RESEARCH ARTICLE

Traceability analysis and uncertainty evaluation of electromechanical torque test system

Yu Guo
Guizhou Fenghua Precision Equipment Co., Ltd., Guiyang, Guizhou, 50009, China

Abstract: Grasping the accuracy of the electromechanical servo torque test system has always been an active research issue in the product manufacturing industry. Research on static traceability and dynamic traceability of electromechanical servo torque testing system can better realize the analysis of influencing factors in its use process and improve the reliability and effectiveness of its system use. At the same time, the uncertainty evaluation of the system combined with the influencing factors can fully realize the data analysis and demonstration of the electromechanical servo torque test system, and provide a strong guarantee for the authenticity of the product test data.
Keywords: Electromechanical; torque; dynamic; uncertainty.

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1 Introduction

The electromechanical torque test system is one of the key equipment for testing and verifying the material test and research of elastic shaft parts. It is widely used in aerospace, rail transit, parts manufacturing, quality inspection and other fields. It is an important equipment for torque test and performance analysis of products, and its accuracy directly determines the safety and effectiveness of products in actual use. In this paper, the lens torque and dynamic torque of the electromechanical servo torque test system are analyzed and expounded, and the process uncertainty is evaluated.

2 Traceability Analysis of Electromechanical Servo Torque Testing System

In the aerospace field, common electromechanical servo torque test systems are mainly divided into static torque test and dynamic torque test.

2.1 Static Torque Measurement Traceability

The static torque calibration device of electromechanical torque test system mainly consists of standard torque sensor, calibration tool and data acquisition and analysis system. A test torque sensor is installed on the original work station, and a torque calibration tool is installed, and the test torque sensor, the standard torque sensor and the elastic load are coaxially connected; the test system controller outputs control commands to generate static torque excitation; the data acquisition and analysis system collects the output signals of the dynamic torque sensor, and analyzes and calculates, and compares the calculated results with the torque values displayed by the test system to complete the calibration. During calibration, take the minimum static torque used in model product testing as the lower limit and the maximum as the upper limit of parameter calibration, and select 5~10 points for calibration in this range, and the calibration points are evenly distributed in this range. Select a direction, apply preload for 3 times, and keep the rated load for at least 30 seconds each time. After each preload is completely removed, wait for 30 seconds to return to zero. Check the equipment return to zero to ensure that the installation of tooling and sensors does not affect the sensor return to zero.

According to the selected verification point (including zero point), apply the torque step by step steadily in increasing order until the upper limit of the calibration range, read and record the output value of the standard torque measuring device Mrij and the output value of the calibrated torque measuring device MYIi, and then gradually decrease to zero point, read and record the output value of the standard torque measuring device MRDij and the output value of the calibrated torque measuring device MYDij, and repeat the above operations for three times, each time interval is not less than 30s, and zero adjustment is not carried out in the calibration process. The items of static torque parameter calibration include zero return error, repeatability and indication error, and the calculation methods of each technical index are as follows:

A. Zero-return error

$$Z_{ri} = \frac{X'_{0i} - X_{0i}}{X_{Ni}} \quad (i = 1,2,3) \quad Z_r = \max|Z_{ri}|$$

Where, X0i is the indicated value of the electromechanical servo torque measuring device before I measure the applied torque, x0i is the indicated value of the electromechanical servo torque measuring device after I measure the unloaded torque, and XNi is the indicated value of the electromechanical servo torque measuring device under I measure the rated torque.

B. Repeatability

$$R = \frac{X_{\max} - X_{\min}}{X} \times 100\%$$

Where, Xmax is the maximum value of the three measurement process indication of the electromechanical servo torque measuring device, Xmin is the minimum value of the three measurement return journey indication of the electromechanical servo torque measuring device, and x is the average value of the three measurement process indication of the electromechanical servo torque measuring device.

C. indication error

$$E = \frac{X - X_s}{X_s} \times 100\%$$

Where, x is the average value of the indicated values of the three measurement processes of the torque measuring device of the electromechanical servo mechanism, and XS is the average value of the indicated values of the three measurement processes of the standard torque measuring device.

