CALCULATION METHOD OF DYNAMIC CHARACTERISTICS OF FLOATING RAFT ISOLATION SYSTEM

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Abstract:

The finite element method which can be used to calculate the dynamic characteristics of the floating raft isolation system is given. The calculation inputs include the vibration quantity of the machine, the impedance parameter of the isolator and the admittance parameter of the mounting base. The vibration level of the mounting base is calculated after physical model simplification and modeling analysis using APDL language of ANSYS for numerical simulation and programming. The dynamic characteristic of the floating raft isolation system in different working conditions of a motor raft is simulated and calculated by using this method. The accuracy of the calculation method is verified by comparing the calculated value with the experimental data. A method to evaluate the dynamic characteristics of the floating raft isolation system during the design phase is proposed, which can provide technical support for engineering test and vibration isolation system optimization.
Keywords: floating raft, vibration, dynamic characteristics, finite element

1. Introduction

The floating raft isolation technology is an important technique to reduce the contribution of the mechanical noise in the underwater radiation noise. The technology, which was first built by the US and British naval power, is widely used by naval ships. At present, most of the auxiliary outfitting of multi-type equipment have taken the floating raft isolation measure, this measure effectively reduces the level of radiation noise due to mechanical noise in submarines, which significantly improved the submarine sound stealth performance[1][2]. At the same time, the floating raft isolation technology has gradually promoted in minesweepers，measuring ships, frigates and other surface ships, and achieved a better vibration isolation effect.

In the early stage, the analysis was based on dynamics modeling and vibration characteristics of flat floating raft. A variety of modeling methods are formed, such as Multi-body dynamics method, Power flow method and so on[3].

The calculation method of the floating raft isolation effect is studied based on the ANSYS finite element method. The base vibration in different working conditions of a motor on the raft is calculated and verified by this method. This proves that the method is valid.

2. Calculation method

The calculation inputs of the method are bench test data, including the input force of the equipment exciting on the raft, the impedance of the isolator, the base admittance and so on, using ANSYS to build a finite element model of the raft.

Since exciting force, isolator impedance and base admittance are functions of the frequency, its value will change with frequency, in the modeling process, using APDL programming, respectively assigning the test parameters to the model parameters, calculating the base response at each frequency point and through the entire frequency band.

The calculation process is shown in Fig.1.

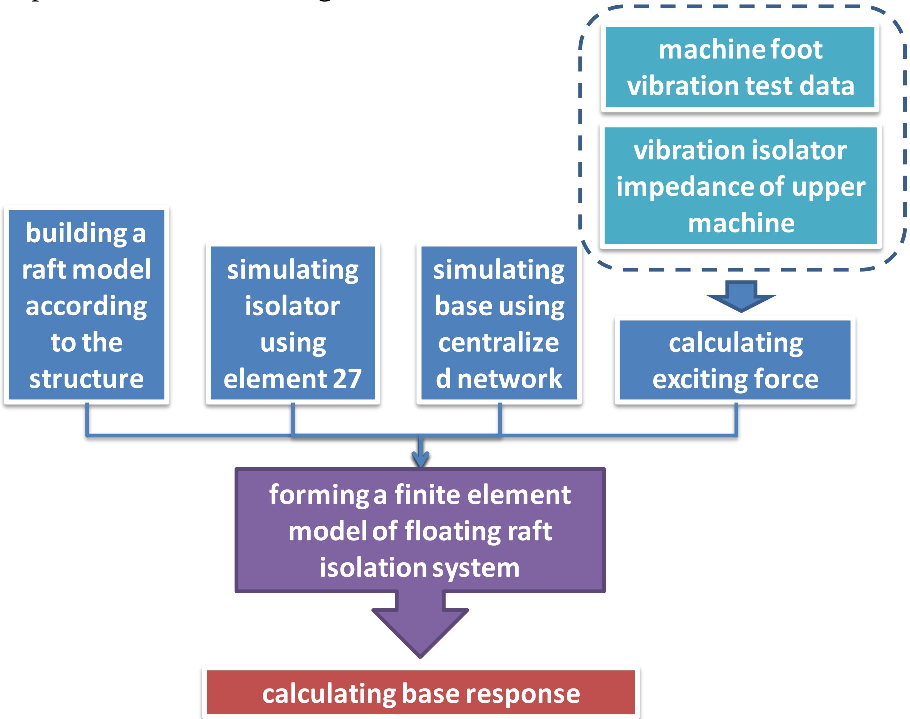


Figure 1: The calculation process of base response.

