# Stability Analysis of Heavy Hoist Frame Based on Numerical Simulation

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**Abstract:** Heavy hoist is commonly used in coal mine, heavy industry and other production transmission equipment, its stability also directly affects the safety and efficiency of production process, and the stability of the rack is the decisive factor of the stability of heavy hoist. This paper takes the rack of heavy hoist as the research object, based on ANSYS Workbench finite element analysis platform. Static analysis and modal analysis are carried out. Through static analysis, the maximum deformation and stress of the frame under normal working conditions are 0.48 mm and 103.64 MPa, respectively, which meet the requirements. Through modal analysis, the vibration frequencies and modes of the first six modes of the frame are obtained. The vibration of the first three modes of the frame is concentrated, and the corresponding motor speed is 1188-1739.4r/min under the interference frequency. In the use process, the motor speed in this range should be avoided. Through the analysis, this paper evaluates the stability of the heavy hoist frame effectively, and puts forward a reasonable optimization scheme based on the analysis results, which provides a theoretical basis for the optimization design.

## 1. Introduction

Hoist is the most commonly used conveying equipment in production activities. Its main role in the process of cargo transportation is to change the height of cargo. For heavy hoist used in coal mines, heavy industry and other production sites, the load situation is more complex, easy to overload conditions, heavy hoist damage, or even occur. Safety accidents, so the stability of heavy hoist main structure is very important.

Based on the finite element analysis software ANSYS Workbench, the stability of a typical industrial heavy hoist is analyzed from two aspects of structural strength and modal characteristics.

## 2. Analytical Model

In this paper, the main components of heavy lifts are frame, lifting motor, lifting chain and loading platform, as shown in figure 1. The lifting motor, lifting chain and loading platform are all installed on the rack. The rated load of the lifter is 2000 kg. The frame is welded with 80*80*4mm square steel. The material of square steel is QSTE420T. Its main characteristic parameters are shown in table 1.

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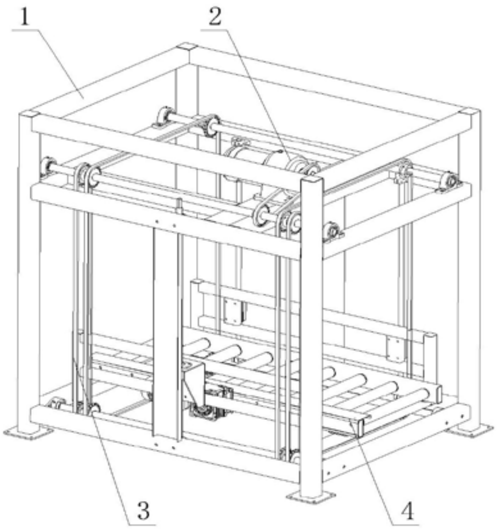


1- frame. 2- lifting motor. 3- lifting chain. 4- loading platform

Figure 1. Schematic diagram of heavy hoist

Table 1. Material properties of QSTE420T

| Material Name | Modulus of Elasticity/GPa | Poisson ratio | Yield strength/Mpa | Tensile strength/Mpa | Density $kg \cdot m^{-3}$ |
|---|---|---|---|---|---|
| QSTE420T | 200 | 0.3 | 420 | 480 | 7850 |

In this paper, the parametric modeling software Creo is used to build the three-dimensional model of the heavy hoist frame. Because the chamfer of the frame and the location of the installation holes will not have a great impact on the mechanical characteristics of the frame, the structure characteristics are simplified in the modeling.

## 3. Static Analysis

**Basic Principles of Static Analysis**. In statics, the dynamic equation of an object.

$$[M](\ddot{X}) + [C]\{\overline{X}\} + [K]\{X\} = \{F(t)\} \tag{1}$$

In the formula, [M] is the mass matrix, [C] is the matrix damping, [K] is the stiffness coefficient matrix, {X} is the displacement vector and {F} is the force vector.

