Simulation Analysis of the Vibration Isolation Performance of Elastic Mounting bracket for Hydraulic Pipeline

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Abstract: The dynamic characteristics of hydraulic pipeline elastic mounting bracket directly affect the vibration and noise characteristics of pipeline system, as well as the strength and fatigue life of the mounting bracket itself. The modeling and simulation method of rubber elastic mounting bracket for hydraulic pipeline is studied by using non-linear finite element analysis method. The validity of this method is proved by an engineering example. At the same time, the analysis results show that the use of flexible rubber mounting bracket in hydraulic pipeline system has a good effect on isolating high-frequency noise, and the exciting forces of higher frequency in pipeline has a significant attenuation when it is transmitted to the base.

1. Introduction
Hydraulic pipeline mounting bracket transfers all kinds of complex loads in pipeline to the installation foundation, and can improve the stiffness of pipeline. Therefore, the strength, stiffness and vibration isolation performance of pipeline mounting bracket itself have an important impact on the reliability of hydraulic pipeline system. At present, more and more hydraulic pipelines adopt flexible mounting brackets to isolate the vibration and noise inside the pipelines and transmit them to the installation foundation. Rubber is one of the most commonly used elastic materials in pipeline mounting brackets. Compared with ordinary metal materials, rubber materials have super-elastic and viscoelastic properties, and have good vibration isolation and noise reduction performance. In this paper, the vibration transmission characteristics of rubber elastic mounting bracket for hydraulic pipeline are analyzed by means of non-linear structural finite element method [1-3]. The non-linear hyper-elasticity and viscoelasticity of rubber materials are also considered in the analysis process.

2. Finite Element Model Establishment and Analysis method for Elastic Mounting bracket of Hydraulic Pipeline
The steps of finite element analysis for hydraulic pipeline elastic mounting bracket are as follows:
   (1) Establishing a detailed three-dimensional geometric model of the mounting bracket;
   (2) Import the model into Hypermesh software;
   (3) Establishing finite element model in Hypermesh software;
   (4) Loading and restraint conditions (according to actual working conditions);
   (5) Using ABAQUS to solve the problem;
   (6) View the results and prepare the analysis report.
The main steps can be summarized as follows:
Fig. 2 shows the three-dimensional structure model of a hydraulic pipeline elastic mounting bracket. In order to verify the performance of the mounting bracket, the finite element method is used to model and simulate the bracket. Fig. 2-3 is the finite element model of the mounting bracket.

Figure 1. Finite Element Analysis Flow Chart of Elastic Installation Support for Hydraulic Pipeline

Figure 2 Geometric model of flexible mounting bracket

Figure 3. Finite element model of flexible mounting bracket
The ABAQUS software is used as the solver of the finite element model of the mounting bracket, and the stiffness, strength, modal and frequency response characteristics of the mounting bracket are analyzed. Because rubber material is viscous, its viscoelastic properties are taken into account in the simulation calculation. In this project, the third-order Prony constitutive model is used to describe the viscoelastic properties of rubber materials. The specific viscous constitutive parameters are shown in the Table 1.

Table 1. The specific viscous constitutive parameters

| $i$ | $g_i$ | $k_i$ | $\tau_i$ |
|-----|-------|-------|---------|
| 1   | 0.1954| 0.0401| 0.5737  |
| 2   | 0.14  | 0.0035| 0.019   |
| 3   | 0.0604| 0.004 | 0.000203|

2.1. Strength/Stiffness Analysis

The load condition of the whole hydraulic pipeline system is analyzed. The maximum load of the mounting bracket is 200N in radial direction and 400N in axial direction. The stress distribution between the two loads is analyzed. Figure 4 shows Mises stress cloud chart of mounting bracket under radial load of 200N. From figure 4, it can be seen that the maximum stress of the mounting bracket is 2.89MPa, which appears in the vulcanized joint of the rubber main spring and the mounting bracket support, which is less than the minimum bonding force of the interface, and the strength of the mounting bracket meets the requirements. It can also be seen from the figure that under this working condition, the stress of each part of the structure of the mounting bracket is uniform, and the material efficiency is high, which conforms to the concept of equal strength design [4]. Figure 5 shows the deformation cloud of the mounting bracket. It can be seen from the graph that the maximum displacement of the mounting bracket is 2.2mm when the pipeline path direction load is 200N, which meets the requirement of the hydraulic system that the maximum displacement of the mounting bracket is not less than 2mm.

Figure 4. Stress cloud chart of flexible mounting bracket under radial load
Figure 5. Deformation cloud chart of flexible mounting bracket under radial load

Figure 6 shows the Mises stress cloud chart of the mounting bracket under the axial load of 400N. It can be seen from the figure that the maximum stress of the mounting bracket is 1.829 MPa, which occurs at the vulcanized joint of the rubber main spring and the mounting bracket support, which is less than the minimum bonding force of the interface, and the strength of the mounting bracket meets the requirements. It can also be seen from figure 6 that under this working condition, the stress of each part of the structure of the mounting bracket is uniform, and the material efficiency is high, which conforms to the concept of equal strength design. Figure 7 shows the deformation cloud chart of the mounting bracket. It can be seen from figure 7 that the maximum displacement of the mounting bracket is 0.876 mm when the pipeline path load is 400 N, which meets the requirements of the index.

