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Design and Dynamic Simulation of Friction - Vibration

Test Rig for Planetary Gearbox

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Abstract—In order to prevent the catastrophic accidents caused by the failure of the reducer, based on virtual technology such as CAD/CAE and Solidworks, the friction and vibration testing device of planetary gear reducer was designed, and the weak links of the transmission device were found out, its life and working efficiency has also been improved. In addition, in order to judge the correctness of the design of planetary gear reducer transmission device and optimized the design process of the reducer, Solidworks was used to build the three-dimensional model of the test bench and Adams was used to simulate the motion of the planetary gearbox transmission system.

Keywords-Optimization Design; Test Bench; Reducer; Dynamics Analysis

I. THE BACKGROUND

With the rapid development of modern industrial technology, various industries have a higher demand for planetary gearbox, serious failures often occur at low speed and heavy load. In order to avoid catastrophic accidents caused by faults[1], in this paper, the transmission mechanism of friction and vibration of planetary gear system

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is studied. But at present, there are fewer devices for testng friction, vibration, wear and other information of planetary gear transmission system. Therefore, the design of friction vibration test rig for planetary gearbox is very important. In order to increase reliability, intuition and flexibility, it is necessary to simulate its transmission system under virtual technology.

II. DESIGN SCHEME OF TEST RIG

This test rig mainly tests the vibration, friction and wear information of the gearbox by collecting, processing, displaying and storing the vibration sensor data in real time; the performance of the gearbox is evaluated by comparing the vibration sensor data and the preset technical parameters. Its structure adopts modular design; the structure plan is shown in Fig. 1 and mainly includes test bench base, motor, coupling, gearbox, sensor and dynamometer.

The control system of the test bench has the following functions: start of motor, adjustment of speed and load, data collection, control of experimental process, processing of test data and graphics.

The system structure diagram of the test bench is shown in Fig. 2.



Figure 1. Test-bench sketch



Figure 2. System structure diagram

III. MAIN COMPONENTS STRUCTURE

A. Sensors

1) Vibration testing device

In the vibration test, the wireless vibration instrument was selected in this experiment. Let its vibration direction in line with the built-up magnet, then the relative displacement of spring and damper occurs. Thus, the output voltage of the hall component varies with its position in a magnetic field[2], its structure is shown in Fig. 3.



Figure 3. Schematic diagram of vibration sensor

2) Friction testing device

In this experiment, resistance strain gauge was selected for friction test. The strain deformation of material under the action of external force makes its resistance value change; the stress can be known by the change of resistance value, so as to reflect the magnitude of friction.[3].

3) Wear testing device

In this experiment, CYT-392 torque speed sensor was selected for wear test.

B. Gearbox and dynamometer

The exploded views of gearbox and dynamometer are shown in the Fig. 4.



Figure 4. Exploded views of Gearbox and dynamometer

IV. MODELING OF FRICTION-VIBRATION TEST RIG FOR PLANETARY GEARBOX

This design used Solidworks for three-dimensional modeling, In addition to the rapid drawing of common parts, the design library can also be used to directly input parameters and obtain standard parts, such as bearings, spring washers, etc[4]. Assemble the main parts at first, then assemble the whole test bench, the assembly drawing of the whole test bench is shown in Fig. 5.



Figure 5. Assembly drawing of test bench

V. DYNAMIC SIMULATION AND RESULTS OF FRICTION-VIBRATION TESTING DEVICE FOR PLANETARY GEARBOX

A. Motion simulation of transmission device

In this experiment, Adams was used for dynamics simulation, because it has numerous sections, convenient

operation and powerful functions, therefore, it is widely used and recognized in many industries[5].

1) Import the model

After the gearbox is simplified by Solidworks, save it directly as Parasolid (*.x_t) file, then Adams and Solidworks can be seamlessly connected. Use Adams to import the model.

TABLE I. MATERIAL PROPERTIES OF EACH COMPONENT

Name	Planetary gear	Sun gear	Ring gear	The left half of planet carrier	The right half of planet carrier
Mass	1.45	1.06	2.95	4.36	6.14
Material	42CrMo	42CrMo	40Cr	ZG40CrMn	ZG40CrMn

2) Establish rigid body motion unit

The moment of inertia is calculated in relative center of mass coordinate in Adams; therefore, after the model is imported, the material properties of parts need to be modified. Enter the parameters as shown in Tab. 1.

Then each part is treated as an independent motion unit, and the material properties of the part need to be modified in turn[6].

3) Add motion pair and load

Add motion pairs to the mechanism and the results are shown in Tab. 2 and Fig. 6 below:



Figure 6. Add motion pairs

TABLE II. CONTACT INSTRUCTIONS

Contact name	Contact objects	
CONTACT_1	planetary gear and sun gear	
CONTACT_2		
CONTACT_3		
CONTACT_4	planetary gear and internal	
CONTACT_5		
CONTACT_6	gear	

4) Add the driver

Add speed drive at the sun gear and set the speed to 2691.8 %s.

5) Set the parameters of simulation

Set the gravity in the Y direction, the simulation time as 0.2s and the number of steps as 200.

B. Simulation results

After starting the simulation program, Adams solved the variation curves of component forces in X direction, Y direction and Z direction of each contact; variation curves of contact resultant forces; and rotational speed curves of each shaft. The results are as follows: (coordinate system direction: X and Y are radial, Z is axial)



Change curve of component force in X direction of each contact Change curve of component force in Z direction of each contact

Figure 7. Simulation results

A. Discussion

Fig. 7 is the simulation results of this experiment, Fig. 7.d is the resultant force curve of the X, Y and Z axis, which is also the summary of Fig. 7.a, b and c, it can be seen that there is a big impact at 0.01 seconds. Then it gradually stabilizes from 0.01 to 0.1 seconds. At 0.2 seconds, it tends to 0 and stabilizes, and its regularity is basically consistent with the changes of each contact force. Like its theoretical analysis, it also conforms to the law of sine and cosine. The peak value, period and simulation results are very similar, which meets the requirements.

Fig. 7.e is the rotational speed curve of each shaft. It can be seen from the figure that the rotation speed of each shaft fluctuates greatly in the start-up stage, this is caused by the sudden change of speed and torque, which is consistent with the actual operation. Then, the fluctuation dropped significantly at 0.1 seconds. After 0.2 seconds, the rotation speed of each shaft fluctuated slightly near the average value, basically approaches 2240 %, which is very close to the theoretical value and meets the requirements.

VI. CONCLUSION

In this paper, friction - vibration test rig for planetary gearbox was designed, which includes reducer, sensor and dynamometer, and realized the test of friction, vibration, wear and other information of planetary gear transmission system.

The dynamic simulation was carried out by using virtual technology, the change curve of each component and contact resultant force and rotation speed curve of each shaft were obtained. Their variation rules were analyzed and the results are in accordance with the theory and meet the requirements.

Therefore, in practical work, the friction, vibration and wear of planetary gearbox can also be detected to predict whether it can be used for normal work.



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