Research on mechanical structure design of bearing testing machine based on finite element analysis

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Abstract. The bearing testing machine has the advantages of high bearing capacity and long service life. It is widely used in the field of engineering machinery. The bearing test machine has a certain bearing capacity and the performance of the fuselage is also good. In this paper, the mechanical structure of the bearing testing machine is designed by finite element analysis, using modern advanced technology to simulate it, and the dynamic performance of the bearing testing machine is simulated to complete the structural optimization design to ensure the bearing testing machine. The service life.

Keywords: Finite element analysis; Bearing testing machine; Structural optimization; Modal analysis

1. Introduction

The fuselage design of the bearing testing machine is mostly based on traditional design methods, such as empirical design or analog design. Because the structure of the fuselage itself is more complicated and larger, if it is not properly designed, it will cause certain quality problems. Moreover, the production cost is high and the design cycle is long. These problems are obstacles to the performance improvement of the bearing test machine. The bearing testing machine will have a large load pressure during the working process, and it is necessary to overcome the vibration caused by the loss of the fuselage [1]. The requirements of the testing machine body will raise higher requirements. The body needs to have high structural strength and stability, but also has a certain shock absorption capacity, but this will also increase the design cost and hinder the development of the bearing testing machine. In view of these problems, this paper focuses on the structural design of the bearing testing machine by means of finite element simulation analysis, checking the fuselage to meet the strength and stiffness under certain working conditions, and calculating the bearing test according to strength and stiffness. The angular displacement of the machine body is modeled and analyzed according to the dynamics of the testing machine, and the simulation calculation is carried out. The damping method suitable for the operation of the fuselage is proposed, and finally it is comprehensively optimized [2].

2. Mechanical analysis of the bearing test machine fuselage

2.1. Test machine composition and working principle

(1) Test machine composition. The composition of the test machine is shown in Fig.1.
(2) Working principle. The bearing is loaded by a single-column hydraulic machine, and the AC servo motor is used for swinging to simulate the actual working environment of the testing machine. The design of the temperature control system is used to design the aeronautical self-running cushion, and the operating life is under the action of the load. Conduct an evaluation. The installation environment of the test machine is an analog system, which can simulate the actual working conditions and measure parameters such as temperature and load on-line [3].

2.2. Characteristics and mechanical analysis of the test machine fuselage

(1) Features of the fuselage. The C-type single-arm structure makes it easy to install the environmental control system. The activity of the fuselage is measured by using the column as a guide to complete the bearing pressurization.

(2) Mechanical analysis. The fuselage of the test machine is a flat frame, and the plane straight lines and curves constitute the force diagram, as shown in Figure 2. By analyzing the entire force of the fuselage, it can be concluded that BC is the weakest position of the fuselage, and the force analysis of the BC is required.
Since BC is susceptible to bending moments and axial forces, it is necessary to calculate the bending moment and axial force:

\[ M = P(l_1 + r \cos \theta) \quad N = P \cos \theta \]  

(1)

M represents a bending moment; N represents an axial force.

Because the fuselage interface of the testing machine is complex, it is impossible to calculate the accuracy accurately. It can only be roughly calculated. The body of the testing machine is simplified into four small parts [4], and the lengths are respectively denoted as \(l_1, l_2, l_3, l_4\), each the partial mean moment of inertia of the part is expressed as \(J_1, J_2, J_3, J_4\), and the relative displacement can be obtained according to the formula of material mechanics:

\[ \alpha = \frac{P l_1^2}{2EJ_1} + \frac{P l_2(l_1 + l_4)}{2EJ_2} + \frac{P l_3 l_4}{EJ_3} + \frac{P l_4^2}{2EJ_4} \]  

(2)

P represents the nominal force; E represents the elastic modulus. Among them: \(l_1 = 0.8m, l_2 = 0.55m, l_3 = 1.5m, l_4 = 1.2m\).

\[ \alpha = 1.56' \]  

(3)

Under the action of the nominal force P, the angular displacement cannot exceed \(3'\), so the stiffness of the fuselage meets its requirements.

3. Static Finite Element Analysis of Bearing Test Machine Body

3.1. Finite element analysis

(1) finite element thought. The main way of the finite element method is to discretely form some continuous units into units and divide several nodes in different units. For the constant function, the node value is compared to the basic unknown. In order to show some irregularities in the unit, an interpolation function needs to be allocated in each unit to obtain a finite element equation group, and then Just solve it. The idea of finite element is discrete and piecewise interpolation. Discretization means that some continuous solution areas are decomposed into units with a certain computational capacity, as shown in Figure 3. The connection in the figure is the node, and each unit needs to implement the corresponding function through the node [5].
(2) Finite element analysis steps. The analysis steps of finite element are divided into pre-processing, solution and post-processing [6]. The important task of pre-processing is to model the distributed tasks and convert the specific problems into finite element models of numerical calculations. The purpose of modeling is to provide data support for all of the following, and to obtain the accuracy of the calculation results by establishing the error of the model. The key task of creating a model is to perform meshing. The 3D model has certain rationality and convergence. These properties need to be determined by meshing. Many details need to be considered. Solving is the data analysis of the finite element model. The finite element numerical calculation is completed; the post-processing is to analyze the calculation results, and after the analysis is completed, the model is correctly evaluated, and the main purpose is to optimize the analysis process [6-7].

