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THE TORQUE STANDARD MACHINES IN CHINA

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Abstract − This paper describes the development of torque standard machines in China, its measurement range and its measurement uncertainty information etc. Also, the situation of torque standard machines which are in building process or will be built in the future is described in this document. In 1970's, the first standard machine for measuring torques was developed in Shanghai and it initiated the history of torque measurement in China. In the whole development process, there appeared four types of machines, which are: a) the rolling bearing type, b) the knife-edge type, c) the air-bearing type and d) the flexible supporting type. Nowadays, the torque standard machines in China are developing to the direction of large torque, super-large torque, small torque and mini torque ranges, and they are stepping into the international level rank.

Keywords: torque standard machine, uncertainty

1. INTRODUCTION

In the Chinese industrial fields, such as ships, vehicles, airplanes and space shuttles, there is a great need for the measurement of torque value. This need began in China from the seventies of the 19 century. The earliest torque standard machine was developed successfully in 1977 by SMERI, Shanghai. The rolling bearing was used as support, the range was 30N·m~3000N·m, the measurement uncertainty was 0.1% (k=2). Although the device was simple and the accuracy was not high, it could do quality transfer work.

With the development of Chinese industry in eighties, SMERI developed 200N·m and 30kN·m torque standard machines, and the measurement uncertainty was 0.1%， k=2. These two machines could serve for middle and low accuracy torque transducers.

Form the nineties, the measurement accuracy of torque transducer in China market become higher and higher. And the NIM developed 1kN·m and 5kN·m torque standard machines (knife-edge type), the measurement uncertainty was 0.01%, k=2.

Since 20 century , the measurement ranges for the torque calibration got wider and wider, and before 2007 SMERI developed successfully 0.5kN·m ~50kN·m torque standard machine, the measurement uncertainty was 0.05%, k=3 and 1mN·m~10N·m torque standard Machine, the measurement uncertainty was 0.1%~0.02% , k=2.

At the same time, SMERI also developed 100N·m dynamic torque standard machine. In 2008, NIM and SMERI cooperated with each other and developed air-bearing type 100N·m torque standard machine ， the uncertainty was 0.002%, k=2. Now we'd like to introduce the typical torque standard machines of different types in China.

2. TORQUE STANDARD MACHINES FROM 10N·m TO 5000N·m IN CHINA

Organization	Torque range	Uncertainty
NIM	10N·m~1000N·m	0.01%, k=2
NIM	50N·m~5000N·m	0.01%, k=2
SMERI	20N·m~2000N·m	0.03%, k=2

2.1. Symmetrical couple construction

The standard arm and the balance arm are of symmetrical couple construction, and the balance arm torsion is not applied on the base but on ground, therefore, a series of uncertainty factors caused by a torsional deformation of the base which is applied onto the transducer will be eliminated.

2.2. Knife-edge bearing construction

The knife-edge bearing is used in arm supporting. The knife-edge is made of special material, ground precisely and polished. The diameter of knife-edge is 0.2mm. The knife-edge may roll on concave curve bearing mat. Through the regulation of balance weight, the gravity centre of standard arm will be under the main knife-edge, and the plumb line of gravity will cross the knife-edge on fulcrum perpendicularly, while the standard arm is in horizontal position. At this time, the load of special weight is born by two end knife-edge .The main knife and the side knife are in the same plane and parallel to each other to guarantee the constant value. When the machine stops working, the knife-edge will be fixed by clamping mechanism to prevent from being worn.

2.3. Coaxiality technique

In order to meet the coaxiality requirement of transducer, standard arm and balance arm, the installation stand of torque transducer, standard arm and balance arm are installed on the base with enough stiffness. The installation stand of torque transducer is of three-dimensional

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adjustment and the movement of installation stand and adjustable balance arm on base is completed through the guide of straight rolling bearing with small gap. A special flexible coupling is adopted for connecting standard arm and calibrated transducer to eliminate the error caused by uncoaxiality of standard machine and transducer to apply the whole standard torque onto the calibrated transducer. The adopted flexible coupling can control the uncertainty produced by uncoaxiality to be in the range of 1×10^{4}.

2.4. PLC controlling

All the working process and automatic loading are controlled by PLC. The loading speed is 40mm/min, and there is not any attack and oscillation during the loading and unloading process.

2.5. Horizontal keeping technique

The movement of elevating mechanism is controlled by a non-contact displacement transducer to eliminate the horizontal equal efficient length variation caused by inclination of standard arm after loading and to keep the standard arm in horizontal position from the beginning to the end.

3. 50kN·m TORQUE STANDARD MACHINE

The structure of the machine is given in figure 1.

