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Fatigue life analysis of driving shaft of conveyor system based on nCode Design-life

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Abstract

The drive shaft of the conveyor system of a car assembly shop is broken due to fatigue damage. The finite element theory and nCode fatigue life analysis software are used to analyze the fatigue life and fatigue damage of the drive shaft. Firstly, it uses Catia to build 3D models, imports the established drive axis model into ANSYS/Workbench, performs finite element static analysis, and then imports the analysis results into the fatigue analysis software of nCode. Fatigue life analysis is carried out, and the fatigue damage diagram and life diagram of the drive shaft of the conveyor system are obtained by the S-N analysis method of nCode Design-life. The most vulnerable position and life of the drive shaft of the conveyor system are found, and the method of improving service life of the conveyor system's drive shaft is proposed.

Keywords

Drive shaft; nCode; ANSYS/Workbench; static analysis; fatigue life.

1. Introduction

This paper analyzes the fatigue damage and fatigue life of the drive shaft of a conveyor system in the automobile assembly shop. Firstly, the 3D model of the drive shaft is established by CATIA, then the ANSYS/Workbench is used to check the static strength of the drive system drive shaft to obtain the stress strain cloud map. Finally, the nCode Design-life fatigue damage and fatigue life analysis are carried out on the drive system drive shaft with the load spectrum. and the fatigue damage cloud map and life cloud map are obtained, and the key-node damage data and life data are obtained. The corresponding solutions and improvement measures are proposed[1][2].

2. Finite static analysis of the drive shaft

2.1 The establishment of the finite element model

In the automobile assembly shop, the drive shaft of the drive system is subjected to the gravity of the cargo, the friction between the pulley and the heavy object, the torque that the motor drives the drive shaft to rotate, and the reverse torque of the cargo to the drive shaft. Under these loads, the drive shaft will be bent and deformed. Usually these conditions do not occur separately. If analytical methods are used, it is difficult to consider the response of the conveyor system drive shaft under combined conditions. Based on the finite element analysis of the driving system drive shaft statics, not only the stress and deformation distribution of the conveyor system drive rig under static load can be obtained, but also the weak position of the drive system drive shaft can be predicted, which provides reference and guidance for the design and optimization of the drive shaft of the drive system[3]. A three-dimensional model of the drive shaft of the conveyor system using Catia is shown in Fig.1.

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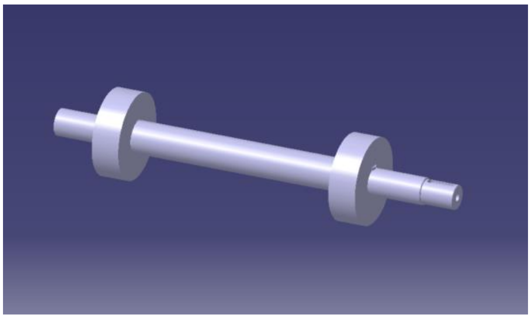

Fig.1 Catia model of the drive system drive shaft

The static equation is:

$$\{K\}\{\delta\}=\{f\} \quad (1)$$

Here, $\{f\}$ is the total load array, $\{K\}$ is the overall stiffness matrix, and $\{ä\}$ is the total node displacement array. The essence of the finite element method for solving the static problem is to solve the equation $\{K\}\{ä\}=\{f\}$. Firstly, the node displacement is obtained, and then the unit strain and the unit stress are derived from the node displacement, and finally the displacement and stress distribution of the whole structure can be obtained. In material mechanics, four strength theories are commonly used to judge the effectiveness of the structure. In this paper, the fourth strength theory is used as the criterion for the plastic failure of the structure. It is considered that as long as the shape change ratio of any point of the structure can reach the stress limit value of the material, the plastic flow of the structure will be caused. This theory is suitable for plastic materials with obvious yield points such as steel, which is closer to the test results than other theories. According to the fourth strength theory, the strength condition of the structure can be given by formula 2, wherein $ó_{eq}$ is the equivalent stress, or stress; σ_1 is the first principal stress, σ_2 is the second principal stress, σ_3 is the third principal stress; $[\sigma]$ is the yield stress. When the equivalent stress of the structure is less than the allowable stress, the strength of the structure is considered to be sufficient [4].

$$\sigma_{eq}=\sqrt{\frac{1}{2}[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2]}<[\sigma] \quad (2)$$

2.2 Import of finite element models

After the Workbench 15.0 software is started, a new Geometry Project A is created by right-clicking on Geometry and selecting the command "Browse" of Import Geometry in the pop-up shortcut menu, where the open dialog box pops up. Select the file path in the pop-up open dialog box and import the .stp geometry file of the drive shaft of the conveyor system. At this point, the question mark after Geometry changes to a check number, indicating that the solid model already exists. Add material properties to edit the specific properties of steel material No. 45, The material properties are shown in Table 1 below:

Table 1 Axis Material Properties

Material	45 Steel
Modulus of elasticity/MPa	2. 09×105
Poisson	0.269
Density/(kg·mm-3)	7.85×10-6
Tensile strength/MPa	≥600
Yield strength/MPa	≥355
Elongation/%	≥16

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End face shrinkage/%	≥40
Impact energy/J	≥39
Impact toughness value/(J·cm-2)	≥49
Hardness（not heat treated）	≤229HB

2.3 Division of the grid and analysis

The division of the grid has a great influence on the static analysis results of the drive shaft of the drive system and the subsequent analysis results of fatigue damage and fatigue life. The divided grid is shown in Fig. 2.