3.2. Establishing a finite element model
In the process of using finite element software for analysis, the model can be built by commands in the finite element software to establish a special platform for the model - Design Modeler. Many commands and functions of the platform are similar to CAD software, which can complete some simple functions. Modeling, but for the complex equipment of the bearing test machine [8], it is difficult to use the platform for modeling; the equipment can also be modeled by some professional modeling software, such as Workbench, Software is a professional model analysis software. Although it has the function of modeling, it has few functions and needs to be assisted by CAD software. The last way is to use SolidWorks to build the model of the bearing testing machine, and work with the Workbench to complete the simulation optimization calculation. As shown in Figure 4.
3.3. Analysis of finite element results

(1) Analysis of deformation field. The deformation of the test machine body is shown in Figure 5.

Analyze the deformation diagram of the test machine. The maximum deformation value is 0.584mm. The hydraulic cylinder is in the upper part of the fuselage, and the lower part is less stressed. The bearing tester returns the deformation of the upper beam and the throat of the fuselage at full load. There are two cases of deformation, one is the deformation of the fuselage x of the testing machine, and the other is the deformation of the fuselage y. According to the principle of the coordinate axis, if the y-direction deformation occurs, it indicates that the fuselage is deformed by force, and the height of the center line is stressed [9]. A certain change will occur, causing deformation on the back of the fuselage. This is because the fuselage of the test machine itself is subjected to a downward pressure, which causes the body of the test machine to have a tendency to deform. The intermediate plate cannot withstand such pressure, so the upper beam is positive and the rear of the fuselage is negative. The x-axis deformation is similar to the y-axis. There are also positive and negative directions. The maximum positions of the positive and negative displacements are 0.019 mm and 0.450 mm. These deformations will cause deformation of the bearing test machine and affect the normal use of the test machine.

(2) Stress field analysis. The equivalent stress cloud of the bearing test machine is shown in Figure 6.
The maximum stress of the fuselage occurs in the upper beam of the hydraulic cylinder. The maximum equivalent stress should be 160 MPa. The stress of the rib and the intermediate plate is 40 MPa. The large rounded corners of the two sides of the fuselage will be subjected to a certain tensile stress, which causes local occurrence. Concentrated stress conditions. By increasing the thickness of the plate, the phenomenon of concentrated local stress can be alleviated [10].

(3) Calculation of the angle. The calculation of the angle is divided into angular deformation and angular stiffness. The calculation of the angular deformation is due to the fuselage of the testing machine. The deformation of the z-axis is not affected by the force. Only the x-axis and the y-axis are required. It can be deformed. The eight points of the upper beam of the fuselage determine the displacement of the x-axis and the y-axis, and calculate the angular deformation. The way to calculate the angular deformation is: the calculation of the y-direction deformation amount and the calculation of the x-direction deformation amount. As shown in Fig. 7, the known y-distance distance points have 1, 3, 5, and 7, and the deformation tangent of the x-direction displacement is calculated based on these points.

The stress of the model was marked using the labeling tool in ANSYS software, and the measuring points of the upper beam of the testing machine were measured using the labeling tool in the software. The measurement results are shown in Table 1.

Table 1. Displacement of measuring points in the y and x directions (mm)

| Measuring point | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    |
|-----------------|------|------|------|------|------|------|------|------|
| Y direction     | 0.5388| 0.3911| 0.5422| 0.3884| 0.2985| 0.3958| 0.2987| 0.3695|
| X direction     | 0.1251| 0.1301| 0.1177| 0.1228| 0.3058| 0.3065| 0.3151| 0.3144|
4. Improved design of the fuselage after finite element analysis

This research mainly from the test machine fuselage as the main research direction, analysis of the deformation cloud of the test machine fuselage, and the angular deformation of the computer body, the research on the improvement of the fuselage design. According to the static analysis of the fuselage of the test machine, the upper beam of the fuselage is most deformed, and the upper part of the fuselage is caused by the angular deformation, and the deformation of other parts of the fuselage is small. Therefore, in order to reduce the deformation caused by the beam on the fuselage, it is necessary to appropriately thicken the upper beam. The stress cloud diagram of the fuselage is analyzed. The most stressful part of the fuselage is also at the upper beam. Thickening the upper beam not only prevents deformation, but also prevents stress from increasing. The deformation of the top of the fuselage is the most prone to deformation. It is necessary to strengthen the design of the ribs, and increase the radius of the arc to reduce the stress concentration.

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