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An Experimental Study on the Effect of Acoustic Absorbers in Reducing Noise Emitted by a Top Loading Washing Machine Roman

Seyed Amir Hoseini Sabzevari [1,*] , Marzieh Noorani [1]

[1] *Department of Mechanical Engineering, University of Gonabad, Gonabad, Iran*

**Corresponding author: Hoseini.Sabzevari@gonabad.ac.ir*

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Abstract

The adverse effects of unwanted and disruptive noise in industrial and domestic applications are widely recognized. The significance of controlling such noise, particularly in household settings, has drawn the attention of many researchers to this field. This study aims to experimentally investigate the reduction of noise emitted by a vertical domestic washing machine. To this end, various acoustic absorbers were proposed and examined. A database was constructed using the results of these experiments, which includes recorded noise data from four directions around the washing machine at varying distances, in the presence of the proposed acoustic absorbers. In the proposed method, the effect of acoustic absorbers on noise intensity reduction is first evaluated. Subsequently, the impact of these absorbers on the recorded signals in the time-frequency domain is discussed. The findings indicate a direct influence of the acoustic absorbers on the recorded signals in all directions, with nearly equal intensity reductions. The reduction in sound intensity varied depending on the type of acoustic absorber used, with an average decrease of 6.35 dB. The highest and lowest performance were recorded for felt fiber and polystyrene foam, resulting in sound intensity reductions of 8 dB (10%) and 4.5 dB (4.5%), respectively. Additionally, the experiments show that the use of appropriate acoustic absorbers can significantly improve the quality of life in domestic environments by reducing unwanted and disruptive noise, thereby having a substantial positive effect on user well-being.

Keywords:

Noise control, Acoustical properties, Sound absorber, Sound pressure level, Signal processing.

1. Introduction

Noise pollution has become one of the most significant environmental concerns due to its adverse effects on human health, comfort, and overall quality of life. Excessive noise can interfere with speech communication, disturb sleep, reduce work efficiency, and contribute to both physiological and psychological disorders. Growing awareness of the harmful impacts of unwanted sound in residential and industrial environments has encouraged researchers to investigate effective noise-control strategies and develop practical mitigation methods.

In recent decades, the widespread use of household appliances has considerably increased the level of indoor noise exposure. Among these appliances, washing machines are recognized as one of the major sources of noise and vibration in residential buildings. Although modern washing machines generally satisfy standard acoustic requirements, many users still perceive their operational noise as disturbing. The complex interaction between rotating mechanical components, structural vibrations, and airflow within the machine generates a broad spectrum of noise. In vertical-axis washing machines, vibrations are mainly associated with mass imbalance within the drum and the transmission of dynamic forces through the suspension system to the cabinet structure.

Various approaches have been proposed to reduce washing machine noise. These methods can generally be classified into direct and indirect techniques. Indirect methods focus on reducing vibration levels through balancing mechanisms, suspension optimization, and active control strategies. Direct methods, on the other hand, aim to attenuate sound propagation using acoustic absorbers or active noise control systems [1, 2]. Among these approaches, sound-absorbing materials offer a simple, low-cost, and practical solution for broadband noise reduction.

Previous studies have investigated vibration suppression, noise-source identification, acoustic modeling, and advanced control techniques for washing machines [3]. However, limited attention has been paid to the comparative performance of readily available and low-cost sound-absorbing materials under practical operating conditions. Therefore, the present study experimentally evaluates the effectiveness of several commonly accessible acoustic absorbers in reducing the noise emitted from a domestic vertical-axis washing machine. Noise data were collected using low-cost acoustic sensors, and the performance of the selected materials was assessed through comparative analysis of the recorded sound signals.

2. Experimental Setup

A series of experiments was conducted using a domestic vertical-axis washing machine with a nominal capacity of 5 kg and overall dimensions of approximately 40 × 40 × 100 cm. The machine was operated under normal washing conditions at a constant rotational speed to ensure repeatability and consistency throughout the measurements. Noise generated during operation was recorded using condenser microphones with a maximum frequency response of 20 kHz and a mass of approximately 0.8 g.

To evaluate the spatial distribution of the emitted sound, microphones were positioned around the washing machine at distances of 50 cm and 100 cm from the cabinet surface. The sensors were arranged in four directions corresponding to the four sides of the machine. This configuration allowed the acoustic field surrounding the appliance to be examined and enabled comparison of the effectiveness of the sound absorbers from different observation points.