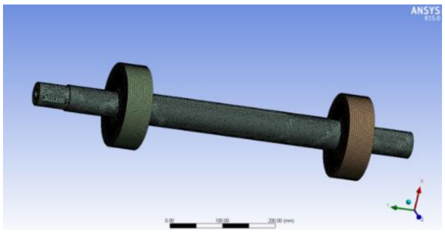

Fig.2 Catia model of the drive system drive shaft

The static analysis of the drive system drive shaft is used to analyze the response of the structure under a given static load. It is more concerned with the parameters of displacement, stress, restraining reaction and strain. The general equation for classical theoretical objects is:

$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = \{F(t)\} \quad (3)$$

Where: $[M]$ represents the mass matrix; $[C]$ represents the damping matrix; $[K]$ represents the stiffness coefficient matrix; $\{x\}$ represents the displacement vector; $\{F(t)\}$ represents the force vector. In linear static analysis, all time-related options are ignored [6].

The parameters in calculation process are as follows: the matrix $[K]$ is continuous, and the corresponding material satisfies the linear elasticity and the small deformation theory; the matrix $\{F(t)\}$ is a static load, and does not consider the load that changes with time, regardless of the influence of mass, damping and the like. When the drive shaft is working, one end of the shaft is connected to the drive motor, and the middle two slots are connected to the gear drive motor with a power of 7.5k W and a rotational speed of 70r / min. The drive system drive shaft is subjected to the gravity of the cargo on the conveyor belt, and the frictional force of the pulley and the heavy object, the torque that the motor drives the drive shaft to rotate, and the reverse torque of the cargo to the drive shaft.

The load and boundary simulation strengths acting on the drive shaft are calculated using two different loads: “Moments” and “Bearing load”. The constraints are “Cylindrical Support” and “Fixed Support”[7],which is as shown in Fig.3.

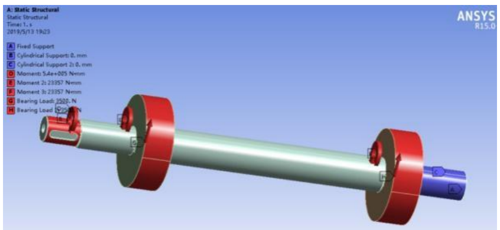

Fig.3 Diagram of constrained load on drive shaft

After dividing the grid and setting the load and constraints, select the “solution” toolbar in the analysis tree bar and the body command at the top of the interface to select the conveyor system drive axis. Without selecting the gear connected to the drive system drive shaft through the keyway, the analysis of the stress strain and total strain of the drive system drive shaft can be output [8].

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As shown in Fig.4, an analysis of the equivalent stress of the drive system drive shaft is performed. The result shows that the maximum concentration of stress on the drive shaft of the conveyor system is at the side of the shaft that is connected to the motor.

As shown in Fig.5, an analysis of the equivalent strain of the drive system drive shaft is performed. The result shows that the maximum equivalent strain point of the drive system drive shaft is located at the side of the shaft connecting the drive system drive shaft to the motor.

As shown in Fig.6, the total deformation of the drive system drive shaft is analyzed. From the results, the total strain concentration point of the conveying system can be seen.

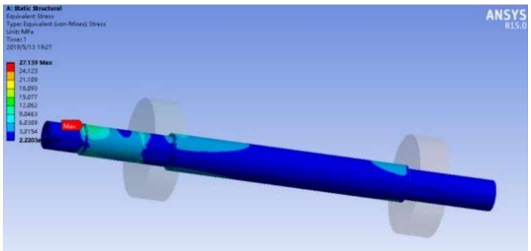

Fig.4 Equivalent Stress

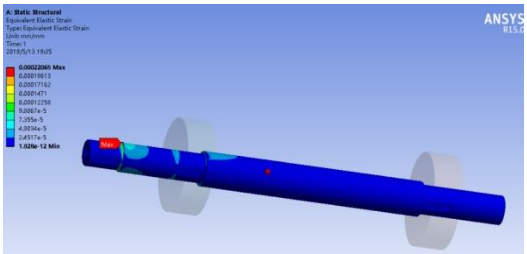

Fig.5 Equivalent strain

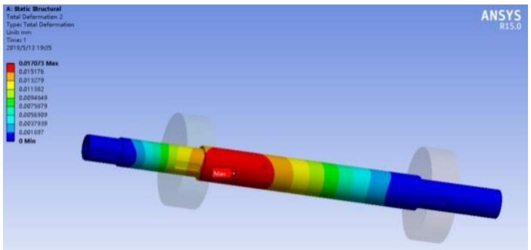

Fig.6 Total deformation

3. Fatigue reliability analysis

Fatigue reliability analysis generally follows the process below:

As shown in Fig.7, it is a flow chart for fatigue life analysis. Fatigue analysis considers the influence of the following parameters: material tensile strength b, material surface influence factor s_K, material surface residual stress m_O, load scaling factor lS, load compression threshold G, surface roughness z_{R1}. Under the default conditions, define the tensile strength of the No. 45 steel material, ignore the influence of the surface microscopic on the factor s_K (neither weakened nor enhanced). There is no residual compressive stress on the surface. The cycles extracted from the load spectrum all have an effect on fatigue (threshold is zero) and the roughness is N8 [9].

