Research on Reducer Power Measurement System of Bridge Crane

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Abstract. In this paper, the reducer is taken as the research object for power measurement. First, the demand of reducer power measurement is analyzed, and the method for measuring power is determined. Then, in view of the power measurement method adopted by the reducer, the overall framework of the measuring system is carried out, and the host system is designed.

1 Introduction

With the development of bridge crane, energy consumption of crane transmission has attracted much attention [1].As an important transmission part, the reducer plays an important role in the hoisting mechanism. Therefore, measuring the efficiency of the reducer in service is essential for studying the energy consumption of the hoisting mechanism for bridge crane. The efficiency of reducer is traditionally measured in open and closed manners. The parameters measured in both manners to calculate the transmission efficiency of reducer are the same: torques and speeds of both high speed and low speed shafts. Currently, because of the structure of torque sensor, it is hard to measure a working reducer. Therefore, it is extremely rewarding if the efficiency can be measured when the reducer is in service. This paper investigates a measurement system that can measure torque and speed of a working reducer and transmit the data to a host computer to calculate the power of both low-speed and high-speed shafts of the reducer.

2 Demand Analysis of Reducer Power Measurement

The hoisting mechanism is one of the most important transmission mechanisms of the bridge crane and the transmission efficiency is an important indicator for its energy consumption[2]. The input energy for entire hoisting mechanism is electricity which is applied onto both the motor and the brake. However, the mechanical energy converted from the electricity by the brake acts as the braking energy and is not transferred to transmission parts.The mechanical energy converted from the electricity by the motor during non-braking process and transferred to each transmission part in serial way, as shown in Figure 1. If the entire mechanism or a single part is taken as the object to study the energy consumption, it is hard to find the solution since a lot of variables have to be studied. A method is adopted to break down and simplify the complicated problem so as to easily solve a difficult or even dissolvable problem. So, the hoisting mechanism under non-braking condition is broken down into a reducer, a coupling and a suspension system, which is composed of a drum, wire rope, a plurality of pulleys and a lifting hook[3]. This method enables the study of mechanical transmission efficiency to be performed on each subsystem instead of the entirety. As the intermediate part of the energy transmission, the input power and output power of the reducer can be used to calculate the efficiency of other transmission parts. Therefore, it is necessary and meaningful to measure the power of the reducer of the bridge crane.

Actually, very few measuring devices can be used to effectively measure the energy consumption of reducer on-site due to inappropriate on-site conditions. Although the reducer power cannot be directly measured by a device, two parameters: torque and speed, which are related to the power, can be measured to calculate the power and the efficiency of reducer. And then Equation(1) and Equation(2) can be used to calculate the power and real-time efficiency of reducer.

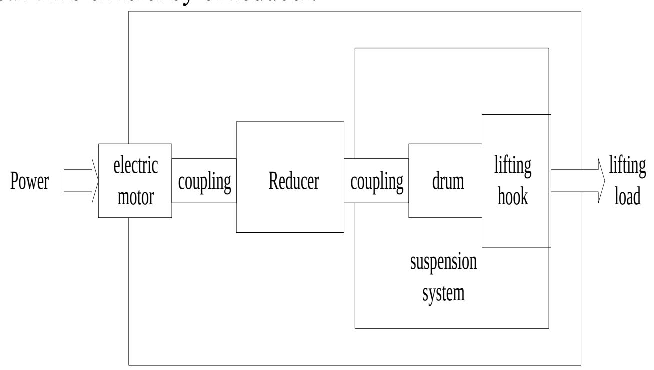

Figure 1. Transferring process of mechanical energy

$$P=\frac{n\times T}{9500} \quad (1)$$

$$\eta_{Ji}=\frac{P_{JOi}}{P_{JIi}}\times 100\% \quad (2)$$

Where

T is the torque to be measured in $N\cdot m$;

n is the speed in r/min;

P is the power in kW;

P_{JIi} is the high speed shaft power of the reducer, namely the input power;

P_{JOi} is the low speed shaft power of the reducer, namely the output power.

