Research on the Calibration Method of Torque Sensor

Lei Cheng*, Yang Su, Lifang Wang
Chongqing Academy of Metrology and Quality Inspection, Chongqing, China.
*Corresponding author’s e-mail: chenglei@cqjz.com.cn

Abstract. Remote calibration has the property of real-time and remote location, and can be used to control the calibration method for the calibration instrument. It is an effective method to improve the calibration efficiency. Based on the torque sensor calibration method for research, because the remote calibration technology has complex structure, calibration are not allowed to wait for a characteristic, through the remote technology combined with a torque sensor automatic calibration technology, analyze the torque sensor remote calibration technology research, which not only can improve the traditional calibration technology cycle is long, low efficiency of faults. Remote calibration technology based on the basic methods and characteristics are studied, by using the method of torque meter calibration, according to the characteristics of torque sensor, choose corresponding calibration program and method, which can effectively improve the technical problems in the process of system design and analysis of torque sensor remote calibration method research, in addition, through the analysis of electromagnetic interference technology research, which can restrain the interference is proposed; Finally, the remote calibration technology of the torque sensor is effectively improved through the calibration experiment of the system debugging.

1. Remote calibration

1.1. Basic concepts of remote calibration
Remote calibration is refers to the process of measurement instrument calibration, calibration generally refers to the staff by using the network communication technology for measuring instruments in real time, remote areas, to control instruments, remote calibration process is dependent on the traditional calibration instruments, calibration standards of measurement and calibration specifications, calibration data acquisition and data processing and other factors.[1] The difference between remote calibration technology and traditional calibration technology is that remote calibration technology can not only control the calibrated equipment remotely, but also control the personnel of the calibrated equipment locally. [2]Remote calibration equipment through the use of computer network transmission technology, the calibration equipment to carry out remote control. The remote control mainly includes collecting sensor signal, setting calibration parameters, data storage, processing and data analysis, etc. Remote calibration technology is involved in many purposes, such as: the range of measurement can be extended,
resource sharing, remote comparison, and even international comparison, and even the accreditation of laboratories.[3]

1.2. Features of remote calibration
The characteristics of remote calibration technology are as follows:
(1) Reduce the transmission time of measurement standards, thereby shortening the traceability chain.
(2) reduce the uncertainty of laboratory calibration, so as to improve the measurement level.
(3) Effectively expand the number of ranges measured by laboratory data.
(4) effectively improve the technical level of measurement management.
(5) Accelerate the comparison of international measurement data.

2. Basic structure of remote calibration
The remote calibration system generally adopts C/S mode, which is divided into three parts: client, network transmission part and server. Figure 1 to analyzed the structure of C/S mode, in which the client for calibration on site, the client computer connected to the instrument, will be connected to the server network transmission parts: network transmission part is mainly responsible for the client and server data connection and transfer of command: the server is mainly operated by calibration professionals, to the remote client instrument calibration, and supervised the client.[4-7]

![Fig. 1 Basic structure of remote calibration system](image-url)

Remote calibration system mainly involves the types of technology including measurement calibration technology, automation technology, network communication technology, database technology and relevant technology to ensure data security. The main functions of the remote calibration system include: collecting status information by using remote instruments and equipment; Send out measurement and control instructions to the remote instrument, and record the collected measurement data, thus forming the original measurement record; Compile measurement data into measurement report. In addition, the functions of the remote calibration system include: performance, security, scalability and so on.

3. Calibration of torque sensor
The torque standard machine forms the standard torque mainly through the lever principle of the moment arm. By virtue of the torque balancing device, the predetermined sequence is automatically connected to the acting torque and balancing torque, and then applied to the torque sensor (Figure 2). The reading difference between the standard torque and the torque sensor is the error of the torque sensor.
Since there is no clear calibration specification report for torque sensor, the calibration method of torque sensor is mainly formulated by referring to the Verification Regulations of Torque Trigger Verification Instrument JG797-1992.

### 3.1. Technical requirements for torque sensor calibration

1. **Nameplate information of torque sensor.** The nameplate of the torque sensor shall clearly indicate the name, manufacturer, model and specification, accuracy level, factory number and date of production of the torque sensor.[8-9]
2. **There should be no cracks, rust and other defects on the surface of the torque sensor and supporting equipment.** There should be sufficient strength and stiffness on each part of the torque sensor, and each part of the torque sensor should be firmly and reliably connected without loosening.
3. **The torque accuracy of the torque sensor within the use range should meet the requirements in Table 1.**

#### Table 1. Parameters of torque sensor

| Grade of accuracy | Relative error of indicated values (%) | Repeatability of shown value (%) |
|-------------------|----------------------------------------|---------------------------------|
| 0.3               | ±0.3                                   | 0.3                             |
| 0.5               | ±0.5                                   | 0.5                             |
| 1.0               | ±1.0                                   | 1.0                             |
| 2.0               | ±2.0                                   | 2.0                             |

### 3.2. Calibration conditions of torque sensor

In view of the current situation of torque parameters "static test and operation", this project plans to establish a 300Nm dynamic torque standard device and a unified dynamic torque calibration method.