In linear static structure, force is independent of time.

$$[K]\{X\} =\{F\} \tag{2}$$

**Analytical Pretreatment.** Firstly, the three-dimensional model built in Creo is imported into ANSYS Workbench, and the material of the model is set as QSTE420T. Fixed constraints are then applied on the four legs of the rack, and then loads are applied on the rack according to the actual situation, as shown in figure 2. Finally, the finite element meshes are divided.

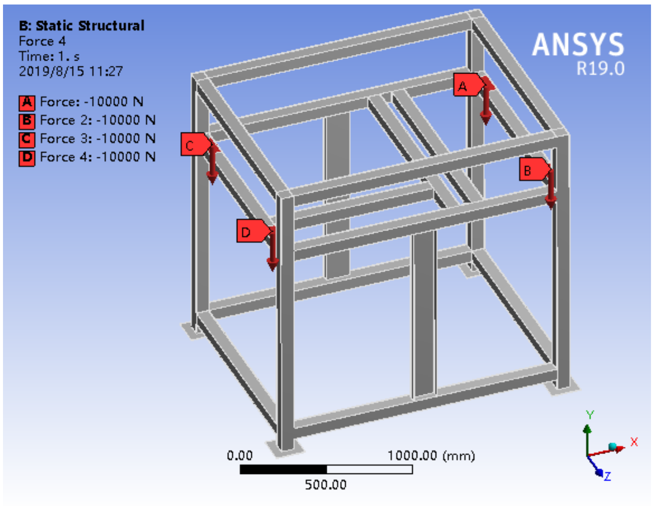


Figure 2. Constraints and loads

**Analytical Pretreatment.** Through solving calculation and post-processing, the total deformation characteristics and equivalent stress characteristics of the frame are obtained. Figure 3 is the total deformation cloud of the frame. From the figure, it can be seen that the maximum deformation occurs in the central position of the frame support rod, and its deformation is 0.48 mm. In addition, there are some deformation in the four support rod positions of the frame, but not in the frame. Affect the overall stability of the rack.

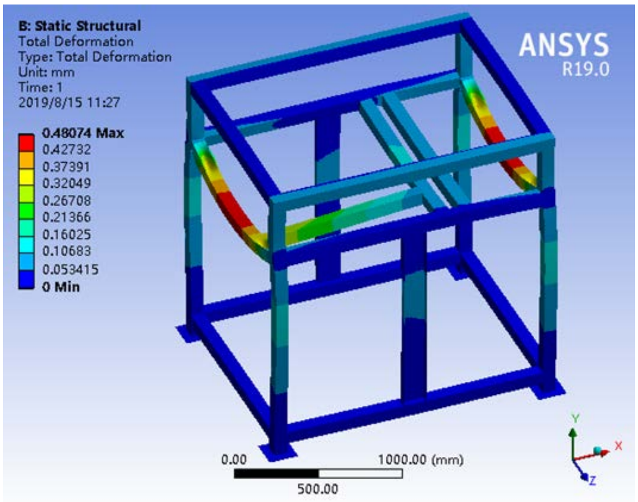


Figure 3. Equivalent strain nephogram

Figure 4 is the equivalent stress nephogram of the frame. It can be seen from the figure that the maximum equivalent stress appears at the stress point of the frame. The maximum equivalent stress is 103.64 MPa, which is far less than the yield strength of the material 420 MPa, and will not affect the stability of the frame. At the same time, there are some stresses in the frame connected with the brace.

