Vibration characteristics analysis of double-layer vibration isolation platform

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Abstract. In order to control the vibration and noise level of mechanical equipment and realize the optimal design of double-layer vibration isolation platform. In this paper, the three-dimensional model and dynamic model of the double-layer vibration isolation platform are established. Based on the model, the modal analysis and harmonic response analysis are carried out, and the modal and dynamic characteristics of the double-layer vibration isolation platform are calculated. Through analysis, it is found that the vertical load of the mounting base is mainly generated by the vertical and longitudinal excitation, and the peak value appears at 17.8 Hz and 39.8 Hz respectively. The relationship between the dynamic response characteristics of the system and the system mode is obtained, and the vibration characteristics analysis of the double-layer vibration isolation platform is effectively completed.

Keyword: double-layer vibration isolation platform; vibration characteristics analysis; modal analysis; harmonic response analysis.

1. Introduction

Machinery and equipment that make a large contribution to ship vibration and noise directly affect the comfort and reliability of the ship. In order to improve the comfort and reliability of the ship, vibration isolation treatment is usually carried out for the main machinery and equipment, so as to control the vibration and noise level of the ship, and thus achieve the green operation of the ship.

With the development of ship modular construction, the vibration control of mechanical equipment is gradually developing towards integrated arrangement and vibration isolation of double-deck platform. The design level of the double-layer vibration isolation platform directly affects the vibration control effect of the mechanical equipment. Therefore, in this paper, a double-layer vibration isolation platform is taken as the research object. Through the modal analysis and harmonic response analysis, the system modal characteristics are calculated, the dynamic performance of the double-layer vibration isolation platform is analyzed, and the relationship between the structural elastic parameters and the response performance is obtained. On this basis, through the analysis of its structural characteristics, from the vibration acceleration The vibration load and response peak are analyzed to determine the effectiveness of the vibration isolation structure, and then provide support for the design and test verification of the double-layer vibration isolation platform.

2. Simulation modeling

The three-dimensional model of double-layer vibration isolation structure is shown in Figure 1. The top platform is equipped with vibration excitation equipment, the middle part is for floating raft vibration reduction, and the bottom part is for bracing column. The top and middle floating raft are connected with E60 vibration isolator, and the middle floating raft is supported with E160 vibration isolator. On this basis, a rigid body dynamics model is established based on the mass and stiffness parameters of the system. Since the structural stiffness is larger than that of the vibration isolator, the rigid body dynamics method is used to establish the rigid body dynamics model. The mass and inertia parameters of the structure and equipment are obtained based on its volume and density, and the vibration isolator is modeled using the bushing element. The dynamic model is shown in Figure 2.

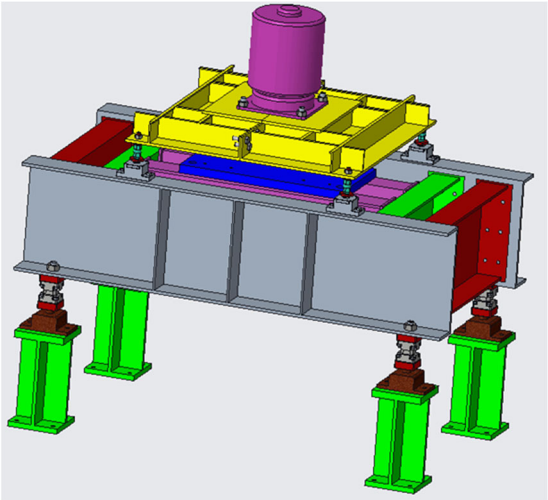


Figure 1. The three-dimensional model

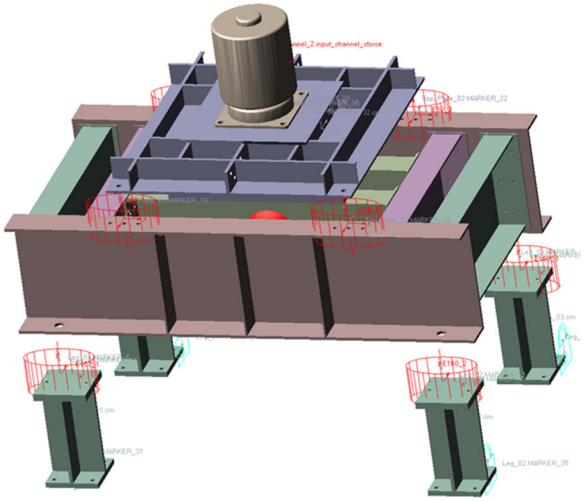


Figure 2. The dynamic model

3. Modal characteristics

The modal characteristics of the double-layer vibration isolation platform are shown in Table 1. A total of 12 modes are calculated in the range below 100 Hz. According to the order of frequency from low to high, the system mode shapes first appear in the same phase of roll/vertical, then in the opposite phase of roll/vertical, and gradually transition to the mode shapes dominated by local vibration.

