Dynamic Characteristic Analysis of Planetary Gear with Pitting Corrosion Fault based on ADAMS

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Abstract

Taking planetary gear of the cutting part of MG-1370 shearer as study object, the dynamics analysis simulation of it is carried out by using ADAMS virtual prototype technology. By comparing the meshing force curves in time domain and frequency domain of the health and several pitting corrosion fault of varying degrees and crack fault, the dynamic response of planetary gear system under fault condition is analyzed. It can be found that under pitting corrosion fault condition, the impact force and side frequency band become intensive, and the intensity increases with the extent of the damage increase. There are some some differences between pitting corrosion fault and crack fault which can be used to identify them. The research results can provide a theoretical basis for planetary gear fault diagnosis and testing.

Keywords

Planetary gear; pitting corrosion fault; ADAMS; dynamics analysis.

1. Introduction

Planetary gear reducer in cutting part of shearer is an important structure of shearer, but gear damage often occurs due to manufacturing error, heavy load or poor lubrication. Pitting of gears is a common failure form. Although pitting faults may affect the operation of gear trains, if the faults are predicted and diagnosed as early as possible, it can prolong the service life of the machine and reduce the cost, so it is necessary to study the pitting failure of the gear in the planetary gear train.

In recent years, there have been many scholars at home and abroad to analyze and study the dynamic characteristics of gears under the condition of fault. In the dynamics analysis of gears, Cheng and others have pitting corrosion comparative study of gear fault characteristics using dynamic model and experimental results of crack damage, but the dynamic model is too simple. Basis on this, taking the planetary gear reducer in the cutting part of MG-1370 shearer as an example, taking the pitting fault gear as the reference, using pro/E to establish the normal and pitting fault planetary gear system model, and introducing ADAMS to analyze the dynamic characteristics. The speed of gears, the time domain analysis of gear meshing force and the frequency domain analysis are studied. By comparing the difference between the normal gear and the pitting fault gear of different degree, the paper makes a comparative analysis, which is beneficial to the identification and diagnosis of the gear fault, and the research results provide a reference for the subsequent research.

2. Working Principle

Take the planetary gear reducer of the cutting part of the MG-1370 shearer as an example. The planetary gear reducer consists of two center wheels and a rotating arm, which belongs to the 2K-H structural reducer. As shown in figure 1, the sun wheel Z1 located at the center has the same rotational speed as the input shaft. The inner gear Z3 is fixed on the frame, the planetary gear Z2 revolves around the sun wheel and rotates according to the transmission ratio, and the planetary frame H1 rotates as the output shaft speed.

3. Analysis of Planetary Gear

3.1 Model Data Conversion

After setting up the gear part model and assembling it by using pro/E, interference and simplification, the perfect entity model file is saved into Parasolid format and imported into ADAMS, and the unity of the unit is ensured in the process of format conversion. Prevent analogue distortion.

Fig. 1 Three-dimensional model of planetary gear train

3.2 Addition of Motion Pair

There are several main motion pairs in the planetary gear reducer, the autobiography of the solar wheel Z1 around its axis, the autobiography of the planetary wheel Z2 and its rotation around the solar wheel Z1, the rotation of the planetary shelf H1. By adding the rotating pair between the solar wheel Z1 and the ground, the rotation pair between the planetary rack H1 and the ground, the rotation pair between the planetary gear Z2 and the planetary shelf H1 determines the rotation relationship. The fixed pair is added to the inner gear ring. The contact pair between the solar wheel Z1 and the planetary wheel Z2, the planetary wheel Z2 and the inner gear Z3 is added to guarantee the complete constraint.

3.3 Driver and Load Addition

According to the actual working conditions of the planetary gear reducer in the cutting part of the MG-1370 shearer, the input speed is 670 r / min（4020 degr / s）, the sun wheel Z1 is driven at a constant speed, and the load torque is applied on the planetary frame H1. The direction of load is opposite to the direction of drive. In order to prevent the sudden change of load, the STEP function is applied gradually in 0. 05 s.

3.4 Definition of Contact Force Parameters

In the process of ADAMS simulation, in order to make the meshing force between gears more in line with the actual situation, the contact force parameters need to be defined. The impact function model is used to calculate the meshing contact force of the gear in ADAMS, and the Coulomb friction method is used to calculate the friction force between teeth. ADAMS shock function expression:

$$F\_impact = \begin{cases} 0 & \delta \geq 0 \\ K \times \delta^{e} - STEP(\delta, 0, 0, d_{\max}, C_{\max}) \dfrac{d\delta}{dt} & \delta < 0 \end{cases}$$

Where K is the contact stiffness coefficient and STEP () is the step function, dmax is the maximum penetration depth, and δ is the contact damping when the contact permeability reaches the maximum penetration depth, and the contact damping is a nonlinear elastic exponent.

According to Hertz collision theory, when the contact area is circular

$$\delta = \frac{a^2}{R} = \left(\frac{9F^2}{16RE^2} \right)^{\frac{1}{3}}$$

The normal force F and deformation δ relation can be obtained.

$$F = K\delta^{\frac{3}{2}}$$

The shape of the contact gear and its material depend on the shape of the contact gear

$$K = \frac{4}{3} R^{\frac{1}{2}} E$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\frac{1}{E} = \frac{\left(1 - \mu_1^{\ 2}\right)}{E_1} + \frac{\left(1 - \mu_2^{\ 2}\right)}{E_2}$$

R1 and R2 are the contact radius of two gears, and μ1 and μ2 are Poisson's ratio and E1 and E2are the elastic modulus of the two gear materials.