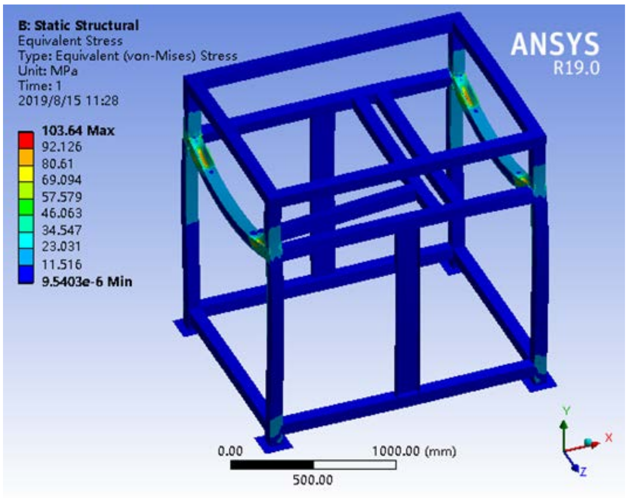


Figure 4. Equivalent strain nephogram

## Modal Analysis of Prestressing Force

**Basic Principles of Static Analysis.** Modal is the inherent characteristic of mechanical structure. It is a common method to study the vibration characteristics of mechanical structure. Different mechanisms have different modal characteristics. The same mechanical structure also has numerous different modes. The modal characteristics are expressed by vibration frequency and modal mode. The relationship between them is as follows.

$$[\mathrm{K}] - \varphi_i^2[M]\{\emptyset_i\} = 0 \tag{3}$$

In the formula, [K] is the stiffness matrix, [M] is the mass matrix. $\emptyset_i$ is a modal mode. $\varphi_i$ is the vibration frequency.

**Modal Analysis Results.** The first six modes of the frame are obtained by calculating and solving. The vibration frequencies of the first six modes are shown in table 2. The frequency range of the first six modes is 19.8-83.04 Hz, and the vibration of the first three modes is concentrated. Heavy hoist is driven by motor. The relationship between disturbance frequency and rotational speed is as follows.

$$\mathrm{n}=60\mathrm{f} \tag{4}$$

In the formula, n is the speed, unit r/min; f is the interference frequency, unit Hz.

According to the relationship between motor speed and interference frequency, when the interference frequency is 19.8-28.99 Hz, the speed range of the motor is 1188-1739.4 r/min, which is exactly the speed range of most commonly used motors. The motor working in this speed range is very easy to cause frame resonance and produce danger.

Table 2 First six order modal frequencies

| Step | Frequency/Hz | Max displacement ratio |
|---|---|---|
| 1 | 19.8 | 2.58 |
| 2 | 24.59 | 2.65 |
| 3 | 28.99 | 3.55 |
| 4 | 65.01 | 3.50 |
| 5 | 79.50 | 9.02 |
| 6 | 83.04 | 10.38 |

Figure 5 and figure 6 are the modal nephograms of the first and second modes. The maximum deformation is 2.58 mm and 2.65 mm. The maximum deformation occurs at the upper part of the frame. In the first mode of vibration, the installation position of the motor also has a large deformation.

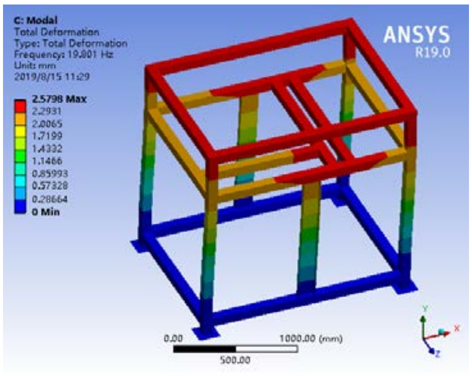


Figure 5. The modal nephograms of the firs modes

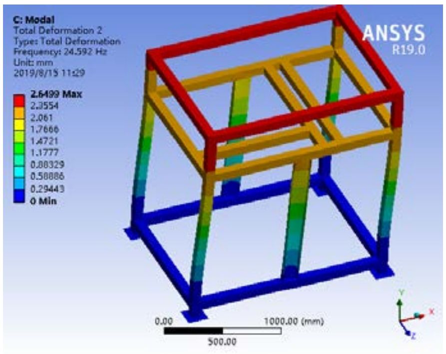


Figure 6. The modal nephograms of the second modes

Figures 7 and figure 8 are the modal nephograms of the third and fourth modes. The maximum deformations are 3.55mm and 2.5mm. The maximum deformations occur around the frame. When the frame is opened as a whole, the whole frame is distorted.

