Finite element Simulation of damped Sound Insulation Plate based on COMSOL

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Abstract. In this paper, based on the acoustic impedance tube model established by COMSOL, we studied the influence of the boundary conditions on the frequency characteristics of the damping acoustic plate, the effect of the thickness of the damping layer on the single-layer and double-layer sandwich structure damping acoustic plate. Based on the simulation results, two conclusions can be obtained: (1) the damping layer can effectively increase the sound insulation of the sound insulation plate, and when the thickness of the damping layer is 2~3 times of the bottom plate thickness, the performance-price ratio is the highest; (2) the sound insulation characteristics of the damping sound insulation plate follow the law of mass, and the sound insulation increases with the increase of frequency under the free boundary condition, while under the fixed support boundary condition, the low frequency sound insulation is larger.

1. Impedance tube model in COMSOL

Figure 1 shows the schematic diagram of the impedance tube model in COMSOL, with a diameter of 10 cm and a length of 40 cm. The plate structure divides the pipe into two cylinders of the same size. The length of the two divided cylinders should bigger than the long side of the plate structure, which is specified to ensure that the sound wave near the front and rear end surface of the pipe is plane wave. In the center position near the front and rear end of the pipe, two field points are established to read the sound pressure and particle vibration velocity. The upper end surface of the cylindrical pipe is set as the acoustic pressure loading surface, the lower end surface is set as the no reflection surface, and the surface of the air contact with the plate is the acoustic solid coupling surface.

Figure 1 The schematic diagram of the impedance tube model in COMSOL.
In the simulation model, the damping coating material parameters are set as follows: diameter of 10 cm, thickness of 0–8 mm is adjustable, Young modulus of $3.0 \times 10^8$ Pa, Poisson's ratio of 0.25, density of 1400 kg/m$^3$, damping factor of 0.43 in 63–1600 Hz frequency range. Aluminum plate and iron plate material are COMSOL built-in material parameters. Based on the above impedance tube model, the structure and installation mode of damping sound insulation plate are changed, and the sound insulation performance under different conditions is calculated.

2. Analysis of the influence of boundary conditions
Based on the impedance tube model in COMSOL, different boundary conditions (free, simple support, fixed support) are set for the sound insulation plate structure of 3mm damping layer of 2mm aluminum plate, and the frequency characteristic curve is calculated, as shown in figure 2 below. It can be seen that the frequency characteristic curve of sound insulation plate is very different under different boundary conditions. Under the free boundary condition, the sound insulation characteristics of the damping sound insulation plate follow the law of mass, and the sound insulation quantity increases with the increase of frequency, while under the fixed and simply supported boundary conditions, the sound insulation capacity of low frequency is larger, and the trough of sound insulation appears at a certain frequency, and then increases with the increase of frequency.

![Figure 2](image-url)
The simple support and fixed support around the sound insulation plate lead to the increase of the sound insulation curve at some frequencies and the emergence of wave peaks, and also lead to the decrease of some frequencies and the travel wave valley. The frequency characteristic curve under free boundary condition is consistent with the theoretical calculation results of mass law, while the calculation results of simple support and fixed support are related to the size of impedance tube model. Because of the simple support, the boundary conditions of fixed support are also dependent on the model to accurately describe the sound.

3. Simulation Analysis of single layer damping Sound Insulation Plate

Based on the impedance tube model, the sound insulation frequency characteristic curve corresponding to different damping layer thickness (0mm thickness corresponding to pure aluminum plate) is obtained under free boundary condition and solid support boundary condition. The aluminum plate thickness is fixed to 2 mm thickness. The frequency characteristic curves of sound insulation corresponding to different damping layer thickness are shown in Fig.3 and Fig.4. Under the condition of free boundary, the frequency characteristic curves of sound insulation are in good agreement with the law of mass. The damping layer can effectively increase the sound insulation of the sound insulation plate, and when the thickness of the damping layer is 2~3 times of the thickness of the bottom plate, the performance-to-price ratio is the highest, and the lifting amount of the more thick damping layer to the sound insulation is gradually reduced. Under the solid support boundary, the frequency characteristics of the damping plate are very different from the free boundary, and the thickness of the damping layer has little effect on the sound insulation, and the characteristics of the structure are dominant.

![Figure 3](image1.png)

**Figure. 3** The frequency characteristic curves for single layer damping sound insulation plate of different damping layers under free boundary conditions.

![Figure 4](image2.png)

**Figure. 4** The frequency characteristic curves for single layer damping sound insulation plate of different damping layers under solid support boundary condition.
4. Simulation Analysis of damping Sound Insulation Plate of double layer Sandwich structure

Based on the impedance tube model, the sound insulation performance of aluminum plate-damping-aluminum plate is calculated, which is similar to that of sandwich structure. The frequency characteristics of sound insulation corresponding to different thickness of intermediate damping layer under free boundary condition and fixed boundary condition are calculated. The results are shown in Fig. 5 and Fig. 6. Under the free boundary, the sound insulation quantity of the sound insulation plate basically follows the law of mass. Under the fixed support boundary condition, the frequency characteristic curve of the double layer structure is quite different from that of the single layer structure, especially in the high frequency band, which is mainly due to the resonance and coincidence effect, which also shows that the calculated results of the fixed support boundary are much correlated with the model.

![Figure 5](image1)

**Figure 5** The frequency characteristic curves for double layer Sandwich structure of different damping layers under free boundary conditions.

![Figure 6](image2)

**Figure 6** The frequency characteristic curves for double layer Sandwich structure of different damping layers under solid support boundary condition.

5. Conclusion

The following conclusions can be obtained by the above modeling simulation calculation results: (1) the damping layer can effectively increase the sound insulation amount of the sound insulation plate, and the thickness of the damping layer is 2~3 times of the thickness of the bottom plate (the aluminum plate is used in the model), and the cost performance is the highest; Under the condition of free boundary condition, the sound insulation property of the damping acoustic plate follows the law of mass, and the sound insulation is increased with the increase of the frequency, while the sound insulation of the low frequency is larger under the fixed-branch boundary condition.
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