3.5 Determination of Other Parameters

Damping

In the dynamic simulation of ADAMS, the damping coefficient C is usually 1% to 0.1% of the contact stiffness coefficient.

Force Exponent

Based on the simulation speed and convergence, the force exponent e is 1.5.

Penetration Depth

In ADAMS, the depth of invasion should correspond to the maximum damping force, and the value of the depth of invasion should be 0.1 in simulation.

Friction factor

Coulomb (Coulomb method) is chosen to calculate the friction between teeth.the static friction coefficient is 0.08; the dynamic friction coefficient is 0.05; the static slip velocity is 0.1; the dynamic slip velocity is 0.1.

4. Dynamic Simulation and Analysis of Planetary Gear

4.1 Setting of Simulation Parameters

Considering the efficiency and accuracy, the simulation time 0.2 s and the simulation step size 0. 0001 are determined. the planetary gear is simulated by choosing the type of Dynamics dynamics analysis.

4.2 Analysis of Simulation Results

In the simulation process, due to the contact collision and friction in the gear transmission process, the speed of the gear will have a certain range of periodic fluctuations. Figure 2 shows the output rotational speed of the planetary frame. According to the ADAMS graphic analysis tool, the average speed is 803.66 / s, which is basically in accordance with the theoretical value 804, and the error is 0.040.Therefore, the simulation value of the planetary gear train speed has a high accuracy within the allowable error range.

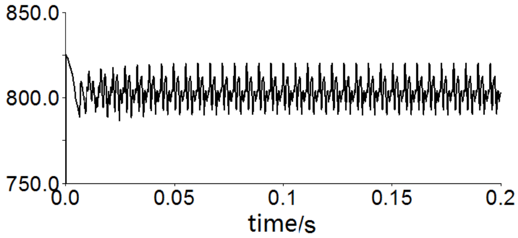


Fig. 2 output speed of planetary gear

4.3 Pitting Fault Modeling of Gears

According to the pitting fault gear as reference, the gear with pitting fault is established. Because the solar wheel has the highest rotational speed, the force is dense and the pitting failure is easy to occur, taking the solar wheel as an example, the pitting zone with width of 2.5 mm and 3.5 mm is established on the solar wheel Z1, and the dynamic characteristics are analyzed by introducing the ADAMS.

4.4 Analysis of Dynamic Response in Time Domain

The meshing force between teeth of planetary gear train is analyzed. By comparing the dynamic response of gear with normal gear and pitting area of 2.5 mm, as shown in figure 3, the time domain response of normal gear contact force is relatively smooth and stable. The contact force of pitting failure gear appears obvious impact phenomenon, the amplitude of time domain signal increases gradually, and with the expansion of pitting area, the sudden region of gear contact force increases.

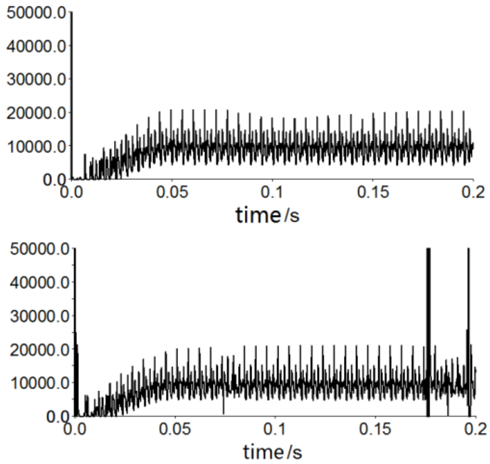
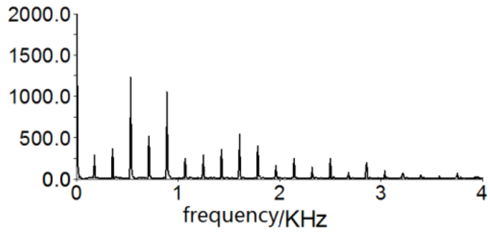


Fig. 3 Gear force diagram

4.5 Comparative Analysis of Dynamic Response in Frequency Domain

The frequency domain analysis of the contact force between the teeth of the planetary gear trains with normal, pitting and pitting regions of 2.5 mm respectively is carried out, as shown in figure 4.



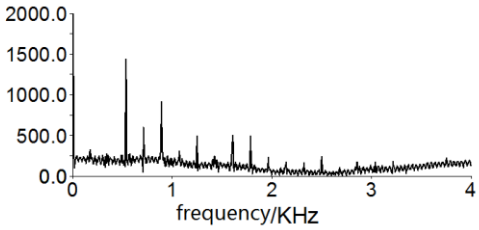


Fig. 4 Gear frequency

Compared with the normal gear meshing frequency and its frequency doubling, the amplitude of the frequency increases with the occurrence of pitting faults. It can be seen that there are a lot of side bands around the frequency and frequency doubling of pitting failure gear, and with the increase of pitting area, the edge band density increases, and the degree of disturbance increases gradually.

5. Conclusion

Taking the planetary gear reducer in the cutting part of the MG-1370 shearer as the prototype, the three-dimensional model was established by using pro/E software, and the system dynamics analysis was carried out by importing ADAMS. The higher accuracy of the model was verified by verifying the output rotational speed of the planetary gear train. On this basis, the normal gear, the gear with pitting corrosion fault and the cracked gear are studied respectively. The results show that: 1. According to the time domain analysis, the contact force between the teeth with pitting fault is increased, and the impact force between the two teeth is larger. According to the frequency domain analysis, the gear with pitting fault appears a large number of frequency conversion bands. The results will provide a theoretical reference for the subsequent planetary gear fault diagnosis.

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