Figure 6. Stress cloud chart of flexible mounting bracket under axial load
2.2. Vibration Isolation Performance Analysis

As shown in Figure 8, the constraints are applied to the bottom of the fixed base, and the unit excitation force is applied to the central point of the pipeline. The direction of excitation force is radial and axial respectively. The direction of coordinate axis is shown in the figure. Acceleration measurement point is chosen at the center of the pipeline, and constraint reaction point is another measurement point, which is taken as the resultant force of all nodes on the constraint surface, and the resultant action point is located at the center of the constraint surface. Because the rubber material is a non-linear material, the dynamic model is solved by direct integral dynamics method in this project, and the amplitude-frequency characteristic curve of the pipeline mounting bracket under dynamic load is obtained.
(1) Amplitude-frequency characteristics of radial force (Y) excitation

Figure 9 shows the amplitude-frequency characteristics of radial (Y-direction) acceleration at the acceleration measurement point. From the acceleration curve, the two peaks on the acceleration curve correspond to the first three natural frequencies of the mounting bracket. However, due to the damping effect of rubber, when the exciting force on the pipe reaches the natural frequency of the mounting bracket, the acceleration of the pipe does not reach “infinite”, only about 0.3g, and below 50Hz and above 150Hz, the vibration acceleration amplitude of the pipe is small, which is conducive to reducing the dynamic stress in the pipe caused by vibration and improving the fatigue life of the pipe. Fig. 10 is the amplitude-frequency characteristic curve of the force transmitted from the mounting bracket to its mounting base. It can be seen from the figure that when the frequency is greater than 100Hz, the amplitude of the force is less than 1 (the amplitude of the exciting force). This shows that the mounting bracket has a good vibration isolation effect on the radial exciting force above 100Hz. There is an anti-resonance point between 700Hz and 750Hz, and the magnitude of the force is 0, which indicates that at this frequency point, the excitation of the pipeline will not be transmitted to the base. From the results of frequency response analysis, the rubber flexible mounting bracket has a good effect on isolating high frequency noise.

Figure 9. Acceleration Amplitude-Frequency Characteristic Curve of Y-Direction Acceleration at Acceleration Measuring Points

Figure 10. Amplitude-Frequency Characteristic Curve of Force Transferred to Installation Base (Center of Fixed Constraints)
(2) Amplitude-frequency characteristics of axial force (X) excitation

Figure 11 shows the amplitude-frequency characteristic curve of the axial acceleration at the acceleration measuring point under axial excitation. From the figure, it can be seen that when the excitation frequency reaches the natural frequency of the mounting bracket, the vibration acceleration amplitude of the pipe is less than 0.23g, and the rubber damping plays a better role. Figure 12 is the amplitude-frequency characteristic curve of the force transmitted from the mounting bracket to its mounting base under the axial excitation. It can be seen from the figure that when the frequency is greater than 200 Hz, the amplitude of the force is less than 1 (the amplitude of the excitation force). It shows that the mounting bracket has a good vibration isolation effect on the axial excitation force above 200 Hz, especially above 400 Hz.

Figure 11. Acceleration Measurement Point X-direction Acceleration Amplitude-Frequency Characteristic Curve

Figure 12. Amplitude-Frequency Characteristic Curve of Force Transferred to Installation Base (Center of Fixed Constraints)

(3) Amplitude-frequency characteristics of torque (My) excited vibration

Figure 13 is the amplitude-frequency characteristic curve of the three-dimensional acceleration at the acceleration measuring point under torsion excitation. It can be seen from the figure that when the
excitation frequency reaches the natural frequency of the mounting bracket, the vibration angular acceleration amplitude of the pipe is also about 1.0 rad/s^2, and the rubber damping plays a better role.

Figure 14 is the amplitude-frequency characteristic curve of the torque transmitted from the mounting bracket to its mounting base under torsional excitation. From the figure, it can be seen that the amplitude of the torque at all frequency points is far less than 1 (the amplitude of the exciting torque), which shows that the mounting bracket has a good vibration isolation effect on the torsional excitation force.

Figure 13. Amplitude-Frequency Characteristic Curve of Angular Acceleration at Acceleration Measuring Points

Figure 14. Amplitude-Frequency Characteristic Curve of Torque Transferred to Installation Base (Center of Fixed Constraints)

3. Conclusion
In this paper, the non-linear finite element method is used to model and simulate the vibration isolation performance of the elastic mounting bracket of hydraulic pipeline. The analysis results show that the rubber flexible mounting bracket has a good effect on isolating high frequency noise, and the exciting force of higher frequency in the pipeline decreases greatly when it is transmitted to the base. It is
assumed that the radiated noise transmitted from the mounting bracket to the base can be attenuated by an average of 13.98 dB when the excitation frequency is 200 Hz to 1000 Hz on a single mounting bracket. According to the trend of the curve, the average attenuation of radiated noise above 1000Hz is higher.

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