Tab. 1 The modal characteristics of the double-layer vibration isolation platform

Modal order	Frequency	Damping ratio	Mode shape
1	17.8	0.311	Overall in-phase trim
2	18.9	0.180	Overall in-phase roll
3	32.4	0.895	Overall reverse roll
4	34.3	0.195	Top trim
5	38.1	0.591	Overall in-phase horizontal torsion
6	39.8	0.218	Overall in-phase floating and sinking
7	41.8	0.871	Overall reverse roll
8	44.0	0.155	Top roll
9	48.4	0.331	Overall reverse floating and sinking
10	82.5	0.093	Overall reverse horizontal torsion
11	86.1	0.065	Top center trim
12	90.6	0.065	Top center roll

4. Spectrum characteristics

The modal characteristics of the structure directly affect its vibration isolation performance. The natural vibration frequency of the vibration isolation system must be lower than the excitation frequency to achieve the effect of vibration isolation. For the double-layer vibration isolation system, there are many degrees of freedom, and only the mode with the same excitation direction has the vibration reduction effect. In this paper, the vibration isolation performance of the system is calculated by harmonic response analysis.Apply 1-100 Hz vertical excitation (load 1) and 10 N longitudinal excitation (load 2) with amplitude of 50 N at the center of gravity of the top equipment to simulate the normal and tangential excitation generated during equipment operation. Then calculate the vibration amplitude of each component under each harmonic excitation and the excitation amplitude transmitted to the installation base.

In the design of vibration isolation, not only the influence of normal load direction on vibration should be considered, but also the additional load generated by tangential load should be considered. As shown in Figure 3 and Figure 4, the vertical and longitudinal force response diagrams at the mounting seat under load are shown respectively. Through comparative analysis, the results are as follows:

1) The vertical load of the mounting base is mainly generated by the vertical and longitudinal excitation, with the peak value of 17.8 Hz and 39.8 Hz respectively.

2) The peak value of local vertical force near 17.8 Hz is mainly caused by load 2, which corresponds to the first mode and is the overall in-phase trim mode of the system. The peak value near 39.8 Hz is mainly caused by load 1, corresponding to the 6th order mode, and the system vibration is the in-phase sinking and floating mode of the system.

3) The longitudinal load at the mounting position mainly occurs around 17.8 Hz, mainly caused by longitudinal excitation, and the additional load generated by vertical excitation is small.

4) The excitation frequency shall avoid 17.8Hz and 39.8Hz when the vibration exciter excitation test is carried out on the double-layer vibration isolation platform.

