Effect of modal analysis on vibration reduction of hollow aluminum alloy profiles

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Abstract: Through the classification of the noise types in the train, this paper discusses the influence of the car body profile structure on the vibration reduction and noise reduction in the train compartment, introduces the principle and advantages of modal analysis in the natural frequency analysis of the object, attempts to use the modal analysis function of ANSYS software to analyze the natural frequency and mode of the complex hollow aluminum alloy profile structure, and finds out the relevant parameter changes. The influence of chemical on the overall vibration reduction and noise reduction effect of profiles.

1. Introduction
In recent years, the development momentum of high-speed railways in our country is vigorous. In 2013, the operating mileage of high-speed railways nationwide was only 11,000 kilometers. By 2018, this number had risen to 29,000 kilometers, almost tripled. At the same time, according to statistics from relevant departments, China’s high-speed rail transported more than 10 billion passengers in only the first quarter of 2019, which shows that it has benefited a wide range of people. Thus, high-speed rail is now playing a very important role in people's work and life. Therefore, I think we should pay attention to in-depth research on technologies related to high-speed rail ride comfort in order to make high-speed rail better benefit for the people. There are two main factors affecting the comfort of high-speed rail: stability and quietness. This paper mainly explores how to use the modal analysis method to study the vibration characteristics of the aluminum alloy profile used in the car body, so as to achieve vibration and noise reduction and improving the comfort of high-speed rail.

2. The source of sound in the cabin
There are many sound sources in the carriage, but they can be roughly divided into two categories. The first category is human voices, train broadcast sounds, and mobile phone ringtones. These types of sounds have a common feature, that is, they have a higher frequency. It is concentrated between 100-1000Hz. At the same time, this type of sound has another feature, that is, they are usually what people need. People need these sounds to obtain information during the journey. This type of sound plays a role in transmitting signals. Therefore, high-frequency sound usually neither noise, or our research object of vibration and noise reduction. The second type of sound includes the running sound of the air intake and exhaust fans in the car, as well as the sound generated by the friction between the train components and the train and the rail. This type of sound is usually expressed as a "buzzing" sound, obviously people don't need this kind of sound on their journey. At the same time, the frequency of this kind of sound is generally concentrated in 20-200Hz, which is relatively low in...
frequency and belongs to low-frequency sound. Therefore, the research object of vibration reduction and noise reduction in this paper is this kind of low-frequency noise [1].

There are three main sources of low-frequency noise: direct sound, transmission sound and vibration radiated sound. The attenuation of the direct sound should consider reducing the noise source inside the cabin and improving the sealing performance of the vehicle. The transmission sound is different from the vibration radiation sound. Their propagation process needs the participation of the car body structure. Therefore, if the vibration and noise reduction performance of the car compartment can be improved, the effect of suppressing these two noises can be achieved [2].

The natural frequency is the inherent property of an object, which is related to its material and structure. When an object is subjected to a periodic external force, if the frequency of the external force is close to the natural frequency of the object, the vibration amplitude of the object will increase significantly. This phenomenon is called resonance [3]. Sound waves carry energy, and resonance may occur during their propagation. If resonance occurs during its propagation, it means that the sound waves continue to spread and even be amplified with the object as a medium. If there is no resonance, the energy of the sound wave is weakened during the propagation of this object [4]. In summary, if the natural frequency is taken into account when designing the car body profile structure, and the relevant parameters of the profile structure are changed to change the natural frequency of the changed profile, so that the natural frequency does not coincide with the frequency range of low-frequency noise. The purpose of vibration and noise reduction can be achieved.

3. The role of modal analysis
Modal analysis refers to transforming the vibration equations of a complex system using methods in linear algebra, decoupling the equations, finally becoming a set of independent equations described by modal coordinates and modal parameters. This analysis method is similar to Taylor's formula in higher mathematics. In higher mathematics, when you want to solve a more complex function, you can use Taylor's formula to expand it, and get the sum of countless simple functions. In engineering applications, you can also keep only the first few items according to specific accuracy requirements. In this way, a complex function can be replaced by the sum of several simple functions. Since the properties of simple functions are usually known or easy to find, we can obtain complex functions through the transformed simple functions Some of the properties. The modal analysis method is similar. Our research object is the hollow extruded aluminum alloy profile, the structure is relatively complex. Through modal analysis, it can be decomposed into several independent systems. These systems have their own corresponding frequencies and modes. After arranging these frequencies from small to large, results of different orders can be obtained. Since the first-order frequency is the smallest, if the first-order frequency value is greater than the edge of the frequency range of low-frequency noise, then the profile already has the effect of reducing vibration and noise.

4. Examples of modal analysis
This article uses ANSYS software to model the profile model, selects the common automotive aluminum alloy material 6S01, and defines its parameters: the elastic modulus is 7.1Gpa, the Poisson's ratio is 0.33, and the density is 2700kg/m³.

Here, two profiles with different rib structure are simply selected for comparison. The dimensions are shown in Table 1, and the schematic diagrams are shown in Figure 1 and Figure 2.

| Section Width/mm | Section Height/mm | Length/mm | Thickness of Upper and Lower Plates/mm | Rib Thickness/mm |
|------------------|-------------------|-----------|---------------------------------------|-----------------|
| 350              | 100               | 117       | 4                                     | 4               |
| 420              | 60                | 117       | 4                                     | 2               |
Figure 1: Rectangular profile model

Figure 2: Triangular profile model

After modeling, it is meshed, and then the Block Lanczos is used for modal analysis, and the first to fifth order frequency data can be obtained, as shown in Table 2. It can be seen from the table that the frequency of each order of the triangular rib profile is greater than that of the rectangular rib profile, and basically does not belong to the range of low-frequency noise. Therefore, it can be seen that the triangular rib has a better noise reduction effect.

| Order | Frequency (Hz) | Order | Frequency (Hz) |
|-------|----------------|-------|----------------|
| 1     | 17.402         | 1     | 31.156         |
| 2     | 42.848         | 2     | 80.243         |
| 3     | 78.457         | 3     | 92.121         |
| 4     | 95.990         | 4     | 126.55         |
| 5     | 114.64         | 5     | 132.49         |

Meanwhile, after the modal analysis, the corresponding modes of each order can be derived. Figure 3 shows the comparison of the first-order modes. The red part is the part with larger amplitude. It can be seen that the vibration amplitude of the rectangular rib profile is larger, which can also confirm the previous conclusion, the triangular rib profile reduces vibration and noise better than the rectangular rib profile.
Figure 3: Frequency comparison of two profiles

Figure 4: 1st-order mode shape
5. Conclusion
This article discusses the modal analysis in the hollow aluminum alloy profile design analysis principle of the ability to reduce vibration and noise, and take rectangular ribs and triangular ribs as an example, put forward the analysis process, and get the vibration reduction of triangular ribs. Conclusion of better noise performance. However, modal analysis also has its shortcomings. When modeling, the size and constraint conditions are more idealized and simplified compared to reality, so the final result may be different from the actual situation. This requires that in the actual design process, design specific experiments and compare the software analysis results with the experimental results. If the difference is large, the finite element modal analysis process needs to be revised to make the simulation conditions closer to the real situation, through continuous correction, and finally get a finite element modal analysis modeling method with less error [5].

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