The experimental setup was designed to resemble realistic household operating conditions while maintaining acceptable control over environmental variables. During all tests, the washing machine was placed in the same location and operated under identical loading conditions. The selected measurement distances were chosen to represent typical positions of nearby occupants in residential environments.

Sound pressure signals acquired by the microphones were digitally stored for subsequent processing and analysis. The measurement arrangement provided a reliable basis for evaluating changes in sound intensity and frequency content resulting from the application of different sound-absorbing materials. The adopted setup also enabled direct comparison between the baseline condition, in which no acoustic treatment was applied, and several configurations involving commercially available low-cost absorbers. Figure 1 illustrates the locations of the acoustic sensors used for noise measurements around the washing machine.

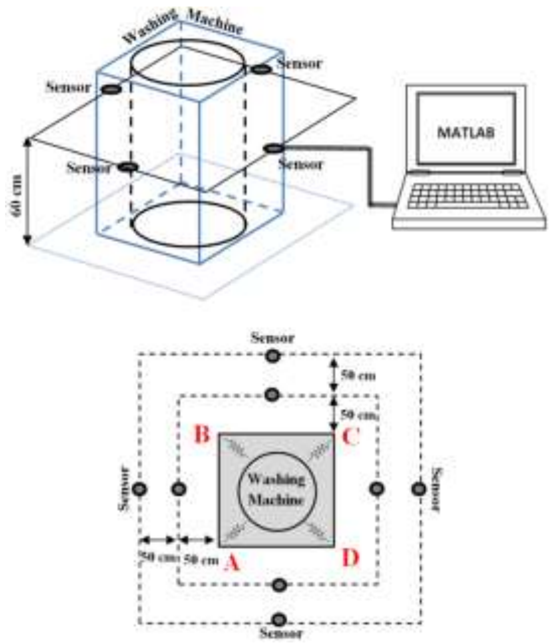

Figure 1. Experimental arrangement and sensor positions around the washing machine.

3. Experimental Procedure and Data

Seven sound-absorbing materials with different physical characteristics were selected for evaluation, including expanded polystyrene foam (Plastofoam), polyethylene foam, glass wool, felt fibers, polyurethane sponge, cardboard sheets, and corrugated plastic sheets. The selection criteria included low cost, lightweight structure, accessibility, and potential suitability for household noise-control applications.

To investigate the influence of these materials on the emitted noise, eight experimental scenarios were considered. The first experiment was conducted without any sound absorber and served as the reference condition. In the remaining seven experiments, one absorber was installed around the washing machine. The absorbers were mounted on all four sides of the cabinet so that the lateral surfaces were completely covered.

During each test, acoustic signals were recorded for 30 seconds using the condenser microphones positioned at distances of 50 cm and 100 cm from the machine. Data acquisition was performed at a sampling frequency of 40 kHz, allowing both sound intensity and frequency-domain characteristics to be analyzed. To reduce the influence of random variations and improve measurement reliability, each experiment was repeated eight times.

Several assumptions were maintained throughout the study. The mass of laundry inside the washing machine remained constant at 2 kg for all experiments. Measurements were performed during the washing phase of operation, and environmental noise conditions were assumed to be unchanged during the fourteen-day testing period. Although the measurements were not acquired simultaneously due to instrumentation limitations, all tests were conducted under similar operating conditions to ensure meaningful comparisons among the investigated absorbers. As shown in Figures 2 and 3, the application of sound-absorbing materials resulted in a noticeable reduction in the measured sound intensity at both measurement distances.

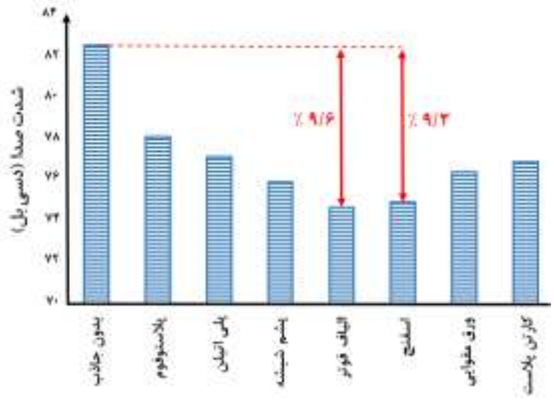

Figure 2. Average sound intensity measured at a distance of 50 cm from the washing machine

