

DESIGN OF TORQUE STANDARD MACHINE FOR CALIBRATION OF REFERENCE TORQUE WRENCH AT NIM

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Abstract – The paper describes the design of a new torque standard machine at NIM. This machine is used to calibrate the reference torque wrench and torque transducer. The measurement uncertainty is expected to reach 0.03 % ($k=2$). The range is designed from 10 Nm to 5000 Nm.

Keywords: torque standard machine, reference torque wrench, calibration method;

1. INTRODUCTION

After the promulgation of national verification regulation of torque wrenches calibrate instrument. The requirements of calibration of reference torque wrench become more and more. The original machine can not satisfy the need of reference torque wrench calibration. So we began to design a new standard machine for this kind of need.

SI trace ability system of torque wrench in China can be seen in Figure 1.



Figure1. SI trace ability system of torque wrench

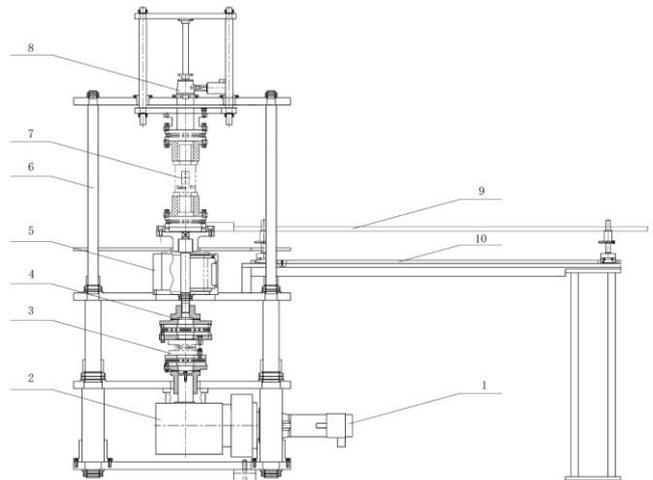
The position of the machine we designed is in the third layer of the Figure 1. Table 1 shows the ranges of reference torque wrench we usually calibrate.

Table 1. the range of reference torque wrench

Torque standard machine	Reference torque wrench
10 Nm~5000 Nm/ 3×10^{-4}	10 Nm~3000 Nm/ 1×10^{-3}

2. THE STRUCTURE AND PRINCIPLE OF THE NEW MACHINE

The researchers at NIM design a new machine. Show in Figure 2



1. Loading motor 2.large speed ratio reducer 3. Standard torque transducer 4. Face tooth adpoter 5. Air bearing 6. Frame 7. Standard torque transducer 8. Lifting mechanism 9.Reference torque wrench 10.reaction mechanism

Figure 2. Standard torque equipment

2.1. The main structure

The new machine is a kind of reference torque standard machine. Use vertical structure. The mechanical structure is shown in Figure 2. The machine mainly consists of the vertical reference structure and the anti torque arm supporting structure. The vertical reference structure consists of four parts. The bottom of the structure is the loading mechanism, which is composed of a loading motor and a large speed ratio reducer. On the top of the loading mechanism is the standard torque transducer. In this part we can change the transducer convenient. The third part of this machine is the support part. Here we use an air bearing as a support. The upper part is a fixed end, including the lifting mechanism and the adapter. The anti torque arm supporting structure is designed for calibration of reference torque wrench, which is located at the middle part of the machine.

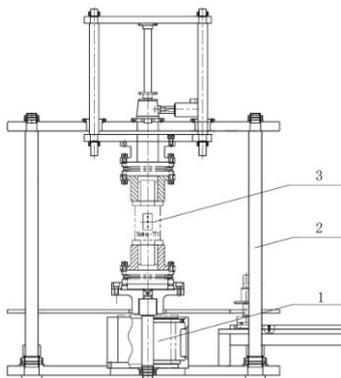
2.2. The performance of standard machine

The design range of the machine is from 10 Nm to 5000 Nm. The measurement uncertainty is expected to reach 0.03 % ($k=2$). This machine with five standard torque wrenches, as Figure 3 shown. Torque transducer including 100 Nm, 500 Nm, 1000 Nm, 2000 Nm and 5000 Nm. After long-term evaluation, the accuracy of each standard sensor is 0.02 %.