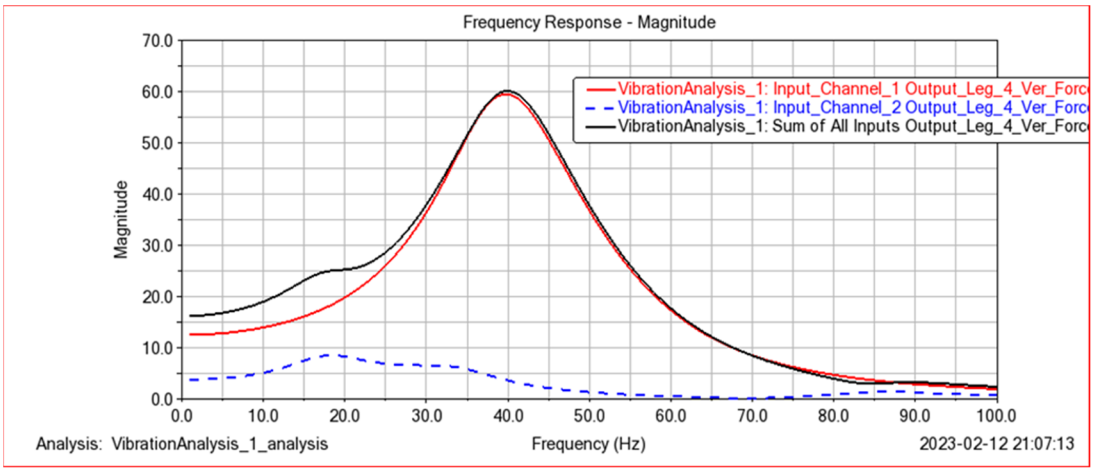


Figure 3. Vertical force response spectrum at the mounting base position (red - load 1, blue - load 2, black - comprehensive)

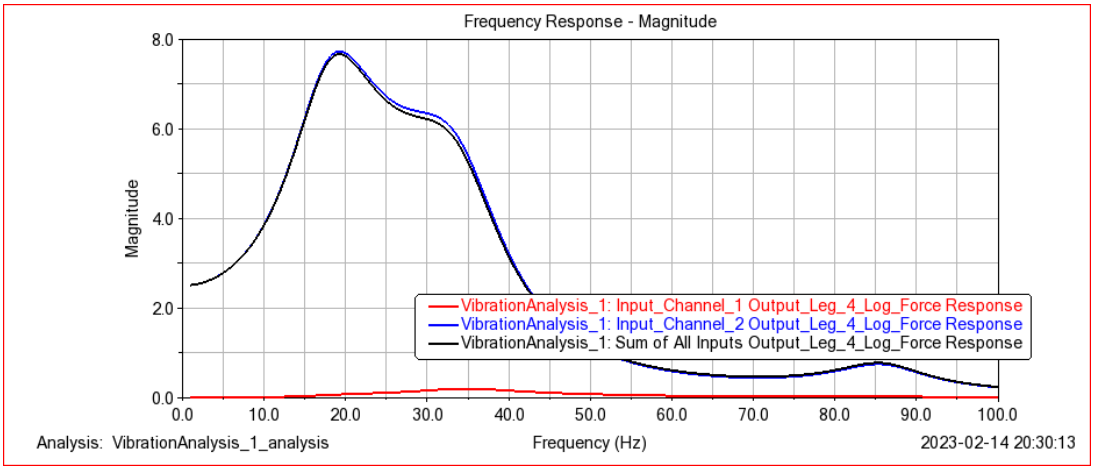


Figure 4. Longitudinal force response spectrum at the mounting base position (red - load 1, blue - load 2, black - comprehensive)

5. Modal contribution analysis

In order to analyze the direct relationship between the dynamic response characteristics of the system and the modes, the contributions of each mode under vertical and longitudinal loads are calculated. As shown in Figure 5 and Figure 6, the contributions of each mode of the double-layer vibration isolation platform are respectively shown. There are many modal orders in the structural vibration isolation design, but in fact, only local quantities have a great impact on the vibration. Under the condition that the overall mass and stiffness characteristics remain unchanged, the optimization design is mainly carried out for the order with large modal contribution to achieve the goal of vibration isolation. The analysis results show that:

1) For the response generated by vertical load, the order with the largest contribution is the 4th and 9th order respectively;

2) For the response generated by longitudinal load, the order with the largest contribution is the first and fourth order.

3) The local component has a great impact on the vibration, so the local structure optimization design of the double-layer vibration isolation platform should be focused on.

