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ACOUSTIC METAMATERIALS APPLIED IN THE HAIR DRYER

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ABSTRACT

Among household appliances, hair dryers are known to generate high noise levels. In this study, we applied two types of acoustic metamaterial structures-absorptive and hybrid types-to hairdryers to investigate their noise reduction performance. Using COMSOL Multiphysics, we simulated metamaterial structures targeting the peak noise. The designed structures were fabricated using a 3D printer. Experiment result shows that the absorptive-type hair dryer's noise level from 80.9 dB to 71.6 dB, while the hybrid-type hair dryer achieved a greater reduction from 73.3 dB to 61.4 dB.

KEYWORD

Acoustic metamaterials, Absorption coefficient, Sound transmission loss

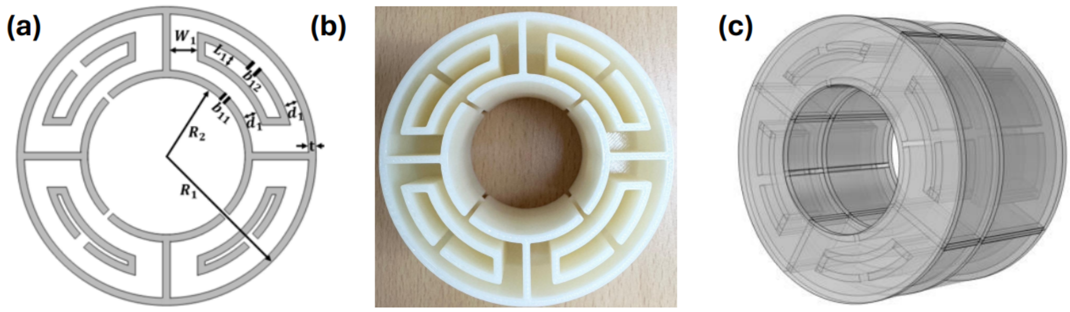
INTRODUCTION

With the advancement of technology in the modern world, people are living in the surroundings environment where home appliances cause a lot of noise. One of the household appliances with strong noise is the hair dryer that is a product people use every day and used close to the ears. To reduce noise, reducing the thickness of the product or using sound absorbing material such as sponges can be used. However, there is a limit to thickening the walls of hair dryers that use hot air. Acoustic metamaterials are emerging as a method to block noise while ventilation is possible. A hole for ventilation is opened in the center area, and an overall circular-shaped structure is selected to enable sound absorption. In this project two types of metamaterial are applied to a hair dryer, which are absorptive and hybrid ones for reducing noise.

METAMATERIAL STRUCTURE DESIGN

The first model involves absorptive metamaterials. The noise from a hair dryer motor was measured at a distance of 15 cm, with an overall noise level of 80.9dB. The dominant noise frequency was 1070 Hz, recording 64.8dB. Referencing previous research, we designed an absorptive metamaterial featuring a labyrinth structure, an advanced form of the Helmholtz resonator (Zhang et al., 2024). To optimize the absorption coefficient and STL simultaneously, parametric sweep was performed by adjusting variables controlling neck and cavity volumes (Figure 1). The aim is that satisfying target absorption coefficient(≥ 0.8) and STL(≥ 15 dB) between target frequency(987 Hz to 1083 Hz) and our final model shows that goals are achieved successfully (Figure 2). Additionally, to preserve ventilation performance, the length of R2 was maximized.

The second model involves hybrid metamaterials. All of the experimental conditions are same with first experiment and overall noise level in this experiment is 73.3 dB. The dominant noise frequency was 2005 Hz, recording 61.2 dB. Referencing second previous research, we designed a hybrid metamaterial adjusting key parameters (Dong et al., 2021). To optimize the absorption coefficient and STL simultaneously, parametric sweep was performed by adjusting variables controlling the length and volume of air path (Figure 3). Although the objective remains the same as in the first experiment, the target frequency range is different (1900 Hz to 2076 Hz). The final design demonstrates that all performance targets have been fulfilled (Figure 4).



Key Geometric parameters of first designed metamaterial (Unit: mm)

d_1, d_2	t	w_1	H_1	H_2	R_1	R_2
3.8	2	5.9	15	30	40	21

Figure 1: Design and desired parameters of first acoustic metamaterial.
(a) Cross-sectional area of metamaterial with parameters.
(b) Cross-sectional area of real metamaterial model.
(c) The whole isometric view of designed metamaterial model.