3 Overall Design of System Framework

As described above, it is of need to measure the torque and speed of both low-speed and high-speed shafts of the reducer. Chuck type power meter comprises two sections: the torque measuring and the speed measuring section. It utilizes a synchronized method to measure the toque and speed of high or low speed shaft on the reducer. Then the measured values are packed and transmitted to the host computer to calculate the power.

The block diagram of measuring system is shown in Figure 2, in which the measuring object, namely the transmission mechanism, is located in the leftmost block; the slave, namely the measuring circuit, is located in the second block; the communication section including data transmission mode and communication protocol is located in the third block[4]; and the host program which is developed by Visual C++ is located in the fourth block.

The host computer can real-time display present torque and speed, calculate and display present power, and save the data in a SQL database. Some parameters of the measuring system like shaft material parameters, the acquisition frequency of system and the output format are all set in the host computer[5].

The chuck type power meter located in the leftmost block is shown in Figure 3. The chuck is consisted of an upper part and a lower part to clamp both internal and external metallic guiderails into the groove and then the guiderails are fixed onto the chuck by screws. An extension spring is arranged inside the moveable slider for connection to ensure reliable contact of the high speed metallic sheave with both internal and external metallic guiderails. The light source for speed measuring is arranged inside the slider and located right above the orbital groove on the guiderail plate. A plurality of light receivers is arranged in the orbital groove. The slider rotates relatively to the guiderail plate and the relative rotation speed is considered to be the shaft rotation speed. The external power is supplied into the chuck via the contact between metallic sheave and metallic guiderails.

A plurality of strain gauges is attached on the shaft to constitute a Wheatstone bridge [6]. The chuck is bolted onto the shaft to avoid relative rotation. The power supply inside the chuck provides stable working voltage for the Wheatstone bridge. When the shaft deforms under torque, the bridge outputs the voltage variation.

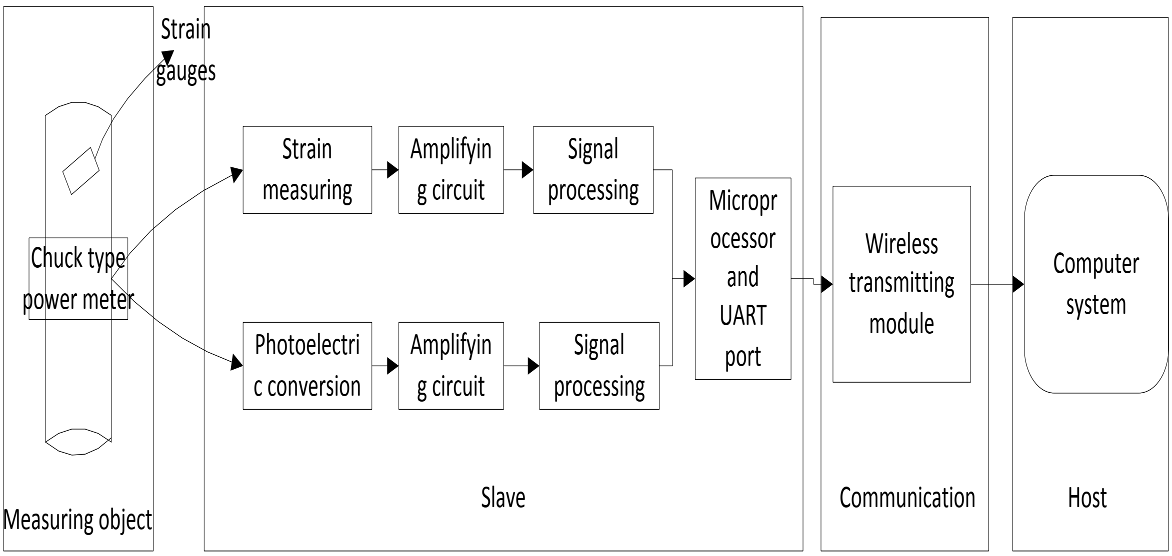

Figure 2. Block diagram of measuring system

The overall hardware structure of slave is divided into three sections based on their functions: a torque measuring section, a speed measuring section and a signal transmission section. The torque measuring section comprises a strain gage bridge, an amplifier circuit, a strain voltage processing circuit and a microprocessor computing circuit. The speed measuring section is designed on the basis of photoelectric measurement and the signal transmission section is physically a wireless transmission module.

