Vibration analysis and optimization of controller bracket

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Abstract. Through harmonic vibration test and harmonic simulation analysis, the first natural frequency of controller bracket did not meet the experimental test requirements that proposed by the manufacturer (greater than 2000Hz). Through modal analysis of controller bracket, we could optimize controller bracket from design structure, processing technology, handling and other aspects. Cast aluminum material ZALSi12 was adopted. After modal analysis, the frequency of optimized structure was 2374Hz, which meets the experimental requirements proposed by the manufacturer.

1. Introduction
There are more and more electronic devices in new-energy vehicles. The environmental factors such as vibration and impact have great impact on their performance [1] when electronic devices are installed in running vehicles. Therefore, it is particularly necessary to conduct harmonic vibration tests on electronic products of new energy vehicles. Resonance is a common phenomenon in nature [2]. The natural frequency is the main determinant of resonance. Finite element analysis (FEA) can be used to determine the natural frequency such as Modal analysis and Harmonic Response analysis [3]. The existing engineering vibration test usually adopts the power spectrum curve or the amplitude-frequency curve of the frequency response function to realize the modal parameter identification by looking for the local peak value [4]. The FEA results could be verified by vibration test [5]. In this paper we will carry out vibration test and FEA simulation on controller bracket and improve it.

2. Harmonic vibration platform test of controller bracket
A set of vibration test scheme was designed by a manufacturer. As shown in FIG. 1, the controller bracket which installed with new energy vehicle controller was placed on vibration platform to conduct vibration test. Before the test, it was required to confirm that the natural frequency of controller bracket is greater than 2000Hz [6] and to avoid the structure resonance under the vibration platform, which will affect the accuracy of the vibration test of new energy vehicles controller.
Therefore, it was carried out first to evaluate the natural frequency range of controller bracket by harmonic vibration test. As shown in FIG. 2, the controller bracket was installed on the electric vibration test system ES-40LS4-445/LT0808, and the harmonic vibration test was conducted with the acceleration of 100g and the frequency of 1Hz~2000Hz.

In FIG. 2, the controller bracket had been installed on vibration platform, and the control point acceleration sensor was installed on the right side of vibration platform to detect whether the frequency of vibration platform is carried out in accordance with the test requirements. A monitoring point acceleration sensor was installed on the left center and upper position of controller bracket to monitor and record the output signal of controller bracket under the condition of harmonic vibration.

The vibration platform adopted the sinusoidal wave with an interval frequency of 5Hz and a maximum sweep range to 2000Hz. The data obtained from the monitoring point was transformed by the vibration test system to obtain the resonance search and resident test control diagram of controller bracket after harmonic vibration, as shown in FIG. 3. The controller bracket began to resonate at 539Hz. Then the controller bracket had multiple points of resonance.
3. Simulation analysis of controller bracket

The three-dimensional controller bracket was imported into ANSYS Workbench, and Harmonic Response was used for harmonic vibration analysis. The material Q235B was selected. The frequency sweep range was 0Hz~2000Hz, and Full method was used for analysis. Bolt holes positions at the bottom were constrained. The simulation results of harmonic vibration were shown in FIG. 4.

In FIG 4, the results of harmonic simulation of controller bracket produced resonance at 580Hz. It was found that the difference between simulation analysis data and harmonic vibration test data [7] is 2.0%. The error was in the allowed range, and the trend of the simulation analysis and the vibration platform test were similar. So the simulation results were reliable which can be used in the subsequent optimal design [8].

|                | Harmonic vibration test | Harmonic simulation analysis | error  |
|----------------|-------------------------|------------------------------|--------|
| First order resonance frequency (Hz) | 539                      | 550                          | 2.0%   |

4. Design and optimization of controller bracket

We know that the current natural frequency of controller bracket couldn't meet the requirements of the manufacturer from harmonic vibration test. The controller bracket needs to be redesigned and optimized.
Without considering the damping, the formula for calculating the frequency could be shown in Formula 1.

\[ f = \frac{1}{2\pi} \sqrt{\frac{k}{m}} \]  

(1)

\( f \) —— frequency  \( k \) —— stiffness  \( m \) —— mass

If we want to improve the natural frequency of controller bracket, which could be consider from the stiffness and mass. The stiffness is related to the structure and the properties of material. The mass is related to the structure and density. Therefore, the structure is an important factor affecting the natural frequency of controller bracket. As FIG. 5 shown, according to the first four modes analysis of controller bracket, the deformation trend of first mode was left and right, and the natural frequency is 550Hz. The subsequent design will focus on first natural frequency. The deformation trend of the second mode was forward and backward. The deformation trend of the third mode was the upper and lower direction. The deformation trend of the fourth mode was torsion. The structure of controller bracket should be optimized from the modes analysis.

Fig. 5 Result of the first four modes analysis

Because the scope of the experimental platform was limited to 580 mm ×580 mm, the scheme of the extension controller bracket volume was not desirable. So the controller bracket could be improved on the original design structure. The controller bracket provided by the manufacturer was welding structure. It's the most intuitive design if the block structure could be provided. Considering the processing technology and mass, the new improvement scheme was shown in FIG. 6. In addition, considering the needs to move the bracket, material Q235B should be changed to cast aluminum alloy ZALSi12, which could greatly reduce the weight of moving.

Fig. 6 New improvement scheme of controller bracket
5. Simulation analysis of optimal structure of controller bracket
The low order mode and frequency of the vehicle structure were obtained through modal analysis to determine whether the vibration characteristics can meet the design requirements [9]. Here we focused on the first natural frequency. The method of Modal analysis in ANSYS Workbench was used to obtain the vibration characteristics. The three-dimensional structure of controller bracket after optimization was imported into ANSYS Workbench and analyzed by Modal analysis. The material was ZALSi12 alloy with a density of 2570 kg/m³, and the simulation results of Modal analysis were shown in FIG. 7. The first natural frequency was 2374Hz, which meets the test requirement of the manufacturer that the natural frequency is greater than 2000Hz.

![Fig. 7 Result of first natural frequency](image)

6. Conclusion
The accuracy of the first natural frequency of Modal analysis was verified by harmonic vibration test, and the controller bracket provided by the manufacturer couldn't meet the test requirements, and its structure should be improved. Based on the formula of frequency, the structure and the stiffness and the material properties etc. had influence on the frequency. Through Modal analysis, the first natural frequency of optimized controller bracket was 2374Hz, which meets the requirement of more than 2000Hz proposed by the manufacturer.

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