The mathematical model of the dynamic torque standard device is as follows:

\[ M(t) = \Psi(t) \ast J \]  

(1)

\( M(t) \) is the dynamic torque value, \( \Psi(t) \) is the dynamic angular acceleration, unit rad/s², \( J \) is the moment of inertia of the system, unit kg · m².

For the inertia body, take a standard disc mass block, assuming it is a standard rigid body, mass is \( M_J \), inner radius is \( R_1 \), outer radius is \( R_2 \). According to the definition of moment of inertia, the moment of inertia in this case can be calculated by means of calculus.
\[ J_M = \frac{1}{2} M_J \left( R_1^2 + R_2^2 \right) \]  

(2)

According to Equation (2), the moment inertia uncertainty of the inertia body consists of three parts, namely mass, geometric size and material uniformity, and the uncertainty is intended to be controlled within 0.5%.

We choose a rate-based pulse count to measure the angular acceleration measurement method. In theory, on the rotating shaft set uniform structure with the axis of rotation, rotation per rotation Angle, uniform structure to produce a pulse, and then to be picked for pulse counts get angular displacement or angular velocity information, quadratic differential operation was carried out on the angular displacement or diagonal speed differential operation can get angular acceleration information.

In actual measurement and calculation, is the difference of pulse count in two units of time as angular acceleration, as shown in Equation (3). Where \( \Omega \ t \) is the acceleration measured in the current clock period, \( \Omega \ 0 \) is the acceleration measured in the last clock period, and \( t \) is the time of one clock period.

\[ \Psi(t) = \frac{\omega(t) - \omega(0)}{t} \]  

(3)

The dynamic torque is intended to be applied through eddy current braking or hysteresis braking principle of the eddy current machine. The purpose of applying torque to the device is achieved by braking the rotor. The device is designed to combine fuzzy control with conventional PID control to form fuzzy self-tuning PID control.

(1) The torque sensor should be properly installed on a stable basis according to the instructions, and there should be space for calibration around it. Its working environment should be clean, no violent vibration and corrosive gas around.

(2) The uncertainty of the torque standard machine should not exceed 1/3 of the uncertainty of the calibrated torque sensor. The calibration lever and force weight should meet the requirements in Table 2, and the calibration lever should have sufficient stiffness.

**Table 2. Lever length and foundry error**

| Level of accuracy | 0.3  | 0.5  | 1.0  | 2.0  |
|-------------------|------|------|------|------|
| Calibration lever arm length error (%) | ±0.03 | ±0.05 | ±0.10 | ±0.20 |
| Weight force value error (%) | ±0.01 | ±0.02 | ±0.05 | ±0.10 |

4. Calibration items and methods

The calibration range of torque sensor should generally start from 20% of the maximum value of each range to the maximum value. Special torque sensors are not limited, but the starting point must not be less than 5% of the maximum torque value. Calibration points should be no less than 5 points. All points should be evenly distributed.

Install the torque sensor on the torque standard machine correctly, and ensure that it is coaxial with the torque standard machine in series. After the torque standard machine adjusts the balance position, adjust the torque sensor to zero. Before formal calibration, it shall pre-twist for three times, adjust the indicated value to zero, then apply the torque steadily and slowly to the maximum torque value, remove the torque, check the return to zero and reset it.

The indicating error \( E \) of the torque at each point is calculated as follows:
\[ e = \frac{M - \overline{M}}{M} \times 100\% \]  

(4)

Type in the $\overline{M}$ -- Arithmetic mean value of multiple indication torques of torque sensor in calibration (N.m)

$\overline{M}$ -- the standard torque value in calibration (i.e. the torque value generated by the torque standard machine)

The repeatability R of the torque at each point is calculated as follows:

\[ R = \frac{M_{\text{max}} - M_{\text{min}}}{\overline{M}} \times 100\% \]  

(5)

Type in the $M_{\text{max}}, M_{\text{min}}$ Under the torque point, the torque sensor indicates the maximum and minimum torque (N.m) for several times.

5. Conclusion

Accuracy and stability of torque sensor measurement calibration data is the main parameter data of torque sensor, which requires regular calibration data. The combination of torque sensor and automatic calibration technology, so as to design a torque sensor remote calibration system, in the remote measurement of data has important significance. This article through to the remote calibration and torque sensor calibration status quo analysis, through the remote calibration technology basic concept, characteristics and structure analysis, overall design scheme of remote calibration system based on torque sensor are studied, by means of the calibration device design scheme and the introduction of calibration system hardware and software in detail.

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