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1aAAb6. Design, optimization and testing of door-grille silencers
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It is a common practice to install doors that have openings in them to improve cross airflow through horizontal ventilation. However, excessive outdoor noise and poor noise privacy are known associated issues. Grilles are often installed in these door openings to address this issue. While they may reduce the noise level slightly, they have proven not to be very effective. Effective silencers would be too thick to be installed in doors. This work investigates the design and development of a novel door silencer that reduces the sound transmission to acceptable limits without compromising the airflow. A model of the silencer has been modelled using the Acoustics module of the COMSOL Finite Element software in a diffuse field environment, and validated with STC ratings. The airflow was modeled using the COMSOL CFD module. The dimensions of the ventilation opening and the silencer have been optimized and tested.

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INTRODUCTION

Door vents are openings built into doors in order to improve the air circulation in buildings. This is seen to be a more common practice in naturally ventilated buildings. Door vents lead to poor speech privacy and noise isolation. Until now grilles have been used in these openings for noise isolation. However these grilles have been found to be ineffective according to a study conducted by Bibby [1]. This report looks into the design and evaluation of a baffle-plate door silencer using Finite Element Methods and suggests optimum parameters for maximizing noise isolation with minimum air-flow reduction.

MODEL

Figure 1 shows the cross section of the silencer that was modelled. A baffle plate of thickness $b$ is lined with a porous absorber of thickness $p$ and flow resistivity $R_f$, placed at an offset of $w$ from the door. Holes of diameter $d_w$ and porosity $R_p$ are made in the baffle plate. The baffle plate extends distance $y$ larger than the opening in both axes. The opening is limited to a square-shaped cross-section (see Figure 1(a)) in these analyses of length $z$ and thickness $x$. The opening is lined with a porous absorber of thickness $m$ and flow resistivity, $R_f$.

FIGURE 1: Figure showing the front view (a) and the cross-sectional view (b) of a door-baffle silencer.

The Finite Element Method (FEM) was used in the prediction of Transmission Loss (TL) and air-flow for the silencer using COMSOL [2].

Acoustic Model

In order to replicate standard testing conditions as close as possible, the silencer was exposed to a diffuse-field source room as shown in Figure 2. For a room to have a diffuse field, the room must be large, cubic and have sources far away from the silencer. However this is a challenge since modelling a large room with mesh density of at least five elements per frequency would create a very dense mesh and would increase the RAM usage. The room was made
FIGURE 2: Figure showing the environment setup for the acoustical model.

approximately cubic, with room ratio of 1 : $2^{1/3} : 4^{1/3}$ for even modal spacing [3, 4]. Point power sources were placed in regions farthest from the silencer. In order to create a diffuse field without being capped in terms of RAM, the simulation was run only for a quarter-model, the model being symmetric. The receiver room was modelled as an anechoic chamber so that the sound does not get reflected back to the source.

**Air-flow model**

For evaluating the air-flow performance of the silencer, the volume velocity, $V_o$ of air exiting the baffle through the outlet was found. Naturally-ventilated buildings generally have air flows of low Reynolds number. The inlet velocity was kept constant and the volume velocity at the outlet was calculated for different silencers. A laminar flow model was used, with automatic mesh generation of ‘fine’ setting. It is to be noted that all the surfaces were modelled as hard boundaries, including the porous layers, due to the complexity of flow in the presence of porous layers. The values of volume velocity $V_o$ are tabulated in Table 1 for various silencer configurations.

**OPTIMIZATION**

In order to design a silencer with maximum Sound Transmission Class (STC) and airflow, a single metric was required that can be used to compare the performance. Following Bibby [1], the STC value and the volume velocity have been normalized with respect to those of the door vent without any baffle plate (refer to silencer s1 from Table 1) to give $N_o$ and $N_f$ respectively. This way the increase in performance with respect to the original configuration can be determined. The normalization ratio $N$ is defined as:

$$ N = \frac{N_f}{N_o} \quad (1) $$

$N$ can be used to evaluate the overall performance of the silencer. Higher values of $N$ mean better performance of the silencer (higher airflow and/or lower sound transmission).

Different types of silencers that were created by changing the parameters have been simulated and a few of them are tabulated in Table 1. Silencers s1 to s5 are a result of
progressive addition of elements in order to study the effect of each. The transmission loss for each of these five silencers has been plotted in Figure 3. Silencer s1 is the door opening without any baffle plate. Silencer s2 is a result of the addition of baffle plates on the either side of the opening. In silencer s3, a porous-absorber lining (fibreglass, in this case) is added to the interior side of the baffle plates, as shown in Figure 1. Silencer s4 is the modification of the baffle plate to a perforated sheet. Finally silencer s6 is the inclusion of porous absorber lining on the inner surfaces of the door opening. It can be seen that the addition of baffle plate increases the overall STC, but creates a dip at around 300 Hz. Inclusion of porous absorbers greatly increases the transmission loss at higher frequencies, but the STC is still low due to poor transmission loss at low frequency. This can be corrected by adding perforations to the baffle plates. The diameter \( d_h \) and porosity \( R_f \) can be adjusted to obtain desired results. This greatly improves transmission loss at lower frequencies, but the transmission loss at higher frequencies is reduced. This is however acceptable, since the STC is not very sensitive to higher frequencies. To further improve the transmission loss at higher frequencies, porous-absorber lining is added to the interior of the door opening. It can however be seen that the STC is not greatly increased. Increasing the opening lengths (z) in silencer s6, keeping the outer dimensions of the silencer constant, has resulted in poorer transmission loss and an increase in airflow. However, the overall performance is seen to be poorer than silencer s3. The effect of changing the baffle-plate offset distance (w) is seen in silencers s8 and s9, that can be compared against silencer s5. The performance of the porous absorber without the baffle-plate backing is shown in silencer s10. The acoustic performance is shown to be reduced.

**CONCLUSION**

A baffle-plate door silencer has been modelled and its acoustic and airflow performance evaluated by varying several parameters. Due to limitations in time, the investigation into the variation of parameters has been done only on the surface. Future work would include the validation of the model with experimental results and a more detailed evaluation. Another important addition would be the consideration of the porous surfaces when modelling fluid flow.
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REFERENCES