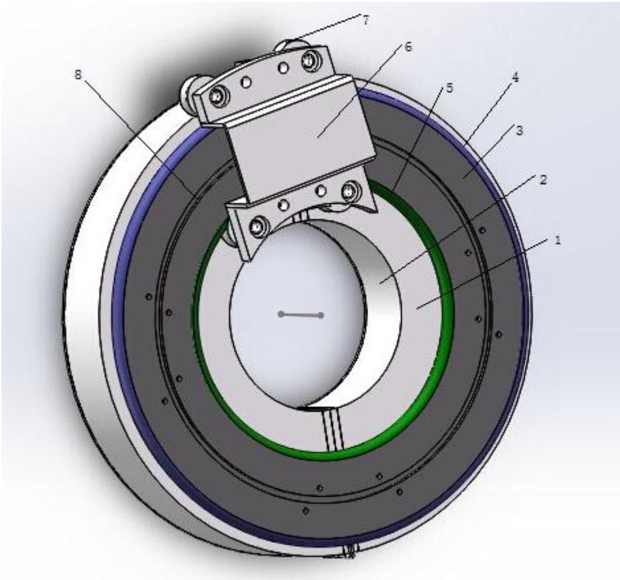

Figure 3. Chuck structure

1. Chuck 2. Internal diameter of chuck 3. High speed guiderail plate 4. External metallic guide ring 5. Internal metallic guide ring 6. Moveable slider 7. High speed metallic sheave 8. Orbital groove on guiderail plate

4 Design of System Parameters

Design parameters of each component are correlated to each other in hardware design. The voltage variation range of strain bridge is dependent on the shaft strain and the strain bridge. The amplification factor of amplifier is determined by the input voltage of V/F converter. The selection of microprocessor is based on above parameters and the speed acquisition frequency. The calibration test is performed at last to determine the maximum measuring range and the accuracy. Their correlation is shown in Figure 4.

During hardware design and selection of microprocessor, parameters have to be reasonably set for successful hardware design. In principle, the strain variation range on the measured shaft and the resulting voltage variation range have to be determined first. Then use the input voltage of V/F converter to determine the amplification factor of amplifier, after which the crystal oscillator and the microprocessor can be selected. Thetransmitting module and the power module are designed at last.

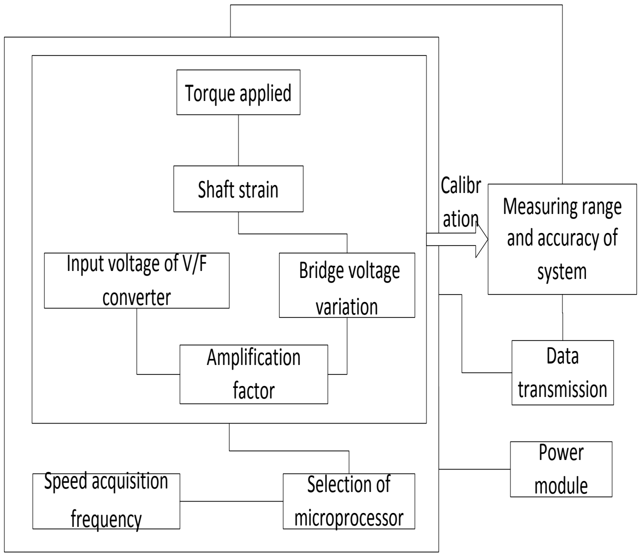

Figure 4. Correlation among parameters

5 Host System Design

The host program system is constituted by a four-layer architecture, as shown in Figure 5. The first layer is a user layer, which is used as the human-machine interface of system for visual display of data, setting of measuring parameters, selection of communication channel, setting of data save and identification for graphic data.

