Dynamic Analysis of Shaft Structure Based on ANSYS/LS-DYNA

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Abstract. In this study, a part of the shafting structure of the accessory transmission system consisting of shaft-gear-bearing is studied. ANSYS/LS-DYNA explicit dynamics simulation software is used to simulate the dynamics of the shaft structure. It compares and analyzes the overall shaft structure, gears and bearings. The simulation results show that: The place where the equivalent stress of the shaft structure is relatively large is mainly concentrated at the tooth root and the tooth surface, where the stress is mainly in the vicinity of two or three teeth. With the change of time, the maximum equivalent stress value and position of the rolling elements are also correspondingly changed, it provides a reference for the design and optimization of gear and bearing in the actual assembly process for transmission system.

1 Introduction

The research on the dynamic characteristics and dynamics of the transmission system is gradually developed from static analysis to dynamic analysis. In recent years, the research on the mechanical characteristics and working performance of gears has mainly focused on two aspects: one is the study of tooth surface contact stress and strain when the gears are engaged, and the second is the study of gear pair dynamics during the transmission process [1-3]. The dynamic characteristics of gears are affected by a variety of random factors, and the impact of assembly errors on the dynamic contact problems of gears is of utmost importance. The bearing is an important component that transmits motion and bears load. It not only acts as a load supporter, but also serves as a moving joint. It has the advantages of easy replacement, low friction, etc., and can slide friction between a fixed body and a moving body that rotates with each other. The force becomes rolling friction, and the friction loss is small, mainly used in the automotive industry, aerospace and other fields [4-5]. In mechanical transmission, the mechanical properties of the bearing have a great influence on the dynamic characteristics of the entire system. In the moving state, the mechanical relationship between the internal parts is complex, mainly including the contact between the rolling elements and the inner and outer rings, and the rolling elements are in contact with the cage. Under no-load conditions, the rolling elements come in contact with the points. As the load increases, the point contact becomes surface contact. The position, size, shape, and frictional force distribution of the contact area are unknown before the analysis. It changes with the load and belongs to the nonlinear contact problem. The traditional research on the bearing characteristics is only in one aspect. It cannot verify the actual

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situation and the interaction with other mechanical systems [6-10]. Therefore, it is very important to establish a traditional system for shafting and to be able to effectively simulate the interaction between parts of the mechanical system.

2 Experiment procedure

This study uses a part of the shafting structure of the accessory transmission system consisting of shaft-gear-bearing as the research object. The main geometric parameters of the gear are shown in Table 1. The main geometric parameters of the bearing are shown in Table 2.

Table 1. basic parameters of gear.

Basic parameters	Driving gear	Driven gear
modulus	4	4
number of teeth	25	23
pressure angle (°)	25	25
tooth width (mm)	30	28
addendum coefficient	1	1
headspace coefficient	0.25	0.25
modification coefficient	0	0

Table 2. The size of the deep groove ball bearings (mm).

Basic parameters	Driving gear	Driven gear
inner diameter	30	25
outer diameter	72	62
bearing width	19	17
ball diameter	10.5	9.25
inside the outer ring	56.25	48.13
inner ring outer diameter	45.76	38.88
outer channel radius of curvature	5.51	4.86

The material has a modulus of elasticity of 211Gpa, a Poisson ratio of 0.3, and a gear torque of 210Nm. The solid assembly model of the shafting structure established in Pro/E is shown in Fig.1. The physical model after importing ANSYS/LS-DYNA is shown in Fig. 2.

Fig.1 The Pro/E assembly drawing of shafting structure

Fig.2 The solid model of shafting structure

In the process of meshing the shafting structure, according to the characteristics of gear meshing and bearing contact, the contact position should be refined. For the overall use of Solid 164 units, sweeping and intelligent methods are used to divide. For the inner ring of the gear, the Shell163 unit is divided by the mapping method; Because the cage model is more complex, it is divided in the form of a free grid, and the dynamic finite element model of the shaft system is finally shown in Fig. 3. In ANSYS/LS-DYNA software, there is no contact unit, only the surfaces that may be contacted, the contact type and contact related parameters are defined, and the frictional force is taken into consideration. This ensures that no contact occurs between the contact surfaces during the calculation process. penetrate. This study selects the automatic contact of the surface and defines the contact pairs of the shafting system by means of the node component. The definition of nine contact pairs is shown in Fig.4.

