Design of Torque Motor Characteristic Test System

Huajin ZHANG \(^1\), Fan LIN \(^1\)*, Xin ZHANG \(^2\), Xianghua WEN \(^3\)

\(^1\)School of Aerospace Engineering, Beijing Institute of Technology, Beijing 100081, China;
\(^2\)School of Mechanical Engineering, Beijing Institute of Technology, Beijing 100081, China;
\(^3\)The 5718th Factory of the Chinese People's Liberation Army, Guilin 541003, China

E-mail: linfanjy@bit.edu.cn

Abstract. The steering gear is an important part of the guided missile control system and the actuator of the flight control system. The torque motor is one of the key components of the steering gear. Its performance directly affects the performance of the steering gear and directly determines the dynamic quality of the guided missile during flight. According to the composition and working principle of the torque motor, to judge its performance, the no-load angular displacement characteristics and pressure characteristics of the torque motor should be tested. In order to accurately and quickly measure the performance of the torque motor under working conditions, the design of the torque motor test system is realized based on the virtual instrument development software. The test system mainly includes two parts: a hardware platform and a human-computer interaction interface. The hardware platform mainly includes an industrial computer, a torque motor test bench, a control box and a data acquisition card. The human-computer interaction interface has the functions of test parameter setting, data acquisition, data processing, data storage and form printing. The torque motor test system has the advantages of small prototype size, convenient operation and accurate test results. The test results show that the test method of the test system is reasonable, the test system runs reliably, the test efficiency is high, it can carry out stable and real-time data collection and processing, is easy to operate and maintain, and meets the key requirements of torque motor testing.

1. The meaning of the test system and system composition

The steering gear is an important part of the control system of the guided missile, and it is also the actuator of the flight control system. Its performance directly determines the dynamic quality of the guided missile during the flight. Therefore, it is not only necessary to develop various steering gears with superior performance, but also to conduct comprehensive testing and comprehensive evaluation of the steering gear performance, which is an important link to ensure the normal operation of the steering gear. In order to comprehensively detect the performance of the steering gear, the traditional physical flight test or wind tunnel test is a reliable method, but due to its own complexity, periodicity, and economy, it is limited in practical applications[1-3].

Therefore, the test of the key components of the steering gear and the proposal of the loading system are of great significance. The torque motor tested in this article is one of the key components of the steering gear. The performance of the torque motor directly affects the performance of the steering gear. The performance of the torque motor needs to meet the corresponding indicators when
The steering gear can be guaranteed to work normally, so the torque motor test is especially necessary. The performance of the torque motor mainly includes the no-load angular displacement characteristic and its pressure characteristic. The test platform for these two performances is relatively rare. In order to meet the test needs, this paper designs a torque motor test control system based on virtual instrument technology[4-5].

The torque motor test system is mainly composed of hardware and software. The hardware part includes a torque motor test bench, an industrial computer, and an integrated control box; the software part adopts the LabVIEW software development platform developed by NI, which can realize the generation of control signals and multiple channels Continuous data acquisition, static characteristic and dynamic characteristic test and other functions. The test bench mainly completes the fixing and installation of the torque motor. The integrated control box includes built-in power supply, controller, driver, pressure sensor amplifier, relay, etc. The control box is used to realize system power supply, signal measurement, connection and control of various system ports. The software part includes industrial computer, acquisition card and test system, etc. It mainly completes the task of generating test instructions and continuous acquisition, processing, display and storage of test signals. The specific system principle and architecture are shown in Figure 1.

![Test control system](image)

**Figure 1. Schematic diagram of the composition of the torque motor characteristic test system**

2. Torque motor test bench composition

Torque motor test bench is mainly composed of gas circuit body, connecting plate, pressure sensor, displacement sensor, micrometer, guide rail and key parts of slider. The torque motor test bench has two major test functions: no-load angular displacement test and pressure test. The angular displacement test part includes torque motor and displacement measuring plate, guide rail and sliding block, micrometer and its bracket, displacement sensor and its bracket. The pressure characteristic part includes torque motor, connecting plate, air circuit body, pressure sensor and air pipe. The torque motor test bench is shown in Figure 2.
1 base plate; 2 handles; 3 air supply connector bracket; 4, 5, 7 pressure sensor; 6 torque motor; 8 micrometer; 9 air inlet; 10 gas circuit body; 11 displacement sensor bracket; 12 displacement sensor; 13 connecting plate; 14 micrometer bracket; 15 force measuring rod assembly 16 guide rail and slider.