Among them, there are two methods of determining force: direct method and indirect method.

Direct method: A force sensor is embedded between machine and hull support structure/base for measuring force directly, which is accurate but difficult to implement. Indirect method: calculating the exciting force by measuring vibration response, structure dynamic characteristics/admittance or acceleration admittance and isolator impedance. the indirect method is easier and more feasible than the direct method in engineering applications.

Theoretically, for the mechanical equipment installed on the isolator, the exact formula of the exciting force is:

$$\begin{bmatrix} F_1 \\ F_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} \tag{1}$$

Where 1 denotes a connected node of isolator and machine, and 2 denotes a connected node of isolator and its support structure.

If isolator and machine are considered as a whole, the formula of the machine on the support structure of the exciting force F_2 is:

$$F_2 = Z_{21}X_1 + Z_{22}X_2 \tag{2}$$

Taking vibration isolation into account, X_2 is far less than X_1, $Z_{21}$and Z_{22} are at the same order, therefore the formula $F_2 = Z_{21}X_1$ is used to calculate the exciting force of machine in engineering applications, which is the exciting force of machine can be obtained just need the parameters of isolator impedance and the vibration data of machine. Comparing actual trials and results, the equivalent formula satisfy the requirements of engineering application accuracy.

Isolator is simulated by a spring damping unit in the traditional calculation method of floating raft isolation, which ignore the quality of the isolator. As the frequency increases, the simulation error increases[4].

The matrix of vibration isolator impedance can accurately characterize isolator, which improve the accuracy of the calculation.

The User Matrix in Ansys (shown in Fig.2) can accurately replace the isolator characteristics. Two node units can be constructed consistent with test impedance data. The equivalent error of vibration isolator can be eliminated completely.

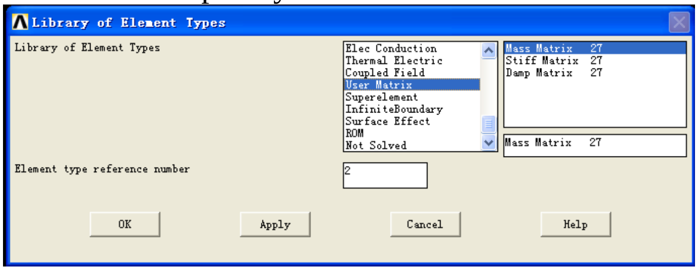


Figure 2: The user Matrix in Ansys.

The base admittance problem is handled by a centralized parameter network[5]. A parameter network is formed between the points of the base using spring and damping units. A four-point parameter network is shown in Fig.3.

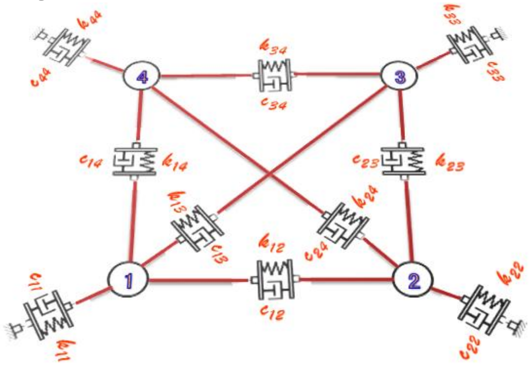


Figure 3: A four-point parameter network equivalent with base admittance characteristics.

