Advances in Machinery, Materials Science and Engineering Application X
M. Giorgetti et al. (Eds.)

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doi:10.3233/ATDE240605

Design and Application of Loading System for Mine Reducer

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Abstract. The quality of gear reducer overhaul plays a decisive role in the stability of coal mine equipment overhaul. This paper introduces the design of a loading test system for gear reducer in coal mine. Through the establishment of the test bench, the loading test, temperature rise test and efficiency test of gear reducer overhaul can be realized, so as to improve the quality of gear reducer and avoid the abnormal operation of equipment due to gear reducer installation failure. This reducer loading test-bed can be widely used in the overhaul industry of continuous excavation equipment. The reducer is an indispensable part of the mechanical transmission device, it is widely used in many fields in our country, with the rapid improvement of China's industrial development and the popularization of mechanization, the use of the reducer is also more and more broad, but in some large industrial and mining enterprises, the working environment of the reducer is relatively harsh, so the design of the reducer loading test bed has no advantages Measurable significance, in the last process of the reducer production of its a series of performance testing, such as temperature rise test, noise test, durability test, overload test, no-load test, this loading test bench designed a small power reducer test bench for a loading scheme, the scheme variable load method is simple and reliable.

Keywords. Loading test, efficiency test, temperature rise test

1. Introduction

Due to the constant transmission ratio, high transmission power, high transmission efficiency and compact structure of the reducer, it is widely used in mining machinery, coal mining machinery, cement machinery and other related industries [1-2], and is an indispensable part of mechanical equipment. However, once the reducer fails in the mine, due to working conditions, the work of replacing the reducer is very laborious and time-consuming [3-4], which greatly reduces the work efficiency. Therefore, whether it is the reducer manufacturer, reducer maintenance factory or the reducer user, the stability of the reducer performance is very high. Loading tests must be carried out in strict accordance with relevant technical standards and technical specifications. Practice shows that the failure rate of the reducer after the load test can be greatly reduced, such as high temperature, abnormal noise, oil leakage, etc [5-7].

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The loading of the reducer must be achieved through a dedicated loading system. Therefore, a mining reducer loading system is designed and developed to realize no-load test, loading test, overload test, durability test, efficiency test and temperature rise test.

2. Test Bench Loading Principle

The mine speed reducer loading system consists of a mechanical system, an electrical system, a measurement and control system, and an alarm system. It controls the speed of the drag motor and loads the motor power to load the speed reducer under test. The plan view of the mine loading test bench is shown in figure 1.

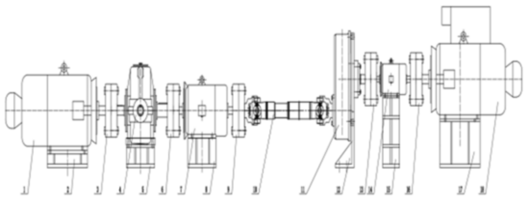

Figure 1. Schematic diagram of the mine loading test bench.

3. Generation Mechanism and Measurement Method of Main Parameters, and Hardware Matching Design of Measurement and Control System

The mining loading test bench mainly tests the speed and torque of the reducer, transmission efficiency, vibration and noise, temperature and other parameters.

3.1. Transmission Efficiency

Transmission efficiency is one of the important indicators of transmission devices. According to the plane test diagram of the transmission test bench, the formula for the transmission efficiency of the reducer can be derived [8]:

$$\eta = \frac{P_{in}}{P_{out}} = \frac{T_2 \times n_2}{T_1 \times n_1} \tag{1}$$

η is the transmission efficiency of the reducer; P_{in} is the power kW obtained by the output speed torque sensor; P_{out} is the power kW obtained by the input speed torque sensor; T_1, T_2 are the torque values measured by the input and output speed torque sensors, N·m; n_1, n_2 are the torque values measured by the input and output speed torque sensors, r/min.

From the formula, it can be seen that when the measured values of the output and input speed torque are collected, the transmission efficiency of the reducer can be obtained.

