Research on diagnostic method for broken tooth fault of reducer with involute helical gear

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Abstract. This article takes the reducer with the involute helical gear as the research object, the diagnostic method of the broken tooth fault and the deterioration trend is researched by vibration spectrum graph, demodulation waveform graph, time domain waveform graph, demodulation spectrum graph. The research results show that vibration spectrum graph has the worst guidance for the broken tooth fault of the involute helical gear reducer, demodulation waveform graph has the poor guidance in the initial stage of the broken tooth fault, with the deepening of the severity of the fault, the fault characteristics of the waveform gradually become obvious, time domain waveform graph and demodulation spectrum graph are the effective means to discover the initial fault and monitor the fault changes.

1. Introduction

Gear reducers are widely used in power plants, among them, the involute helical gear reducer has many advantages such as small size, light weight, high load-bearing strength, high efficiency, long service life, easy installation[1,2]. However, during the operation of such gear reducer, the vibration amplitude is generally small. In the event of the broken tooth fault, the vibration amplitude will generally remain at a low level, even if there are already obvious abnormal sounds and other phenomena, this will result in the changes of the vibration amplitude can not accurately reflect the fault condition and the deterioration trend of the reducer[3-6].

2. Selection of research object

The reducer with the involute helical gear of a low-speed steel ball coal mill in a power plant is took as the research object, the speed of the motor is 990 rpm, the barrel speed of the coal mill is 17.2 rpm, the tooth number of the large gear is 280, the small gear connected to the output shaft of the reducer meshes with the large gear to drive the barrel. The model of the reducer is 165HP-1, which is a single-stage reducer with a reduction ratio of 112:24. During the normal operation, the vibration amplitude is generally low and fluctuates with the load. Long-term follow-up monitoring showed that regardless of the reducer operation is normally or not, the vibration amplitude does not change significantly. The vibration amplitude can not provide a basis for accurately judging the equipment fault and the deterioration trend.
3. Data analysis

During the periodical inspection of the reducer, the abnormal sound occurred. The collected vibration data showed that the amplitude of the vibration velocity of the reducer did not exceed the warning value, and the value was basically the same as that measured before. The vibration spectrum at the low-speed gear side bearing point of the reducer showed that the main vibration components were the gear meshing frequency and its harmonics, their amplitude were low, the amplitude of the meshing frequency in the horizontal direction was only 0.25 mm/s, and a few sideband with the 0.21 times the frequency of the motor speed can be seen on both sides of the meshing frequency. Through the analysis of the spectrum, it can be preliminarily judged that there was wear and tear in the low-speed gear of the reducer, but as the amplitude was low, it can only be judged as a slight fault.

By analyzing the time domain waveform, we can see that there were the sharp shock peaks after the noise occurred, and the shock interval was the rotation speed frequency of the low-speed gear of the reducer. It can be determined that the low-speed gear of the reducer had the broken tooth, as shown in figure 1. Compared with the data before the occurrence of the abnormal sound, we can see that the time domain waveform had the slight shock peaks, the interval was still the rotation speed frequency of the low-speed gear, which meant that the time domain waveform showed the signs of the fault before the noise occurred, as shown in figure 2. According to the comparison of the two measurements, it can be concluded that the gear teeth were broken and the tendency of the deterioration was obvious.

![Figure 1. The time domain waveform at the low-speed gear side bearing point of the reducer after the occurrence of the abnormal sound.](image-url)
Figure 2. The time domain waveform at the low-speed gear side bearing point of the reducer before the occurrence of the abnormal sound.

The demodulation spectrum at the low-speed gear side bearing point of the reducer after the occurrence of the abnormal sound showed that there was the obvious 0.21 times the frequency of the motor speed. Compared with the data measured before the occurrence of the abnormal sound, the fault frequency component had not changed, and the amplitude of the component increased obviously from 0.3 g to 0.8 g in the vertical direction, which increased 2.7 times, as shown in figure 3 and figure 4. The variation of the amplitude in the demodulation spectrum also reflected the deterioration trend of the fault.

Figure 3. The demodulation spectrum at the low-speed gear side bearing point of the reducer after the occurrence of the abnormal sound.
Figure 4. The demodulation spectrum at the low-speed gear side bearing point of the reducer before the occurrence of the abnormal sound.

Compared with the demodulation waveforms of the two measurements, the maximum values of the two measurements before and after the occurrence of the abnormal sound were 4 g and 5.4 g, which were within the normal range, but the shocks of the two demodulation waveforms were all periodic shocks, and the peak and periodicity of the shock were very obvious, the period was the rotation period of the low-speed gear, as shown in figures 5 and 6.

Figure 5. The demodulation waveform at the low-speed gear side bearing point of the reducer after the occurrence of the abnormal sound.
Figure 6. The demodulation waveform at the low-speed gear side bearing point of the reducer before the occurrence of the abnormal sound.

Through the comprehensive analysis of the measured data, it can be determined that the low-speed gear of the reducer had broken tooth before the occurrence of the abnormal sound and deteriorated seriously after the occurrence of the abnormal sound.

4. Verification of the diagnosis conclusion
The reducer was disassembled and inspected, the low-speed gear of the reducer had broken tooth seriously, as shown in figure 7 and 8, the gear was replaced.

Figure 7. The damage 1 of the low-speed gear of the reducer.
5. Research on diagnostic method

In the whole process of the broken tooth fault development, the vibration velocity of the equipment did not change obviously, which showed that the vibration spectrum had the poor guidance for the broken tooth fault.

The demodulation waveform had the poor guidance in the early stage of the fault, the frequency band of the shock was wide, the shock peak was not obvious. The waveform changed continuously with the development of the fault, and the shock peak was obvious in the late stage, the shock frequency reflected the rotation speed of the faulty gear, and the shock amplitude increased continuously, it can be concluded that the demodulation waveform had the certain guiding significance for monitoring the fault deterioration.

The time domain waveform and the dulation spectrum had the obvious gear fault features before the occurrence of the abnormal sound in the initial stage of the fault occurrence, which had the good guiding significance for the discovery of the initial fault. In addition in the process of the fault deterioration, the shock amplitude and the sharpness of the shock peak changed obviously, the shock frequency was the rotation speed of the faulty gear. Based on the above analysis the time domain waveform and the dulation spectrum were the effective means to discover the initial fault and monitor the development of the fault.

6. Summary

The reducer with the involute helical gear is taken as the research object, the vibration spectrum can not effectively indicate the occurrence of the broken tooth fault, and the demodulation waveform has an obvious indication function after the tooth fracture reaches a certain level, changes significantly with the deterioration of the fault. The time domain waveform and the demodulation spectrum have the obvious performance at the beginning of the occurrence of the broken tooth fault, they can reflect the position of the faulty gear, and with the deterioration of the fault, they can be used as the main basis for the trend monitoring and analysis of the gear damage degree.

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