Fig. 3 The dynamic analysis finite element model of shafting structure

Fig.4 The dynamic contact pairs of the shafting structure

For the driving wheel with bearings, due to taking into account the analysis of the force of the driven gear during the software analysis. The drive gear shaft is set as an elastic body, and both ends of the shaft connected to the inner ring of the bearing are set as a rigid body. At the same time, in order to ensure that the shaft and the bearing have synchronous rotation speed, the inner ring of the bearing is affixed to this part of the shaft and is set as a rigid body, and a resistance moment is applied to the rigid body. Therefore, a resistive torque is applied to both the inner ring of the bearing and the shaft, and the rotational speed is applied to the driven wheel. The solving process requires solving control, including calculating the termination time, file output interval, and output file control.

3 Results and analysis

From the LS-DYNA's postprocessor LS-PREPOST, the time-dependent curve of the equivalent stress of the shafting structure is shown in Fig.5.

Fig.5 Equivalent stress with the change in time

Select the equivalent stress cloud at the time of 0.0091s, as shown in Fig.6.

Fig.6 Equivalent stress nephogram of shafting structure at 0.0091s moment

From Figure 6, we can see from the dynamic simulation results more in line with the actual situation, where the stress is relatively large mainly in the tooth root and tooth surface contact, where the stress is mainly in the vicinity of two or three teeth, For places where the contact is far away, the

stress is zero, which is consistent with the St.Venern's law in elastic mechanics (indicating that when the area of a small part of the elastic body or the internal load of the volume is changed by the static equivalent, the stress distribution in the vicinity will be significant. Changes can be ignored in the distance.) In order to analyze the change in the equivalent stress of a pair of gears at different positions in the meshing process, three units are extracted in the middle position of a certain tooth and the tooth roots on the driving wheels of a pair of meshing gear pairs, as shown in Fig.7. The time-dependent change of the equivalent stress of the three elements during the meshing process is shown in Fig.8.

Fig.7 Schematic diagram about the driving gear of tooth surface

Fig.8 Equivalent stress of element curve

Fig.9 Equivalent stress nephogram of rolling with the change in time

From Fig.8, it can be seen that when it enters the meshing position, its equivalent stress abruptly changes and gradually becomes larger, that is, the equivalent stress near the contact line is greatest when the gear is in contact, and the equivalent stress is when the contact is withdrawn. It will be substantially reduced to zero. When the driving wheel and the driven wheel come into engagement, the equivalent force of the driving wheel gradually decreases, because the engaged unit gradually approaches the tooth root.

Take two moments to analyze the results. Fig.9 is the equivalent stress diagram of the rolling bearing.

As can be seen from Fig.9, during the initial rotation of the bearing, the load is mainly concentrated on the rolling elements in the lower half of the bearing, and the force on the lowest rolling element is relatively large, and then decreases sequentially. At 0.005s, the maximum equivalent stress of the rolling bearing is 754 MPa. The maximum equivalent stress at 0.01s is 815 MPa. By comparison, it can be found that the maximum equivalent stress of the rolling bearing in the ideal model occurs at the contact area between the rolling element and the inner and outer rings of the bearing. In the course of operation, the maximum equivalent stress value and position of rolling element operation also change with time.

4 Conclusions

An experimental analysis method for explicit dynamics of shafting structures is proposed. The variation of the maximum equivalent stress with the time during the operation of the shafting structure was obtained. In the process of contact, the equivalent stress in the vicinity of the contact line of the gear is the largest, and when it comes out of contact, the equivalent stress of the gear will be substantially reduced to zero. When the driving wheel and the driven wheel come into engagement, the equivalent force of the driving wheel gradually decreases. The maximum equivalent stress of the rolling bearing in the ideal model occurs at the contact area between the rolling element and the inner and outer rings of the bearing. In the course of operation, the maximum equivalent stress value and position of rolling element operation also change with time.

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