As shown in Fig.8, the damage cloud image shows that the node 249132 is the earliest fatigue failure as the location node. After one cycle, the fatigue damage is 4.19E-07 (the damage amount is increased to 1, which is considered to be the fatigue failure).

As shown in Figures 9 and 10, the fatigue life cloud image shows that the node 249132 is the earliest fatigue failure as the location node. After one cycle, the fatigue damage generated is 4.19E-07 (the damage amount is added to 1, which is considered to be fatigue failure).

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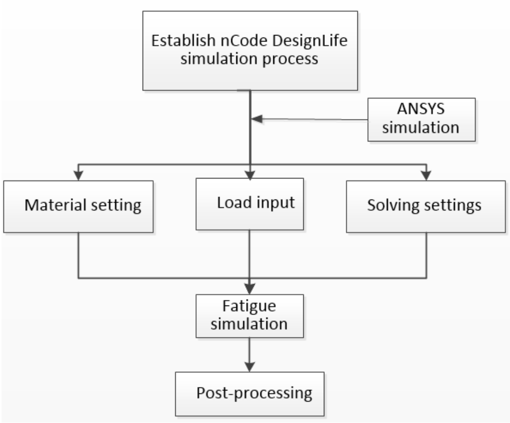

Fig.7 Fatigue analysis process

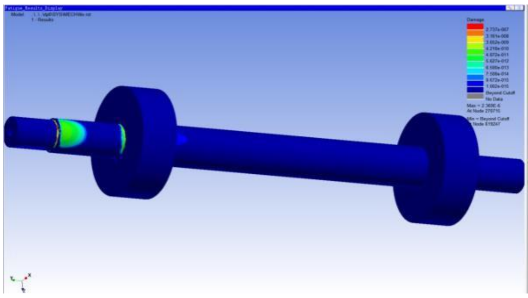

Fig.8 Destroying the cloud display results

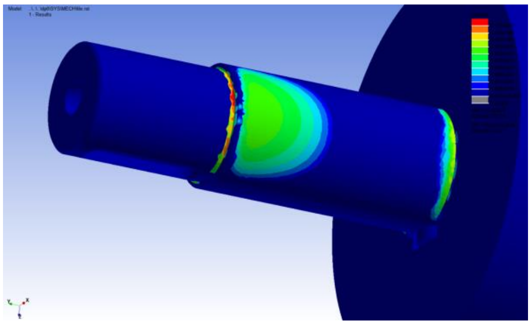

Fig.9 Fatigue life

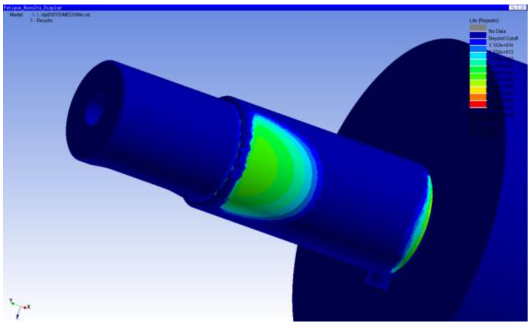

Fig.10 Fatigue life 2

The results show that the shaft step between the drive shaft motor and the pulley is mostly vulnerable, and the node 249132 is the first point to be damaged. The shaft step between the motor of the drive system drive shaft and the pulley is mostly prone to fatigue failure and breaks first.

The cloud map of stress strain is obtained by finite element static analysis of the drive system drive shaft. Fatigue damage、fatigue life cloud map and fatigue damage data of the corresponding nodes are obtained by the subsequent fatigue damage and fatigue life analysis [10]. These data and the most vulnerable locations are optimized,which is as follows:

(1) Reduce the surface roughness of the conveying system drive shaft to avoid friction and scratches.

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(2) Appropriately increase the radius of the transition fillet at the shaft step to avoid stress concentration.

(3) Perform heat treatment at the step of the drive system drive shaft.

(4) Try to avoid wrong operations. Avoid the constant start and stop of the machine, resulting in load changes.

(5) Considering the cost, try to ensure the even distribution of the load,.

(6) Regularly inspect and maintain the conveyor system to kill the loss in the bud.

4. Conclusion

In this paper, the fatigue life analysis of the drive shaft of a conveyor system is carried out. The fatigue life analysis is carried out by statics combined with nCode Design-life. The stress concentration point and the most vulnerable point are obtained, and the method of improving the life of the drive shaft is given. It has certain reference value for fatigue life analysis of shaft parts in engineering field.

Acknowledgments

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