2.2 Traceability of Dynamic Torque Measurement

The dynamic torque calibration device of electromechanical torque test system is mainly composed of standard torque sensor, calibration tool and data acquisition and analysis system.

A test torque sensor and an elastic load are installed on the original station, a torque calibration tool is installed, the test torque sensor, the elastic load and the standard torque sensor are coaxially connected, the test system controller outputs control commands to generate dynamic torque excitation, the data acquisition and analysis system collects the output signals of the dynamic torque sensor, analyzes and calculates, and compares the calculated results with the dynamic torque amplitude displayed by the test system to complete the calibration.

3 Uncertainty Evaluation of Electromechanical Servo Torque Test System

3.1 Uncertainty Evaluation of Static Torque Parameters of Electromechanical Servo Torque Test System

(1) Standard uncertainty component introduced by torque sensor erroru_{b1}

According to the requirements of regulations, the maximum permissible error of 0.1-class torque sensor is 0.1%, and its half width is 0.1%, which is set as uniform distribution. According to Class B evaluation, the standard uncertainty components introduced by torque sensor are: $u_{b1} = \frac{0.1\%}{\sqrt{3}} = 0.058\%$

(2) The standard uncertainty component introduced by the repeatability of torque sensoru_{b2}

In this project, it is planned to adopt a torque sensor of class 0.1, with the maximum allowable repeatability of 0.05%. Assuming that it obeys uniform distribution, its standard uncertainty component is: $u_{b2} = \frac{0.05\%}{\sqrt{3}} = 0.029\%$

(3) Standard uncertainty component introduced by azimuth error of torque sensoru_{b3}

In this project, it is planned to adopt a torque sensor of class 0.1, with the maximum allowable azimuth error of 0.1%. Assuming that it obeys uniform distribution, its standard uncertainty component is: $u_{b3} = \frac{0.1\%}{\sqrt{3}} = 0.058\%$

(4) Install standard uncertainty components introduced by different axes.u_{b4}

According to the previous calibration experience, the uncertainty components introduced by installing different shafts are: $u_{b4} = 0.2\%$

(5) If the components are uncorrelated, the combined standard uncertainty is 0.22%. $u_c = \sqrt{u_{b1}^2 + u_{b2}^2 + u_{b3}^2 + u_{b4}^2} = 0.22\%$

(6) Extended uncertainty (k=2) $U_{\text{rel}} = k \times u_c = 2 \times 0.41\% = 0.44\%$

3.2 Uncertainty Evaluation of Dynamic Torque Parameters of Electromechanical Servo Torque Test System

(1) Standard uncertainty component introduced by

grating encoder resolutionu_{b1}

When the resolution of the encoder is 2″, the standard uncertainty component introduced by the encoder is: $u_{b1} = \frac{a}{k} = \frac{2''}{\sqrt{3}} = 1.2''$

(2) Standard uncertainty component introduced by grating encoder installation erroru_{b2}

According to past experience, the standard uncertainty components introduced by grating encoder installation error are: $u_{b2} = 5''$

(3) The standard uncertainty component introduced by the indication error of grating encoderu_{b3}

The encoder indication error is 5 ″, and if it obeys uniform distribution, the standard uncertainty component introduced is: $u_{b3} = \frac{5''}{\sqrt{3}} = 2.9''$

(4) If the components are uncorrelated with each other, the standard uncertainty is synthesized. $u_c = \sqrt{u_{b1}^2 + u_{b2}^2 + u_{b3}^2} = 5.9''$

(5) Extended uncertainty: U = k× UC = 2× 5.9 "≈ 12" (k = 2)

4 Conclusion

For the electromechanical servo torque test system, the accuracy and effectiveness of the test data is the basic requirement to realize its functions. The static and dynamic traceability methods of the electromechanical servo torque test system proposed in this paper can effectively guarantee the traceability of the torque parameters of the electromechanical servo torque test system, and the uncertainty evaluation of the torque parameters under static and dynamic working conditions can better identify the use risks of the system for reference and analysis in various related fields.