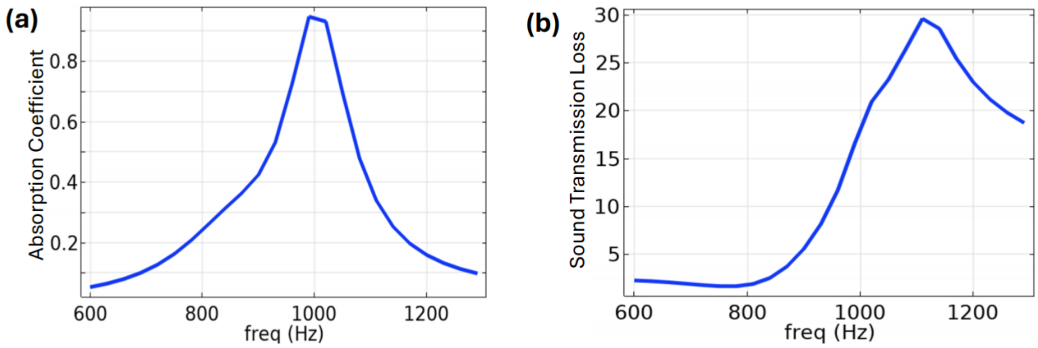
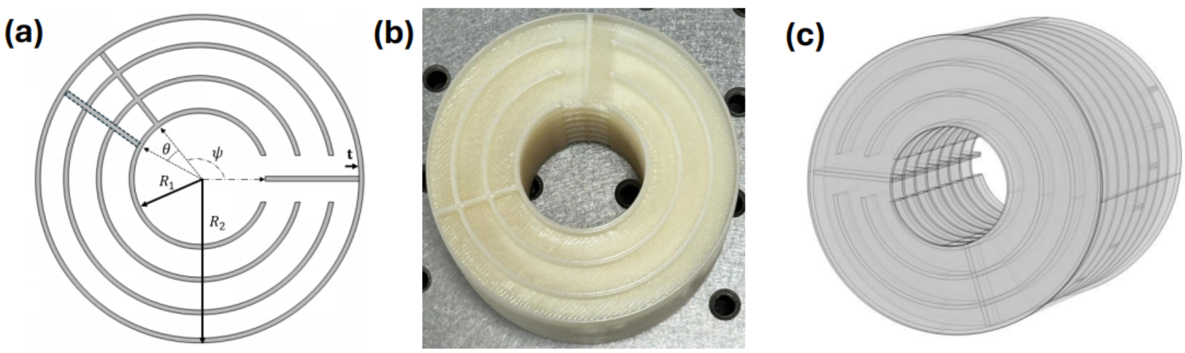


Figure 2: (a) Absorption coefficient graph of designed metamaterial.
(b) Sound transmission loss graph of metamaterial.



Key Geometric parameters of second designed metamaterial (Unit: mm)

a	b	H	θ(deg)	ψ(deg)	R_1	R_2
5.5	1	53	8	120	68	28

Figure 3: Design and desired parameters of second acoustic metamaterial.
(a) Cross-sectional area of metamaterial with parameters.
(b) Cross-sectional area of real metamaterial model.
(c) The whole isometric view of designed metamaterial model.

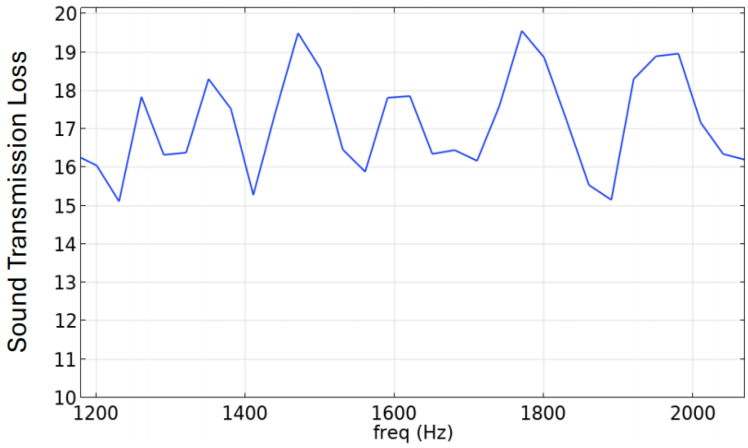


Figure 4: Sound transmission loss graph of metamaterial.