3.2. Vibration and Noise

3.2.1. Generation Mechanism

According to the different vibration states, the noise of the gear system can be divided into two types: slapping and white noise. The former is a transient noise, which is a nonlinear impact phenomenon caused by the slapping of gears, and the latter is a steady-state noise caused by the dynamic excitation of the gear meshing process. According to different generation principles, noise includes acceleration and self-ringing noise. The former refers to the fluctuation of the surrounding medium caused by the acceleration generated by the gear teeth under the impact, and these impacts may come from the impact in the slapping vibration or from the impact caused by the error in the non-slapping vibration. Self-ringing noise refers to the external radiation noise caused by the vibration of various components of the system under the periodic meshing force of the gear.

The noise radiation of the closed reducer mainly comes from the self-ringing noise. The acceleration noise is first radiated into the air and lubricating oil in the gearbox, and then radiated through the reducer housing. The self-ringing noise is caused by the vibration of the wheel body, which is transmitted through the vibration of the shaft and bearing, and then causes the vibration of the reducer housing and radiates.

3.2.2. Noise Test

The physical quantities of noise measurement mainly include sound pressure level, sound power level and sound intensity. The measurement of the first two physical quantities is relatively easy, but the disadvantage is that it has requirements for the test environment. The measurement method of sound intensity is relatively strict, and its corresponding outstanding advantage is that it can eliminate the interference of other noise sources on the measured signal and accurately identify the location of the sound source. After weighing the pros and cons, this test bench finally chose to use a sound level meter to measure the sound pressure level.

Because it is difficult to meet the conditions for sound pressure level measurement during the test and it is difficult to avoid the interference of background noise, the result directly measured by the sound level meter is the total noise including the background noise. To accurately obtain the noise level of the device under test, the influence of background noise must be eliminated first, that is, background noise correction should be performed on it. The specific correction scheme is as follows:

When the difference between the noise value and the background noise is greater than 10dB, the latter can be ignored and the total noise level can be regarded as the noise level of the device under test.

When 3dB < the difference between the two < 10dB, the noise level can be corrected according to table 1;

When 3dB > the difference between the two, the measurement result is invalid and further measures to reduce the background noise are required, or even a semi-anechoic chamber should be built to ensure the effectiveness of the test.

Table 1. Background noise correction scheme.

Difference /dB	3	4~5	6~10
Correction/dB	-3	-2	-1

3.3. Temperature

Power loss in mechanical transmission will generate heat, which is the source of the temperature increase of the transmission device. In the gear transmission, the temperature of the gear teeth determines whether the gears will produce bonding and softening, affecting the service life of the gears.

In actual measurement, the body temperature and tooth surface temperature of the gear teeth are relatively difficult to measure, so the temperature of the transmission device during operation or the temperature rise of the box wall is usually used instead. Considering that the temperature at the reducer input shaft is higher than the box temperature, in order to comprehensively measure the reducer test temperature, this test bench uses an insertion temperature sensor to measure the oil temperature at the oil filling port, and an adsorption temperature sensor to measure the reducer housing.

4. Test Data Collection and Processing Methods

After the signals collected by each sensor pass through the data acquisition card, the industrial computer analyzes the data and the human-computer interaction with the operator is carried out through software on the display screen. Therefore, the data acquisition and processing method is mainly implemented through software programming.

This project has completed a set of measurement and control software, the functions of which include parameter setting, data acquisition, process control, alarm and fault handling, log function, data processing, etc. (automatic display, storage, printing tables, drawing curves, test process playback).

The console software system is mainly written by Siemens PLC programming software, and the industrial computer is used as the host computer for control and display functions.

4.1. Communication Method and PLC Composition

The communication mode between PLC and 1# and 2# inverters is USS communication, which is a special protocol of Siemens. The communication mode between PLC and host computer (industrial computer) is TCP/IP protocol through Ethernet port. The communication mode between PLC and cloud server is Modbus TCP protocol. PLC is composed of CPU (model SR20) and expansion modules, U1 is CPU, and U2~U7 are expansion modules. U2 is DE08 digital input module (8×24V DC) which can collect 8-way button input model; U3 is DR08 digital output module (8×relay output) which can output 8 on-off signals; U4 and U5 are AR04 thermal resistor input module (4 channels), which mainly collects thermal resistor temperature sensor signals. Each module can collect 4 channels and a total of 8 channels of temperature sensor signals; U6 is AE08 analog input module (8 channels) which can collect 8-way sensor voltage or current signals, such as noise sensor, vibration sensor, torque sensor, etc.; U7 is AQ04 analog output module (4 channels), which is reserved as a spare channel.

