Research on Bearing Stress Characteristics of Stacking Robot Base under New Engineering Background

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Abstract. Under the background of the continuous development of new engineering, more and more researches are aiming at new cutting-edge technologies, among which industrial robots have attracted much attention. Based on typical trajectory and a given load condition of the palletizing robot, the dynamics analysis and calculation was accomplished by using the dynamics analysis and calculation module of Adams software under the condition that the palletizing robot was working normally, then obtained the dynamic load variation when rolling bearing was running, furthermore, the contact stress change rule was obtained by using the finite element analysis calculation method, and the rule was regard as the basis of rolling bearing fatigue life analysis and evaluation. Judging from the results of analysis and calculation, the contact stress distribution of rolling bearing under the combined effect of both external load and dynamic load, which was similar to the phenomenon of commonly used rolling bearing stress fatigue destruction, this method can effectively overcome the deficiencies of traditional rolling bearing fatigue life calculation method that only consider static load, and reference for relevant engineering and technical personnel.

1. Introduction

Under the background of the development of new engineering education, more and more researches around robots are emerging. As an important part of palletizing robot, rolling bearing plays supporting and guiding role at work. Rolling bearing life and carrying capacity, is one of the key factors that decides the main technical performance indicators of palletizing robot. The carrying capacity and fatigue life of traditional rolling often primarily uses the empirical formula and analysis method to calculate the axial force and radial force, and obtains the rolling bearing stress change rule by using the finite element analysis and calculation method, then the stress be used for rolling bearing fatigue analysis and evaluation. Compared with the traditional method, in this article, the dynamics analysis and calculation was accomplished by using the dynamics analysis and calculation module of Adams software under the condition that the palletizing robot was working normally, then obtained the dynamic load variation when rolling bearing was running, furthermore, the contact stress change rule was obtained by using the finite element analysis calculation method, and take the result as the basis of analysis and evaluation for rolling bearing fatigue life. The main technical innovation point of this kind of method is that not only the external load but also the dynamic load to bearing service life are considered.
2. Palletizing Robot Dynamics Analysis

2.1. Palletizing Robot Dynamics Simulation

Bases on Inventor modelling capabilities, establish the three-dimensional model of palletizing robot was completed, and the model of palletizing robot was be imported into Adams to dynamics simulation by the data file #.X_ t which could be accurately identified, 3D model was shown in figure 1.

In order to be able to accurately move on to the dynamics simulation for the palletizing robot. Firstly, material properties should be given to every part of the palletizing robot, the base of the robot uses cast iron, arm adopts the aluminum alloy material, and the bearings with bearing steel. Secondly, the constraints must be added to each connection parts, so that the palletizing robot can carry out the simulation, therefore, in addition to the base and ground were fixed constraint, other rotary joints and bearings are added as rotating hinge constraint. Finally, the most important step was adding right driving joints for each joints on the basis of robot’s trajectory and initial conditions, so that the dynamics simulation was carried on with having adjusting suitable perspective and simulation time.

2.2. Force Analysis of the Base Bearing

The results of a dynamic analysis was checked in Adams-Post Processor depended on the dynamics analysis calculation result of palletizing robot, and the changing curve of hinge contact force that between bearing inner ring and the shaft along the three directions was obtained by dynamics analysis of palletizing robot. As follows, shown in figure 2, figure 3, and figure 4.

Through the curve editing features of Adams-Post Processor, the maximum force of rolling bearing center of mass was accurately and accurately obtained by Adams sortware. As follows $F_r=7891.26N; F_y=628.5N; F_z=7924.96N$, and $F_x$ was radial force, as well as $F_y$ while $F_z$ was axial force. So that the greatest of axial force and radial force were $F_t=628.5N$ and $F_r=11183N$. Then the area of the bearing inner surface and the upper surface were measured by 3D drawing software, and $S_{inner}=13483.72mm^2$, $S_{up}=7389.03mm^2$. Through the formula $P=F/S$ for computing the pressure, the
pressure on bearing inner surface was $P_{\text{inner}}=0.829\text{Mpa}$, as well as pressure on bearing upper surface was $\text{sup}=0.085\text{Mpa}$.