1-PC 2-Base 3-magnified arm of force
4-displacement transducer 5-standard arm of force
6-knife Edge support 7-calibrated transducer
8-three-dimension working platform
9-balance arm of force 10-stretch mechanism
11-weight group 12-clamping mechanism

Figure1: 50kN·m torque standard machine

The machine consists of loading mechanism, balance mechanism, alignment adjusting mechanism, control system and base. It can generate standard torque according to the dead-weight principle, and can apply standard torque to the calibrated torque transducer.

The loading mechanism consists of the standard arm of force (5), the magnified arm of force (3), the weight group and the loading mechanism (11).It can generate the standard torque. The magnified arm of force and the loading mechanism of weight group can magnify the weight force to 10 times, and apply it to the standard arm of force. The balance mechanism consists of balance arm of force (9) and the stretch mechanism (10) for deceleration. It can generate the balance torque and pull back the standard arm of force to the horizontal position.

The loading mechanism and balance mechanism can form a standard torque and the latter can be applied to the calibrated transducer. The alignment adjusting mechanism consists of the axis adjusting mechanism , flexible coupling and the three-dimension working platform (8) of transducer, and it can make the supporting centre of the standard arm of force knife-edge(6),the centre of calibrated transducer (7) and the bearing centre of balance arm of force on the same line . Above mentioned mechanisms are installed on the rigid base (2) .The calibration process is controlled by PC (1),and the mechanism work is controlled automatically according to the order of PLC software.

4. 1mN·m ~10N·m TORUE STANDARD MACHINE

Fig2: 1mN·m~10N·m torque standard machine (U = 0.02 %, k=2)

The whole machine is an automatic continuous loading and automatic accurately measuring system and the electromagnetic torque device is used to replace the weights force to produce the force.

There are standard beam (front beam) and balance beam (rear beam), when the torque transducer “D” is introduced, the acting parts of the machines are connected into a whole component. The relative positions of whole component are fixed and not changeable. The displacement transducer “S” and the speed transducer “V” are installed on the standard beam and the acquisition electric resistance k_0 is connected with torque device “F” through the combined amplifiers k_s, k_v, k_z, k_p.

The whole machine acts on the horizontal smooth agate knife mat through the high speed knife-edge with very small radius (R0.1). The mass centre of the machine is adjusted on the knife-edge to mark the machine work in the indifferent equilibrium status. Then the torque standard machine becomes automatic compensation system with negative feedback and the electromagnetic torque is not different.

The principle of 1mN•m~10Nm torque standard machine is as follow:

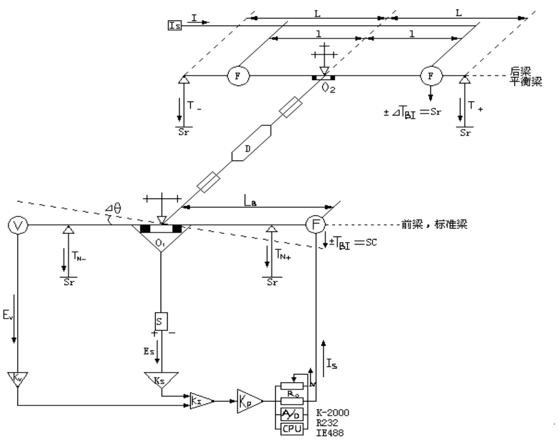

Fig 3: Measurement principle of the torque standard machine

100mN•m~10N•m U=0.02%, k=2
1mN•m~100mN•m U=0.1%, k=2

5. 100N•m NEGATIVE STEP DYNAMIC TORQUE STANDARD MACHINE

The 100N•m negative step dynamic torque standard machine consists of torque block, three-dimension working platform, electric controller, steel rope, cylinder, electro-magnet weight, base and torque wall etc. as shown in figure 4.

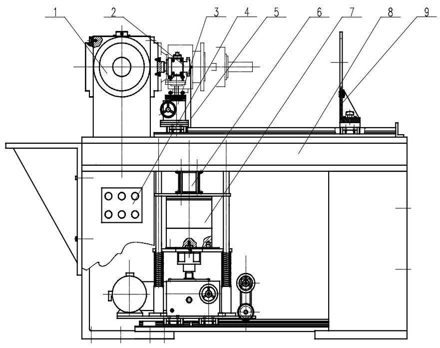

Fig4: Principle of 100N·m negative step dynamic torque standard machine

1- torque block
2- measured transducer
3- three-dimension working platform
4- electric controller
5- steel rope
6- cylinder
7- electro-magnet weight
8- base frame
9- torque wall