The displacement impedance matrix of the four-point parameter network can be expressed by: $Z = Z_k + \omega j Z_c$, among them, Z_k、 Z_c is shown in the following formula:

$$Z_k = \begin{bmatrix} k_{11}+k_{12}+k_{13}+k_{14} & -k_{12} & -k_{13} & -k_{14} \\ -k_{12} & k_{12}+k_{22}+k_{23}+k_{24} & -k_{23} & -k_{24} \\ -k_{13} & -k_{23} & k_{13}+k_{23}+k_{33}+k_{34} & -k_{34} \\ -k_{14} & -k_{24} & -k_{34} & k_{14}+k_{24}+k_{34}+k_{44} \end{bmatrix} \quad (3)$$

$$Z_c = \begin{bmatrix} c_{11}+c_{12}+c_{13}+c_{14} & -c_{12} & -c_{13} & -c_{14} \\ -c_{12} & c_{12}+c_{22}+c_{23}+c_{24} & -c_{23} & -c_{24} \\ -c_{13} & -c_{23} & c_{13}+c_{23}+c_{33}+c_{34} & -c_{34} \\ -c_{14} & -c_{24} & -c_{34} & c_{14}+c_{24}+c_{34}+c_{44} \end{bmatrix} \quad (4)$$

The displacement admittance matrix data M is based on testing, according to $Z = M^{-1}$, each spring and damping unit parameter values can be calculated.

3. Experimental verification

3.1 Build model

To verify the correctness of the method, the floating raft isolation system on the simulation cabin is taken as the calculation object, to calculate the acceleration level of the base vibration in the "on" mode of the motor. The calculation model is shown in Fig.4.

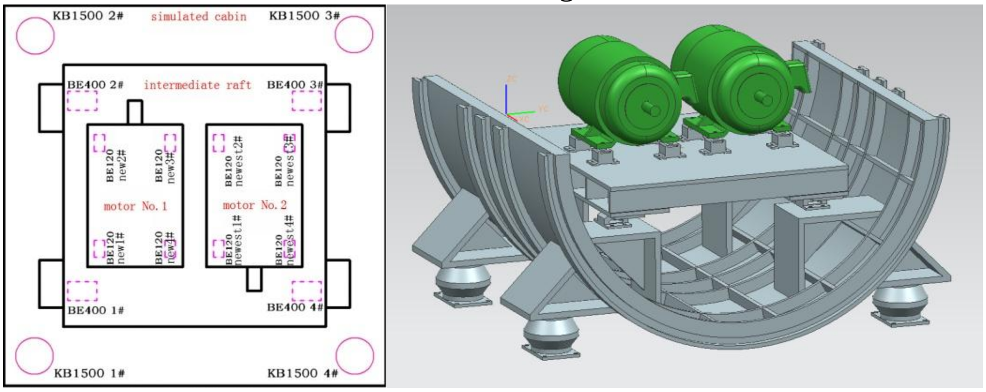


Figure 4: The calculation model.

The simulated cabin is supported by 4 rubber isolators KB-1500（1#～4#）as a whole, the middle raft is supported by 4 rubber isolators BE-400（1#～4#）. Motor No.1 and motor No.2 are mounted on the intermediate raft by the rubber isolators BE-120.

The finite model (shown in Fig.5) is established according to the actual size of the floating raft after the inputs such as base admittance, isolator impedance and machine exciting force are obtained to calculate the vibration effect of the floating raft.

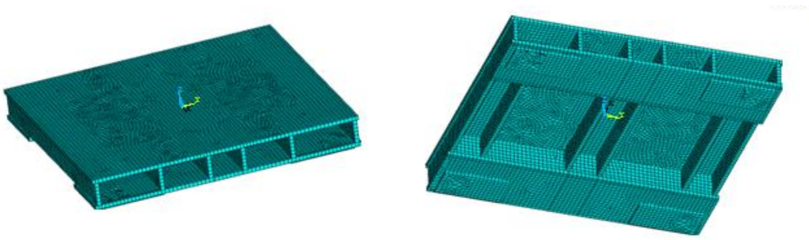


Figure 5: The finite model of floating raft.