3. The Finite Element Analysis of Rolling Bearing

3.1. Material Properties and Meshing of Rolling Bearing

Because of rolling bearings belongs to completely symmetrical model, so that just 1/4 model of rolling bearing is needed to analyze and compute. Inner ring, out rolling and rolling element all adopt bearing steel GCr15SiMn, and density is $7820\text{kg/m}^3$, elasticity modulus is $2.16 \times 10^5\text{Mpa}$, Poisson's ratio is 0.3, compressive strength is $1813\text{Mpa}$ and yield strength is $1323\text{Mpa}$. The cell C3D8I which belong to 8 nodes hexahedron linear non-conforming finite element is selected as computing element in Finite element analysis software Abaqus by the reason of that it has many advantages, for instance, non-conforming mode can overcome the shear locking problems in linear completely integral unit, so that the results of displacement and stress are more accurate under the condition of less distortion in the unit. Then the structural grid of rolling bearing is meshed by using the scanning grid partition technology in software Abaqus, and get 69512 unit grid, figure 5 is the grid model.

![Three-dimensional mesh model](image)

**Figure 5.** Three-dimensional mesh model

![Definition of contact pairs](image)

**Figure 6.** Definition of contact pairs

![Define the constraint and load](image)

**Figure 7.** Define the constraint and load

3.2. Define the Constraint and Load

The outer ring is fixed on the frame, and the inner ring is rotating with the spindle when the rolling bearing of palletizing robot is working normally. So that a fixed constraint should be defined on the outer ring of rolling bearing. Definition of contact pairs is shown in figure 6. In addition that rolling bearing’s analysis and calculation adopts 1/4 substance model, therefore, symmetry constraints are imposed on plane XOY and YOZ.
Furthermore, rolling bearing’s dynamic load which was obtained by dynamics analysis of palletizing robot must be applied on the corresponding position of rolling bearing, consequently, the result of rolling bearing’s constraint and load is shown in Table 1 and Figure 7.

Table 1. The result of rolling bearing’s constraint and load

| Position                | Outer ring of rolling bearing | Inner ring of rolling bearing |
|-------------------------|-------------------------------|------------------------------|
| value                   | 0.085Mpa                      | 0.829Mpa                     |

3.3. Analysis and Summary of Stress Results

Mises stress [6] equivalent clouds of rolling bearing’s stress characteristics is shown in Figure 8, and it is obtained by the numerical iteration calculation of rolling bearing’s finite element model after completing the mesh generation, the constraint definition and applied load of rolling bearing in Abaqus.

![Figure 8. Mises stress equivalent clouds of rolling bearing’s stress characteristics](image)

Firstly, it is the mises stress [7] cloud of outer ring (Fig.8-a) showing that the maximum mises stress is 60.52Mpa, and appears on the top of the contact area between the surface of rolling element and outer ring, and then, the mises stress gradually reduces along the axis(X) of inner ring; Radial maximum stress of outer contact area all appear on the contact surface.

Secondly, the mises stress cloud of rolling element (Fig.8-b) shows that the axial stress mainly concentrate on the top and bottom of contact surfaces between rolling element and both outer and inner ring, while, stress is relatively small in the middle; furthermore, roller radial stress of rolling element mainly appears on the contact surface, and the maximum value is 224.9Mpa.

Thirdly, the mises stress cloud of inner ring (Fig.8-c) shows that the maximum mises stress is 140.2Mpa, and appears on the bottom of the surface within the inner ring, and then, the mises stress gradually reduces along the axis(X); Stress mainly appears on the bottom section of the inner ring.

In general, the mises stress cloud of solid bearing (Fig.8-d) shows that The maximum equivalent mises stress occurred on the bottom of contact area between the inner and the rolling element, and it is 224.9Mpa; stress mainly occurs on the contact surfaces between rolling element and both outer and inner ring. These phenomena indicate that fatigue damage of rolling bearing forms mainly on the contact surface and appears small fatigue crack on the contact surface, then fatigue pitting corrosion and erosion.
are gradually formed, so the service life of bearing is ultimately reduced. The result is consistent with the stress fatigue destruction phenomenon of rolling bearing used commonly.

4. Conclusion
This article is based on the typical trajectory and a given load condition of the palletizing robot, the dynamics analysis and calculation was accomplished by using the dynamics analysis and calculation module of Adams software under the condition that the palletizing robot was working normally, then obtained the dynamic load variation when rolling bearing was running, furthermore, the contact stress change rule was obtained by using the finite element analysis calculation method, and the rule was regard as the basis of rolling bearing fatigue life analysis and evaluation. Judging from the results of analysis and calculation, the contact stress distribution of rolling bearing under the combined effect of both external load and dynamic load, which was similar to the phenomenon of commonly used rolling bearing stress fatigue destruction, this method can effectively overcome the deficiencies of traditional rolling bearing fatigue life calculation method that only consider static load, and reference for relevant engineering and technical personnel.

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