4.2. PLC Program Functions

4.2.1. Collection and Control Functions

After power is turned on, the initial status of each device is collected first, such as the input voltage and current status of the inverter. Whether the motor is started or not, the 1# and 2# inverters input the motor start signal to the PLC through the USS protocol. If the motor is started, the motor can be started through the mechanical button or the upper computer display button. The communication procedure is shown in figure 2.

After starting the motor, the information of multiple sensors is collected through the analog input AI port, including voltage, current, torque, speed, temperature, noise and other information. After filtering and conversion in the PLC, it is displayed in real time on the upper computer display. The signal acquisition program segment is shown in figure 3.

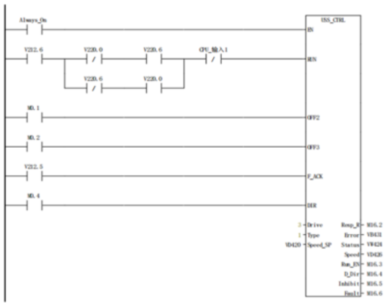

Figure 2. USS communication program initialization.

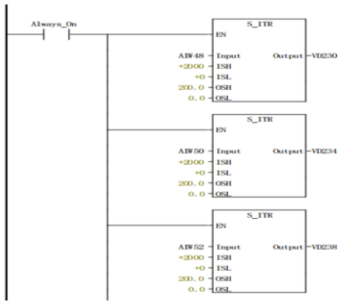

Figure 3. Signal acquisition program segment.

According to the reducer test requirements, loading is carried out according to the formulated test outline. Parameters are input from the upper computer display screen and passed to the PLC. The PLC then controls the loading motor and the drag motor to complete the scheduled test. The signal acquisition program segment is shown in figure 4.

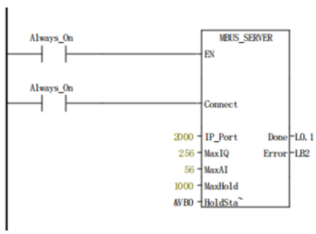

Figure 4. Signal acquisition program segment.

4.2.2. Generate Report

The PLC uploads data to the host computer through the Ethernet port, and the host computer generates reports according to the report content requirements.

4.2.3. Remote Display

The PLC uploads data to the cloud server via the cellular network using the Modbus TCP protocol, and then accesses the cloud server as a client through a mobile or PC terminal to obtain and display the data.

5. Test and Application

After the test bench completes the collection, a report is automatically generated. Figure 5 below shows the processing results of the reducer loading test data. To facilitate diversified analysis of the data, the underlying data can be exported at the same time.

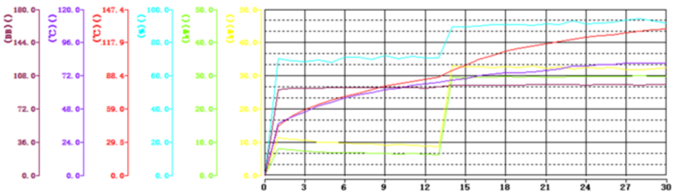

Figure 5. Data curve chart.

6. Conclusion

This optimization design project of the mine reducer performance test bench is of great significance to the high-quality overhaul of coal machinery. Through application software control, online measurement of temperature, noise, vibration, pressure and other data is realized, and the efficiency test, temperature rise test and loading test of the test reducer are completed. At the same time, the data can be stored in real time, which improves the data processing capability of the mechanical transmission test system.

Based on the original towing test, this project added a sensor to realize the back-to-back test mode, which not only saves energy but also improves the test efficiency by 100%.

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