The metamaterials used in the experiments were fabricated by Stratasys F170. After attaching the structures to both front and back side of the hair dryer, the noise was measured from 15cm (Figure 5). The noise of the hair dryer with absorptive AMMs was decreased in main frequency (987 Hz to 1083 Hz), and the peak noise at 1070 Hz was reduced by 36.9 dB. As a result, an overall noise reduction of 9.3 dB, from 80.9 dB to 71.6 dB (Figure 5, a). The noise of the hair dryer with hybrid AMMs was decreased in main frequency (1900 Hz to 2076 Hz), and the peak noise at 2005 Hz was reduced by 46.5 dB. As a result, an overall noise reduction of 11.9 dB, from 73.3 dB to 61.4 dB (Figure 5, c).

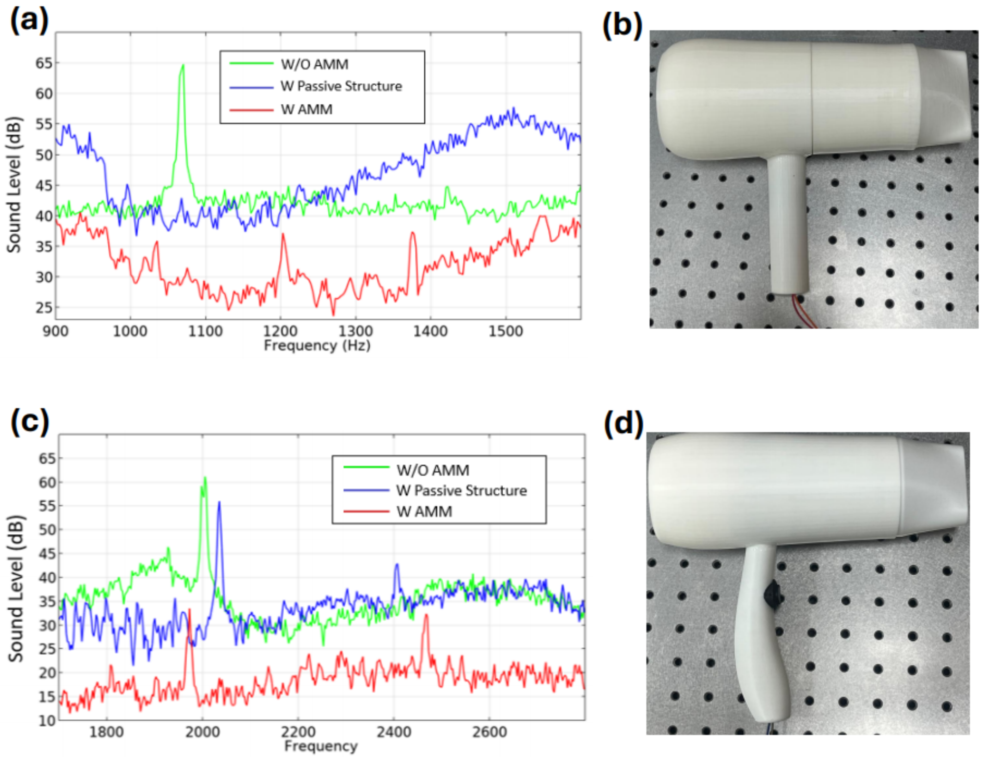


Figure 5: Experimental results of the metamaterial. (a) Sound level of the first hair dryer with AMM, passive structure and only motor. (b) The first hair dryer with absorptive AMMs. (c) Sound level of the second hair dryer with AMM, passive structure and only motor. (d) The second hair dryer with hybrid AMMs.

RESULT AND DISCUSSION

In summary, we proposed the abyrinthine absorptive acoustic metamaterial for noise reduction in a hair dryer firstly. To control the measured target frequency, the metamaterial with an open area of 27.6 %, a thickness of 45 mm, high absorption coefficient in the target frequency band is designed by several optimization processes. However, the smaller size of hair dryer is necessary, so hybrid AMMs are applied with higher noise reduction and smaller size of a hair dryer. In the second experiment using hybrid AMMs with an open area 17 % and a thickness of 53 mm, the hybrid-type hair dryer showed better noise reduction performance. This improvement resulted from its broadband high STL(≥ 15 dB). Therefore, it is necessary to develop a hair dryer with hybrid AMMs that maintain sound attenuation performance while providing a larger open area for improved airflow.

CONCLUSION

In conclusion, labyrinthine and hybrid acoustic metamaterials were effectively applied to reduce hair dryer noise. Among them, the hybrid AMMs showed superior performance with higher STL and compact size.

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