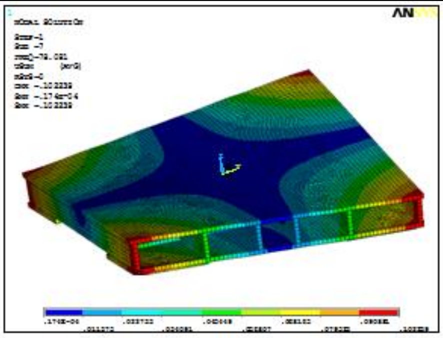
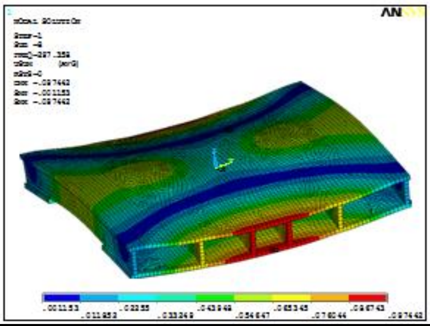
3.2 Calculation process

To verify the correctness of the model, the calculate values of the first 2 order modes (Table 1) of the raft are compared to the test values of the natural frequency which is obtained by hammer. The calculated values and test data deviation of 5%, the engineering accuracy requirements are satisfied.

By verifying the correctness of the simulation, further calculations can be made for simulation of floating raft isolation system including floating raft, isolator and base.

Table 1: Contrast verification natural frequency

order	The test datas of the natural frequency	The calculated values of the natural frequency	Vibration pattern

1	79.5Hz	78.1Hz	
2	305Hz	297.4Hz	

3.3 Comparison of calculation results

To verify the correctness of test methods, when calculating the motor 70% power（2100r/min） and 100% power（3000r/min）, comparison and analysis of raft base vibration level and test values are made. The comparison of calculation results is shown in Fig.6 and Fig.7.