2.1. No-load angular displacement characteristic test part
The angular displacement test part includes a torque motor and a displacement measuring plate, a guide rail and a sliding block, a micrometer and its support, a displacement sensor and its support. The torque motor shaft is fixedly connected to the shift lever through a spring clamp. The quick adhesive glues the displacement measuring plate on the shift lever to form a force measuring rod assembly. The micrometer and the displacement sensor are connected to their respective brackets, and the two brackets are fixed to the slider. Even, use the one-way movement of the guide rail and the slider to adjust the distance between the micrometer and the displacement sensor relative to the displacement measuring disc.

When testing the angular displacement characteristics, the displacement sensor needs to be calibrated. The purpose is to obtain the relationship between the output voltage of the displacement sensor and the displacement of the armature off-center position, and then the relationship between the output voltage of the displacement sensor and the swing angle of the armature. When calibrating, use a micrometer to give the displacement of the armature from the center position at several calibration points, record the corresponding displacement sensor voltage, and process the coefficient of calculating the offset from the center by the sensor output voltage. The current of the control coil is converted into a voltage through a sampling resistor, which is collected and recorded by the acquisition card. After calibration, the relationship between the torque motor jet tube valve deflection angle and the current of the energized coil is obtained through a series of data processing by testing the displacement X of the force measuring rod assembly at the torque motor shaft. The mechanical structure of the no-load angular displacement test is shown in Figure 2.

2.2. Pressure characteristic test part
The pressure characteristic part includes torque motor, connecting plate, air circuit body, pressure sensor and air pipe. The bottom of the torque motor is connected to the air circuit body through the connecting plate. The three pressure sensors are connected deep into the air circuit body and the outlet of the torque motor to form a seal. The pressure sensor on the left side of the gas circuit body is to test the gas source pressure P3, and the two pressure sensors in the positive direction of the gas circuit body test the two outlet pressures P1 and P2 respectively. The mechanical structure of the pressure characteristic test part is shown in Figure 3.
When testing, after connecting the air source, let the industrial computer test system send a specified period of triangular wave command signal to the input end of the drive amplifier, and the triangular wave command signal is linearly amplified and then added to the torque motor. The coil current of the torque motor is input into the industrial computer by way of sampling resistance voltage to record the coil control current. When the cyclically varying voltage is applied to the torque motor coil, the torque motor armature rotates accordingly, and then the sensor generates displacement and the pressure electrical signal enters the industrial computer to record the relationship between the torque motor output displacement and the pressure P1, P2, and P3.

3. Composition and function of torque motor test control system
The test control system includes an industrial computer, LabVIEW test software system and data acquisition card, which mainly completes the generation of test instructions and the collection, processing, display, and storage of test signals. The test system software is developed using NI’s graphical programming tool Labview. The Labview software has powerful functions and beautiful interface, and can make full use of the driver function library provided by NI for its acquisition card to simplify programming. Use NI's PXIe controller to collect, control arithmetic and output control commands and feedback commands. The control instructions of the entire system are generated by the industrial computer platform, and different signals are selected according to the needs of the test, and the performance parameters of the torque motor of the key components of the steering gear are collected by the analog input channel, and then the data is analyzed, replayed, displayed, stored and printed by the software[6-8].

Figure 3. Partial structure diagram of pressure characteristic test

Figure 4. No-load angular displacement characteristic analysis interface
The test bench and industrial computer system application test system software program are used to record the no-load angular displacement characteristic measurement results and the pressure characteristic test results. After the no-load angular displacement characteristic test is completed, the displayed measurement result curve is shown in Figure 4. The figure shows the recorded displacement sensor output, coil current sampling resistor voltage and triangular wave command signal. After the pressure characteristic test is completed, the displayed measurement result curve is shown in Figure 5. The figure shows the recorded air source pressure and two outlet pressures p1, p2, coil current sampling resistor voltage and triangular wave command signal.

![Figure 4. No-load angular displacement characteristic test result curve](image)

**Figure 5. Pressure characteristic analysis interface—showing filtered signal**

4. Conclusion
This article introduces a torque motor test system based on LabVIEW, and explains the system's composition, test bench design, and software design. The advantage of this test system is that the test principle is reasonable and it can carry out stable and reliable tests. The test process is clear, the test operation is simple, and the degree of automation is high. The system can automatically complete the test operation and perform data collection, filtering, and data storage. The test system uses high-precision sensing equipment and acquisition equipment to improve the test accuracy of the test system, reduce manual errors, and filter the collected signals to greatly reduce the influence of interference signals.

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