The second layer is an interaction layer, which is mainly used for data receiving, data calculation, data storage and data monitoring. The data receiving refers to utilizing the Wi-Fi module and the IP communication protocol on the laptop to transmit the torque and speed values measured by the chuck type power meter to the host program system[7]. The data calculation refers to calculating the data which has been processed to obtain the torque, speed and power values of measured object. The data monitoring refers to monitoring the data which has been processed and the host computer shall raise an alarm once a value exceeds the threshold. The processed and calculated data shall be stored for data playback and postanalysis.

The third layer is a core layer which is mainly used for processing data and performing compensation algorithm. The received data will be filtered and the graph display will be processed for curve-smoothing on this layer in order to make the data curve smoother. The curve is fitted by the least square method in order to obtain a curve model with minimum error to the true value. The curve fitting is a very important function during system initialization since it can make the measured data graph closer to the true data graph.

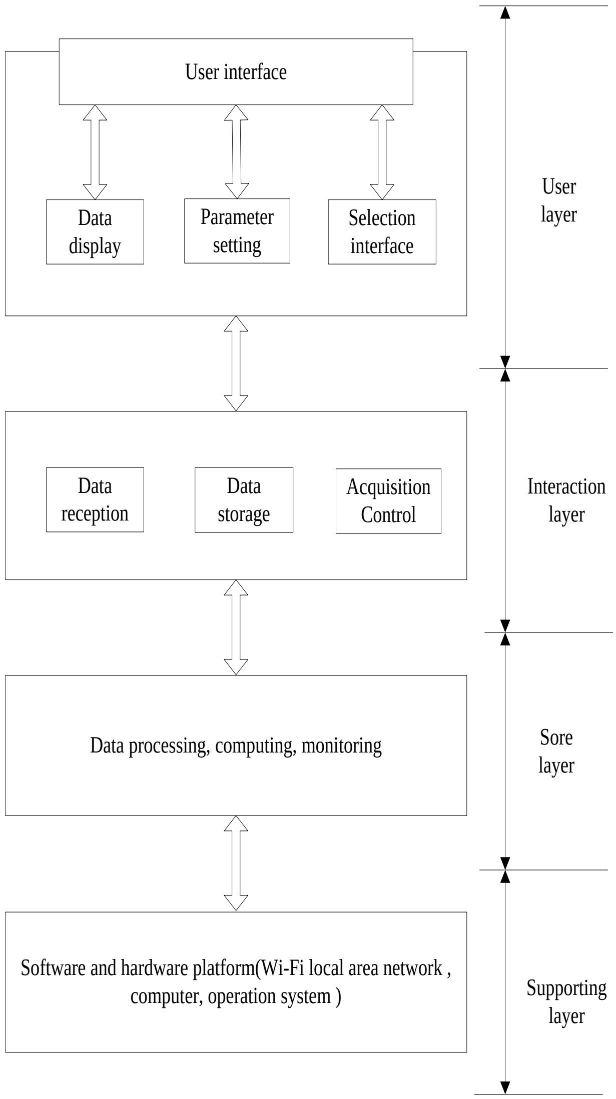

Figure 5. Host program system

The fourth layer is a supporting layer, which is used as a software and hardware platform, on which various elements like Wi-Fi local area network (called as LAN hereinafter), computer, operation system and database interact with each other.

For a measuring system which has been calibrated, be sure the chuck type power meter is in service if the host system is used for data measuring. Then use the host system to check whether the Wi-Fi module is online, the slave is in service, and the sensors and the communication work normally. Then measuring parameters related to input such as the diameter of measured shaft and the shear modulus into the host system. After that, balance channels and remove null points in order to start the measuring.

6 Conclusion

This paper investigates a measuring method that can measure torque and speed of the reducer, and carry out framework of the system. And, the host system is designed according to the requirement of measurement method. In further study, the hardware circuit that is an important part of the power measuring system is needed to design.

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