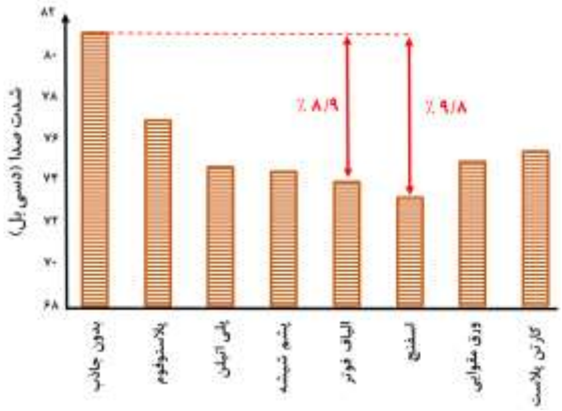

Figure 3. Average sound intensity measured at a distance of 100 cm from the washing machine

4. Results and Discussion

The measured sound intensity values clearly demonstrate the effectiveness of the investigated absorbers in reducing the noise emitted by the washing machine. At a measurement distance of 50 cm, the average sound level of the untreated machine was 82.75 dB. The application of acoustic absorbers reduced this value by an average of 6.35 dB. Among all tested materials, felt fibers exhibited the best performance, achieving an average reduction of approximately 8 dB, followed closely by polyurethane sponge with a reduction of 7.75 dB. In contrast, expanded polystyrene foam showed the lowest effectiveness, providing a reduction of approximately 4.5 dB.

Similar trends were observed at the 100 cm measurement distance. The average sound level under the reference condition was 81.25 dB, while the average reduction achieved by the absorbers reached 6.39 dB. Sponge and felt absorbers again demonstrated superior performance, reducing the sound level by approximately 8 dB and 7.25 dB, respectively. The consistency of these results at both measurement distances indicates that increasing the distance between the sound source and the microphone did not significantly alter the relative performance of the tested materials.

The measurements also revealed differences in sound intensity among the four sides of the washing machine. These variations can be attributed to the asymmetric arrangement of internal mechanical components and the resulting non-uniform distribution of vibration and acoustic radiation.

Frequency-domain analysis provided additional insight into the acoustic behavior of the machine. The recorded spectra showed that most acoustic energy was concentrated within the low-frequency range, particularly below 500 Hz. This observation is consistent with the mechanical operating characteristics of vertical-axis washing machines, where rotating and oscillating components generate dominant low-frequency vibrations.

Comparison of the frequency spectra obtained with and without acoustic treatment indicated that all investigated absorbers contributed to noise attenuation across the dominant frequency range. However, their effectiveness varied with frequency. Felt fibers exhibited the most uniform attenuation behavior and achieved noticeable reductions throughout the analyzed spectrum. Sponge absorbers also provided substantial attenuation in the dominant frequency bands. Overall, the results confirm that the acoustic performance of sound absorbers depends not only on their material properties but also on the frequency characteristics of the emitted noise. Although the findings clearly demonstrate the effectiveness of the tested materials, more detailed investigations under standardized laboratory conditions would be required to establish comprehensive frequency-dependent performance models.

5. Conclusions

This study experimentally investigated the influence of several low-cost and readily available sound-absorbing materials on the noise emitted by a domestic vertical-axis washing machine. The selected absorbers were installed around the machine, and their effectiveness was evaluated through acoustic measurements performed at different locations and distances from the source.

The results demonstrated that all investigated materials contributed to some degree of noise reduction. The average reduction in sound intensity was approximately 6.35 dB, indicating that the application of simple acoustic treatments can significantly improve the acoustic performance of household appliances. Among the tested absorbers, felt fibers and polyurethane sponge consistently provided the highest noise attenuation levels. The maximum reduction achieved by felt fibers was approximately 8 dB, corresponding to about a 10% decrease in the measured sound level, whereas expanded polystyrene foam exhibited the lowest performance with a reduction of approximately 4.5 dB.

Frequency-domain analyses further revealed that the dominant acoustic energy of the washing machine was concentrated below 500 Hz. Both felt and sponge absorbers showed superior attenuation capability within this critical frequency range, which explains their overall effectiveness compared with the other tested materials.

The proposed experimental approach employed inexpensive sensors and commercially accessible materials, making it suitable for practical applications in residential environments. The findings suggest that appropriate selection of sound-absorbing materials can provide a simple and cost-effective solution for reducing appliance noise without requiring modifications to the mechanical structure of the machine.

Despite the encouraging results, the development of optimized acoustic treatments for household appliances remains an open research topic. Future studies should investigate a wider range of materials, geometric configurations, and operating conditions using standardized laboratory facilities. Such investigations could lead to more accurate characterization of absorber performance and contribute to the design of quieter and more environmentally friendly domestic appliances.

6. References

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