Dynamics Characteristics Analysis of Rotary Reducer Assembled Hydraulic Motor in Excavator

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ABSTRACT

This paper presents the analysis of the structure and the gear contact load in the gear reducer used in slewing hydraulic motor system of an excavator. The parameterized structure model of reduction drive assembly is established by using UG software, and the model is imported to the LMS. Virtual.lab software to form dynamics mode, then based on the theory of gear contact load and ANSYS analysis means, the dynamics performance analysis of reducer assembly is completed. The paper provides an analysis platform and theoretical guidance for the design of excavator slewing system.

KEYWORD

Excavator, Slewing Reducer, Hydraulic Motor, Dynamics, Analysis.

INTRODUCTION

Excavator is a kind of engineering machinery with multi-degree of freedom. The slewing motor assembly reducer is one of the important parts of excavator slewing mechanism, and the reducer is consisted of planetary gear reducer. The rotary motor converts hydraulic energy into mechanical energy through the assembly reducer to turn excavator slewing platform to realize the excavator rotary operations. The rotary assembly reducer takes most of the torque load and rotates frequently in the forward and reverses alternately for long continuous working time. The reducer has a big inertial mass, compact structure and high power density ratio. Therefore, the transmission structure of slewing reducer assembly should have high efficiency and high reliability, and the simulation analysis on its dynamic characteristic will help the development significantly.
THE STRUCTURE ANALYSIS OF ROTARY REDUCER ASSEMBLED HYDRAULIC MOTOR IN EXCAVATOR

The structural principle of rotary reducer which assembled hydraulic motor is shown in figure 1.

1-The first level of sun gear, 2-The first level of planetary gear, 3-The second level of sun gear, 4-The second level of planetary gear, 5-The ring gear, 6-The output gear, H1-The first level of planet carrier, H2-The second level of planet carrier

Figure 1. Planetary reducer drive system structure diagram.

The planetary reducer’s input shaft A which connects to the cylinder of hydraulic motor with inner holes and the input of sun-round1 with another inner hole, is a spline shaft. The output shaft C is a gear spline shaft, which connects to the secondary planet carrier H2 and the gear ring of excavator slewing platform. The sun gears adopt the floating assembly. The planetary gears and planets pins are connected by non-standard needle bearings.

THE ESTABLISHMENT OF ROTARY MOTOR ASSEMBLY REDUCER’S PARAMETERIZATION STRUCTURE MODEL

Combines with the 2 d drawings and the actual structure models the planetary reducer’s entity structure model is established by using software of UG NX8.5, as shown in figure 2.

Figure 2. Integral components and assembly of reducer assembly.

THE DYNAMICS ANALYSES OF ROTARY REDUCER ASSEMBLED HYDRAULIC MOTOR IN EXCAVATOR

The Establishment of Planetary Reducer Dynamics Model

Dynamics analysis process is shown in figure 3. The reducer assembly structure models are established by the UG.NX8.5 and the models are imported to the dynamics software of LMS Virtual lab, then it is pre-treated in the Motion module, and the
The whole assembly model of kinematic pair is set up. The whole assembly reducer dynamic model is obtained as shown in figure 4.

![Figure 3. Dynamics analysis process.](image)

![Figure 4. Dynamics model of reducer.](image)

**The Dynamics Analysis of Rotary Reducer**

The analysis of the rigid body contact’s meshing forces and speeds is carried out in the LMS Virtual lab dynamics environment.

**THE VERIFICATION REDUCER DRIVE RATIO**

By Running the LMS Virtual.lab for calculating dynamics model, the input shaft and output shaft angular velocity curve are gained as shown in figure 5. And the corresponding ratio for each discrete time point is calculated, the transmission ratio curve under the time domain can be obtained as shown in figure 6. Then comparing with the theoretical calculation of assembly reducer drive ratio of 24.4486, it can be found that the maximum error is 0.0081. It’s verified by the correctness of the dynamics model.

![Figure 5. The rotational speed of input and output in planetary reducer.](image)

![Figure 6. Rotational gear ratio of planetary reducer.](image)

**THE ANALYSIS OF CONTACT FORCE FOR MESHING GEAR**

Gear meshing between driving part is regarded as elastic mechanical system, according to the theoretical analysis, takes the equivalent load torque for 13800 N • m. Giving the external load is shown in figure 7, under the common function of step speed input and the external load, getting the first or the second planetary gear and the ring gear’s meshing force, and its distributions are shown in figure 8 and figure 9.
When the conditions of work are stable, the first level gear’s meshing force has certain mutation fluctuations, which are basic in the peaks and troughs. It can be determined that those fluctuations occurred in gritting gear meshes into and out of phase, and the two teeth contact area is small and the sliding force is bigger. While the second level gear’s meshing force has no mutation fluctuations.

THE ANALYSIS OF MESHING VELOCITY

In the assembly reducer gear transmission system for given step speed signal of input shaft and the corresponding load, the transmission speeds of the first stage or second stage planetary gears and the ring gear’s meshing can be calculated by the dynamics model, as shown in figure 10, figure 11 and figure 12.

THE RESEARCH OF UNIFORM LOAD PERFORMANCE

Based on the uniform load theoretical analysis of planetary gear transmission, we know the planetary gear uniform load coefficient. Under the Upward step speed’s input, the equivalent load of 13800 N·m equivalent to load torque, and theoretical calculation, we get torque for the first level of planet carrier, and then assign it to three planetary gears. It is concluded that the planetary gear torque T, the planetary gear and ring gear’s meshing force can be input into the Mat lab software and the uniform load coefficient of first level of planetary gear can be obtained. By the same way, the
uniform load coefficient of the secondary gear transmission is available. The uniform load coefficient distributions of the first and the second gear transmission of planetary reducer are as shown in figure 13.

![Figure 13. The uniform load coefficient of the first and second gear meshing.](image)

From the uniform loading coefficient distributions, we know that the first gear transmission coefficient is closer to the first one than the second, and its load distribution is more reasonable within a small fluctuation range. Because during the slewing platform working, the load acts directly on the second output terminal stage in planetary reducer and the external excitation is great, and finally the non-uniformity of load distribution in gear transmission will be increased.

**CONCLUSION**

1) In this paper, the analyses of the structure of the rotary motor assembly reducer planetary gear transmission system is given, and the three-dimensional modeling is established by using UG, and the dynamics characteristics simulation analysis of planetary gear system are obtained by using the LMS. Virtual.lab software.

2) Based on the calculation of dynamic model, the maximum error between the simulation calculation velocity ratios is gained and the theoretical calculation of transmission ratio is 0.0081. The correctness of the dynamics model is verified.

3) Through studying the dynamics contact force, it is known that when the planet reducer works stability, the first level gear’s meshing force has certain mutation fluctuations, and it occurs in gritty gear meshes into or out of phase, while the second gear meshing force has no mutation fluctuations.

4) Through analyzing the meshing speed, it is known that the speeds of planetary reducer are cyclical when it is stable, and the first meshing frequency and meshing speed present all higher than the second.

5) The first gear transmission coefficient is closer to the first one than the second, and load distribution is more reasonable with small fluctuation range.

These conclusions could lay the foundation for the analysis of the subsequent shell vibration response and fatigue reliability.

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