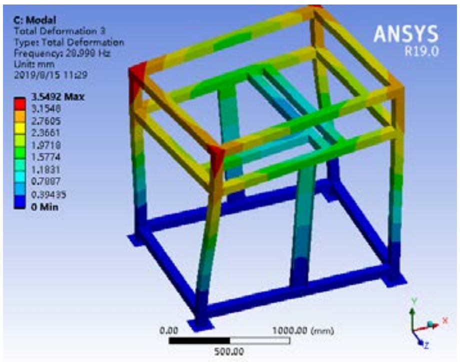


Figure 7. The modal nephograms of the third modes

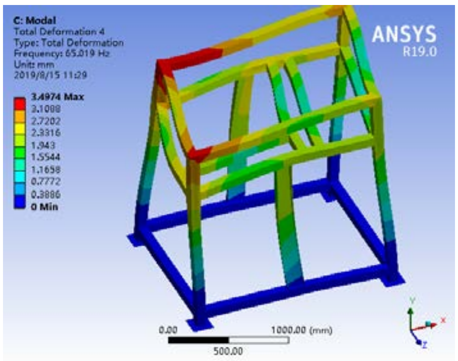


Figure 8. The modal nephograms of the fourth modes

Figures 9 and figure 10 are the modal nephograms of the fifth and sixth modes. The maximum deformations are 9.02mm and 10.38mm. The maximum deformations occur on the reinforcement poles on the side of the frame. The difference is that the two reinforcement poles of the fifth mode are deformed in the same direction, and the two reinforcement poles of the sixth mode are deformed in the same direction. Deformation in different directions.

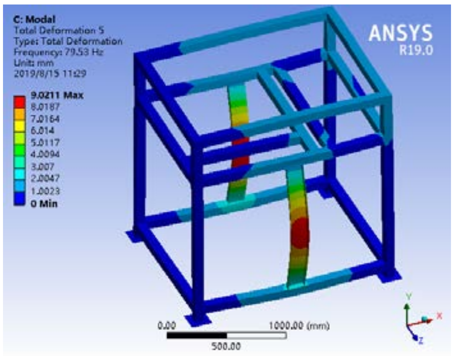


Figure 9. The modal nephograms of the fifth modes

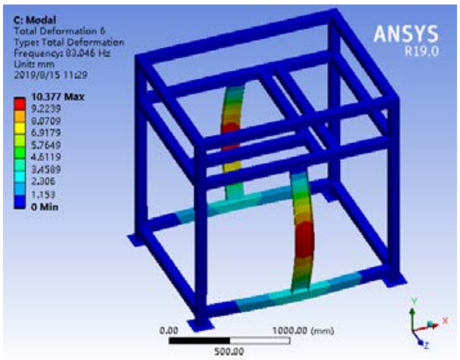


Figure 10. The modal nephograms of the sixth modes

## Conclusion

The stability of heavy hoist is one of its very important indexes, and the stability of the frame is one of the most important factors. Through static analysis and modal analysis of the frame of heavy hoist, the following conclusions are obtained.

(1) Within normal working conditions, the maximum equivalent stress of the frame is 103.64 MPa, which is far less than the yield strength of the material 420 MPa and meets the requirements. However, the stress position of the frame is relatively concentrated, which can increase the uniform pressure distribution of the gasket and reduce the gravitational concentration.

(2) Within normal working conditions, the maximum deformation of the frame appears in the center of the support rod, and the deformation is 0.48 mm, which meets the requirements. The maximum deformation can be reduced by increasing the support reinforcement bar at the maximum deformation.

(3) The vibration of the first three modes of the frame is concentrated, and the corresponding motor speed is 1188-1739.4r/min under the interference frequency. In the use process, the motor speed in this range should be avoided.

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