Fig5: 100N·m negative step dynamic torque standard machine

One end of calibrated torque transducer is installed on the torque block and the other end is connected to the torque wall. The torque block is a big mass piece. The torque wall applies negative step torque to the transducer. The step force is formed by the cylinder and the electro-magnet weight and is suspended on the pure torque wall to form a step torque. When the electro control PLC order is given, the electromagnet attracts the weight and the cylinder is charged with air to form a pulling force needed by 100N·m torque, and the 100N·m torque is supported by the transducer via the torque wall. When the electro-magnet is off, the reacting force of cylinder makes the steel nope weightless and go up quickly, the torque supported by the transducer disappears to zero and to form a negative step process. The negative step torque wave is acquired via the data acquisition device and the change time τ from 90% torque value to 10% torque value may be read, so the ω_n value may be obtained through data processing.

The specification of machine is as follows: measurement range 100N•m, $\tau \leqslant 5$ms, U=3%, k=2.

6. 100N·m HIGH ACCURACY TORQUE STANDARD MACHINE

The deadweight construction is used in this machine and the torque value can be reproduced with the help of the combined force of the gravitation introduced by the weights and the floating force acted on the weights by the air and the vector of the lever length.

The torque value produced by the machine is calculated according to formula: （1）

$$M = mg\left(1 - \frac{\rho_a}{\rho_\omega}\right)L\sin\alpha \qquad (1)$$

M— torque value (N·m);   m— mass of weights (kg);
g— gravity acceleration in the installed place (m/s);
ρ_a—air density (kg/m^3);
ρ_ω—material density of weight (kg/m^3);
L—length of arm (m)
α—angle between arm and plumb line (rod).

The machine consists of the air bearing, the arm—lever system, weights loading system, connector and the machine base. The air bearing supporting system is used in the support part of the lever to reduce the friction brought by the support part. The balance is measured by the displacement transducer and is controlled and adjusted by the servo control system to ensure the initial balance status after loading. The flexible couplings are installed on the active and driven shafts. The shaft locking device is used in the connector between the standard machine and transducer to resolve the parasitic component problem produced by the uncoaxiality of the transducer and the machine, which was brought by the installation of the connector and the deadweight of transducer.

Measurement range: 1N·m～100N·m

Uncertainty: U=0.002%, k=2

The figure 6 is the construction of 100N·m torque standard machine.

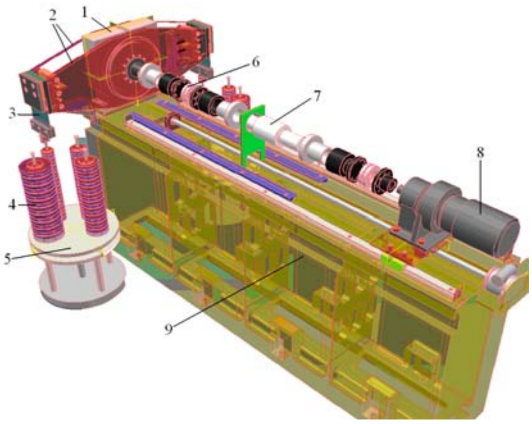

Fig6: Principle of 100N·m torque standard machine

Fig7: 100N·m torque standard machine

7. CONCLUSION

With the development of science and technology, the accuracy of the torque transducers becomes higher and higher and the measurement ranges of torque standard machines in China become wider and wider, and the accuracy become higher and higher.

Before 2012, China will develop deadweight type torque standard machine. At the same time, China will develop a series of dynamic and rotational torque standard machines (see Table 1).

Table 1. To be developed Torque standard machines

Torque standard machine	Measurement uncertainty (k=2)	Support Type
1N·m~10kN·m	0.002%~0.005%	air-bearing
2kN·m~200kN·m	0.05%	knife-edge
100μN·m~100mN·m	0.05%	electromagnetic

In order to meet the requirement of China industrial systems for the standard machines, now the NIM and SMERI are cooperating to work hard to raise the technological levels of China torque standard machines.

REFERENCES

[1] Shang Weilu, Chen Yongpei， Wang Yan， Li Tao， “2000Nm torque standard machine”, APMF2000, Tsukuba, Japan, Nov. 2000.

[2] Shang Weilu, Chen Yongpei， Li Tao， Wang Yan， “50kNm torque standard machine”, IMEKO TC3 19th international conference, Cairo, Egypt, Feb. 2005.

[3] Li Tao, Shang Weilu, Chen Yongpei， Yan Kangping, “100Nm negative step dynamic torque standard machine”, XVIII IMEKO World Congress, Rio de Janeiro, Brazil, Sept. 2006.