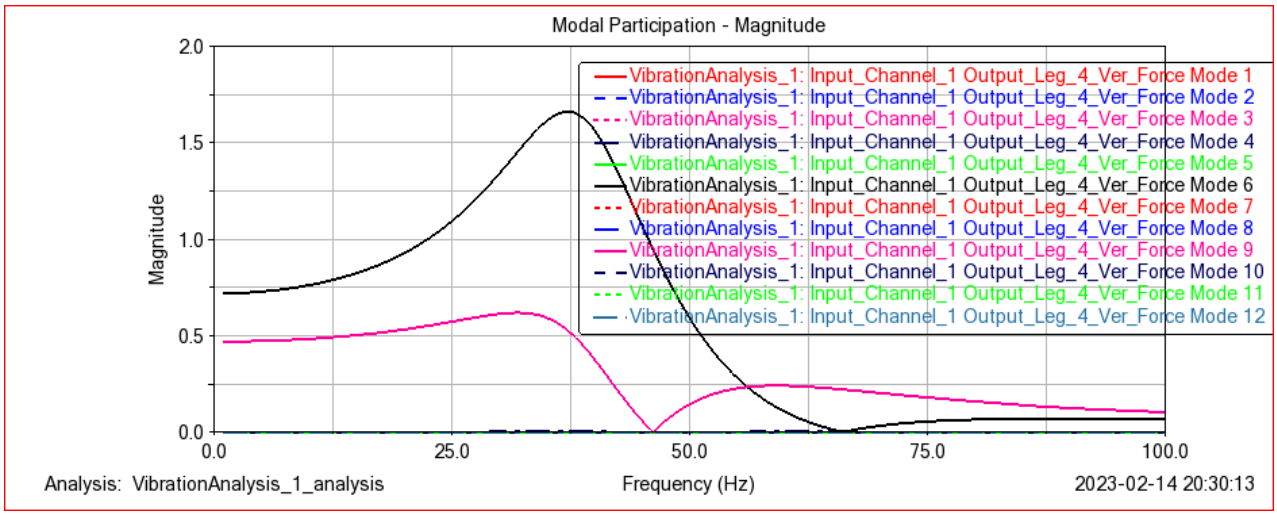


Figure 5. Modal contribution of vertical force response

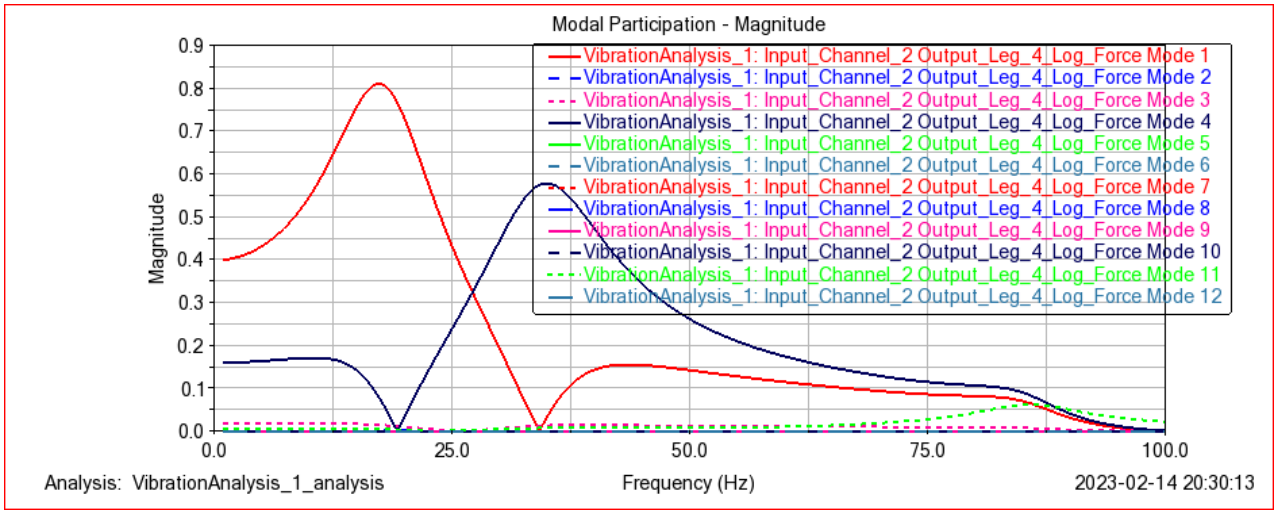


Figure 6. Modal contribution of longitudinal force response

6. Conclusion

Through modal analysis and harmonic response analysis of a double-layer vibration isolation platform, the main conclusions are as follows:

1) The vertical load of the mounting base is mainly generated by the vertical and longitudinal excitation, with the peak value appearing at 17.8 Hz and 39.8 Hz respectively, corresponding to the first and sixth modes of the platform. During the vibration exciter verification test, in order to ensure the safe operation of the platform, the excitation frequency should avoid 17.8 Hz and 39.8 Hz;

2) The analysis of the relationship between the dynamic response characteristics of the system and the system mode shows that for the response generated by the vertical load, the order of the largest contribution is the fourth and ninth order, respectively, and for the response generated by the longitudinal load, the order of the largest contribution is the first and fourth order.

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