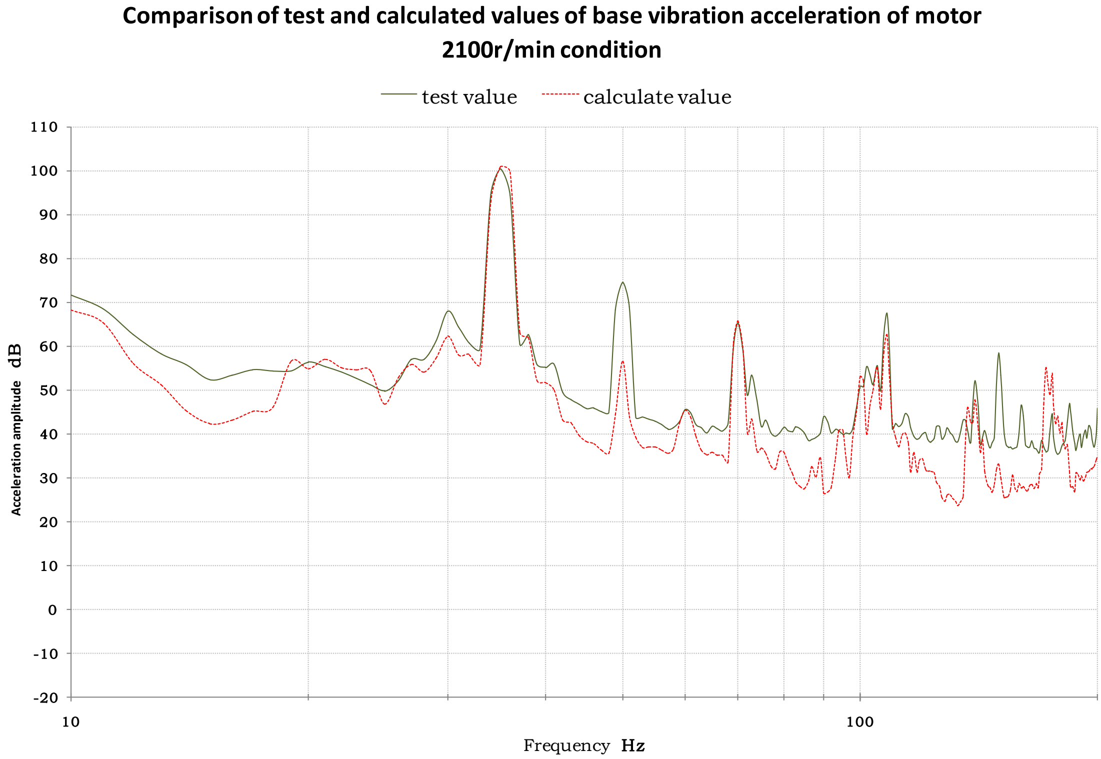


Figure 6: Comparison of base vibration level of 2100r/min condition.

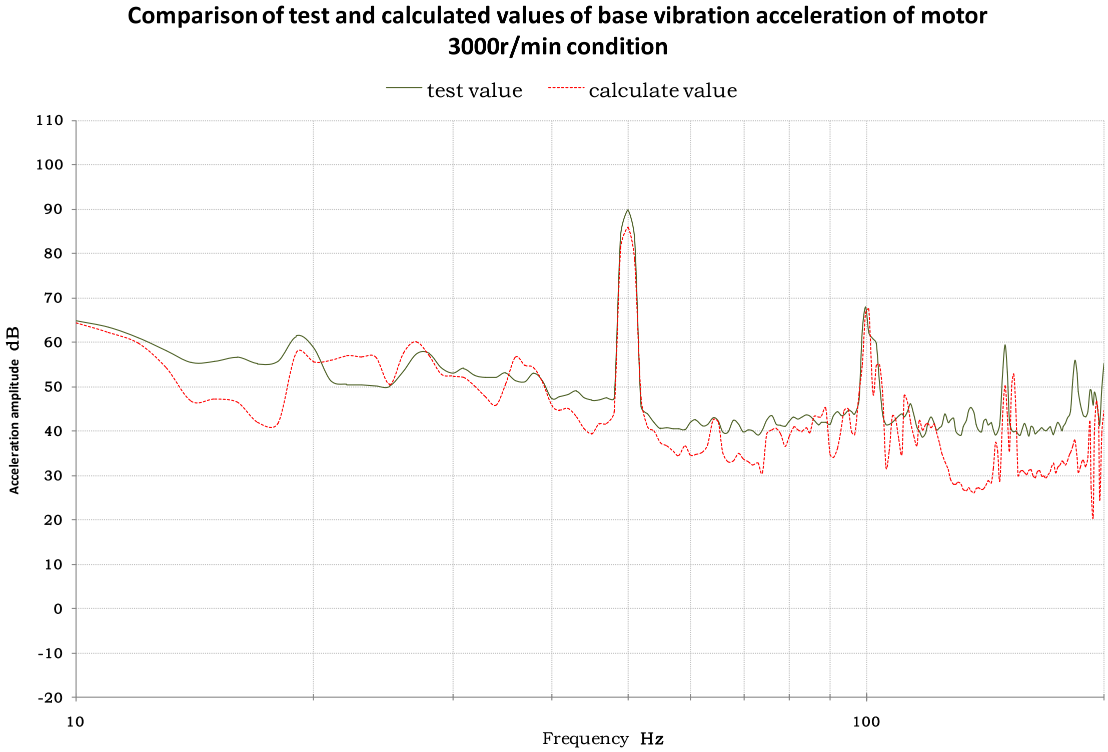


Figure 7: Comparison of vibration level of 3000r/min condition base.

After comparison, it can be seen that the finite element calculation results are different from the test results within 3dB at motor characteristic frequency, which meet the engineering accuracy requirements. But at motor non-characteristic frequency, there is a big difference between the calculate values and test values due to the test background noise affected.

4. Conclusion

The method provided in this paper is simple to calculate. The effect of floating raft isolation system can be estimated in the technical design stage, which can provide reference for the design of raft. But the satisfactory results are not available in the whole frequency range due to the test background noise.

Therefore, it is recommended that the design test be verified, combined with follow-up tasks, at the same time to further affect the parameters of the analysis, to achieve the goal of raft system parametric design.

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