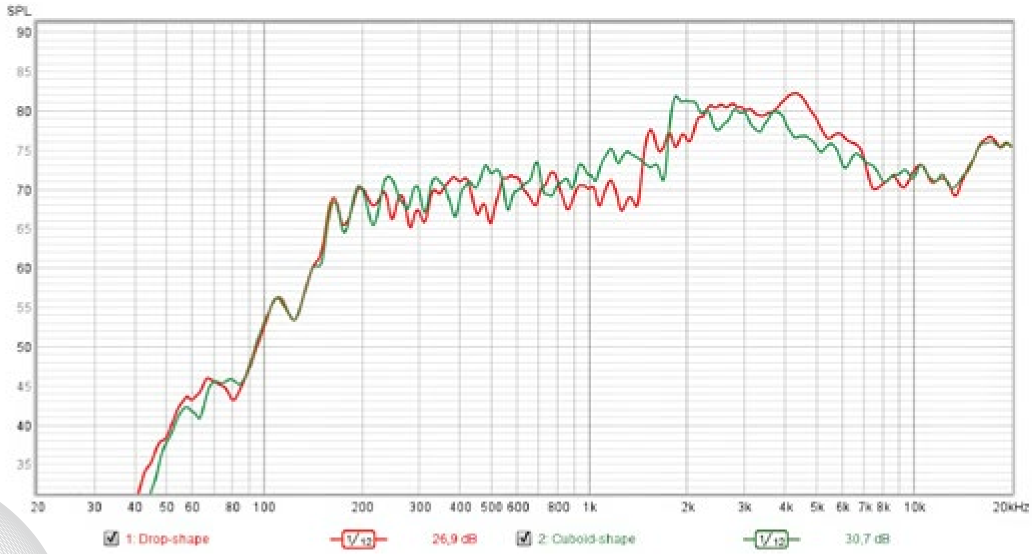

Figure 3. Comparison of frequency characteristics of loudspeaker enclosures.

By damping the baffles, both curves straightened out and the more prominent dips softened, as illustrated in Figure 4. Although there remains a noticeable deviation between the baffles in the previously described frequency ranges, these deviations are less pronounced after damping. The peak between 4 and 5 kHz remains unchanged, which is likely due to the diffraction effect caused by the front edge of the teardrop-shaped enclosure [7,8]. Despite the damping, the block-shaped enclosure continues to exhibit a smoother frequency response. It is important to note that the differences between the two enclosures are not highly significant, and neither response curve exhibits substantial dips, indicating an overall improvement in the frequency characteristics for both shapes [9].

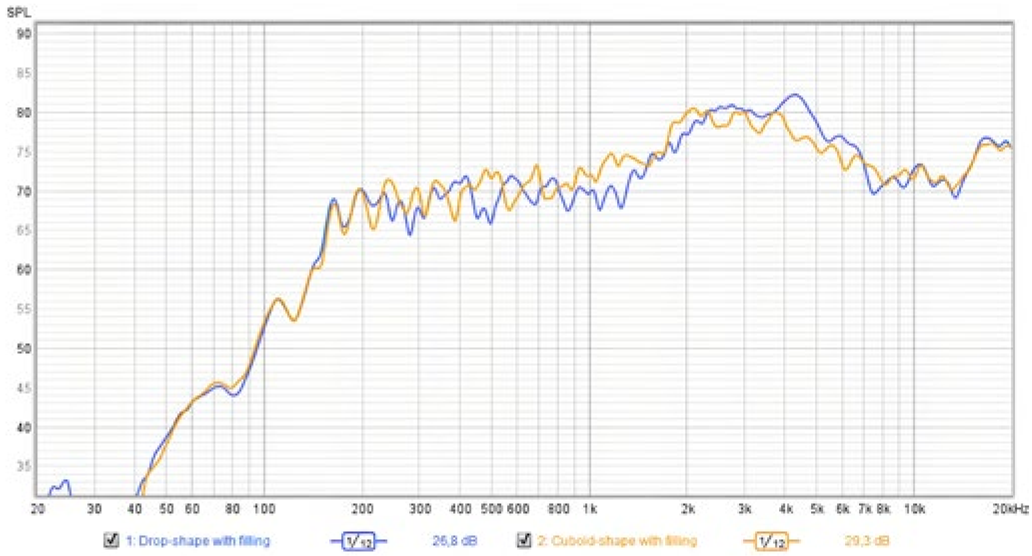

Figure 4. Comparison of frequency characteristics of loudspeaker enclosures with filling.

4. CONCLUSIONS

During the assessment of loudspeaker frequency characteristics, discernible disparities were noted between cuboid-shaped and teardrop-shaped enclosures. Notably, the cuboid-shaped enclosure exhibited a more uniform and balanced frequency response in comparison to its teardrop-shaped counterpart. These findings underscore the significant influence of both external and internal enclosure geometries on sound propagation [2]. However, it is essential to contextualize that while discernable, the magnitude of this influence may vary depending on specific design parameters and environmental factors.

Furthermore, the beneficial impact of integrating damping materials into the baffle structure was unequivocally demonstrated. This augmentation effectively attenuated baffle resonance, leading to a smoother and more refined output response, which also reported in their publications [9, 10, 11].

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REFERENCES

[1]. Čulík, M. (2013). Drevo a jeho využitie vo výrobe hudobných nástrojov: vedecká štúdia (Wood and its use in the production of musical instruments): a scientific study. Zvolen: Technical University in Zvolen. ISBN 978-80-228-2511-5.

[2]. Olson, H. F. (1969). Direct radiator loudspeaker enclosures. In Journal of the Audio Engineering Society, 17(1), 22-29.

[3]. Anderson, N. (2022). ACOUSTIC CHARACTERIZATION OF ROOMS USING DIRECTIONAL AND OMNIDIRECTIONAL SOURCES (Doctoral dissertation, Brigham Young University-Idaho).

[4]. Farina, A. (2007). Advancements in impulse response measurements by sine sweeps. In: Audio engineering society convention 122. Audio Engineering Society.

[5]. Toft, R. (2024). "Digital Audio: Sampling, Dither, and Bit Depth". Technical Matters. 11. https://ir.lib.uwo.ca/popmusicforum_techmatters/11

[6]. Kozel, J. (2021). Analysis of the acoustic parameters of wood-based speaker enclosures [diploma thesis] Prague – Department of Wood processing and Biomaterials, Faculty of Forestry and Wood Sciences, Czech University of Life Sciences, Prague, Czechia.

[7]. Gu, J., Shen, Y., Feng, X. (2021). Comments on" A Diffractive Study on the Relation Between Finite Baffle and Loudspeaker Measurement". In: Journal of the Audio Engineering Society, 69.5: 294-296.

[8]. D'appolito, J. (2016). Testing Loudspeakers: Which Measurements Matter, Part 1. Audioxpress. [Online] 10. 11. [Cited: 23. 5. 2024.] https://audioxpress.com/article/testing-loudspeakers-which-measurements-matter-part-1.

[9]. Newell, P., Holland, K. (2018). Loudspeakers: for music recording and reproduction. Routledge. ISBN 9781315149202.

[10]. Walker, P. J. (1953). The loudspeaker in the home. In: Journal of the British Institution of Radio Engineers, 13.7: 377-380.

[11]. Bauer, B. B. (1953). Acoustic damping for loudspeakers. Transactions of the IRE Professional Group on Audio, 3: 23-34. DOI: 10.1109/T-SP.1953.28133.

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