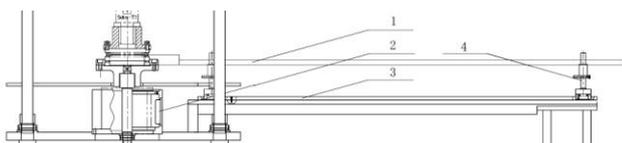
Figure 3. Standard torque transducer

The new machine is designed for calibration of reference torque wrench. But it also can calibrate the torque transducer with high accuracy. The transducer is installed on the upper end of the air bearing through a flange connection as Figure 4 shows.



1. Air-bearing 2. Frame 3. Torque transducer
Figure 4. Transducer to be calibrated

With the adjustable reaction arm, this machine can also calibrate the reference torque wrench. The length of reaction arm is 2500 mm. The distance of reaction point and axis of transducer can be adjusted from 20 mm to 2500 mm.



1. Reference torque wrench 2. Air-bearing
3. Reaction mechanism 4. Reaction column
Figure 5. Reaction mechanism

2.3. The special design of this new machine.

The first design feature of this machine is that it is convenient to replace the standard torque sensor. With this

design we can achieve wide range segment use. And we can change the standard torque transducer within 10 seconds. Here we use the end face of the structure to realize the function of quick replacement of transducer. We use the face tooth structure for the connection of transducer. End face tooth structure was shown in Figure 6.

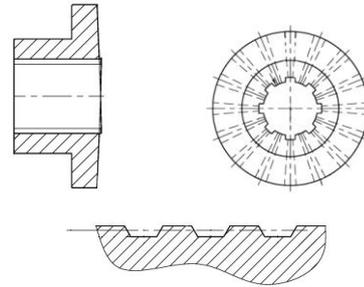
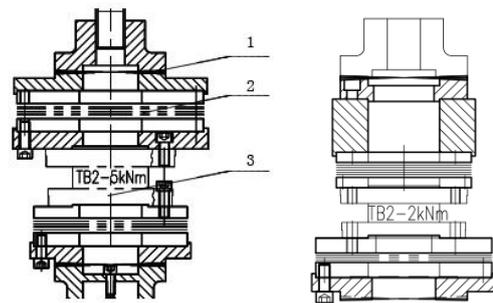


Fig 6 End face tooth

The end of the air bearing and the top end of the loading mechanism are respectively provided with a group of end face tooth structures. The end face tooth conversion device is installed at both ends of each standard sensor as Figure 7 shows.



1. End face tooth 2. Flexible coupling 3. Torque transducer
Figure 7 End face tooth and transducer

The second design feature is the wide range. With rapid replacement mechanism high accuracy machining and Precision control system. The calibration range is from 10 Nm to 5000 Nm. The difficulty is how to install different torque sensors on the device and with high accuracy. When we install the 5000 Nm transducer, the end face tooth is large and heavy. If the end face tooth is placed on the 100 Nm transducer directly. The weight of the end face tooth will cause error. So the connection mode of the 100 Nm transducer is different from large transducer. 100 Nm sensor can be installed directly on the upper and lower shaft. The third design feature is the air bearing support. Different from traditional support method, by the support of air bearing we can eliminating side force effects and reduce the friction effects. Fig 8 is the picture of air-bearing to be used in this machine. This air-bearing is designed and manufactured by Shanghai Marine Equipment Research institute. Performance parameters of this air-bearing are listed in table 2.

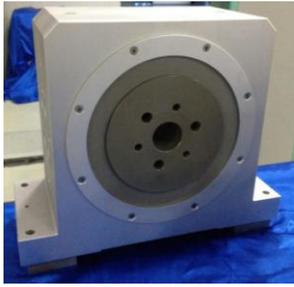


Fig 8 Air-bearing

Table.2. Air bearing performance

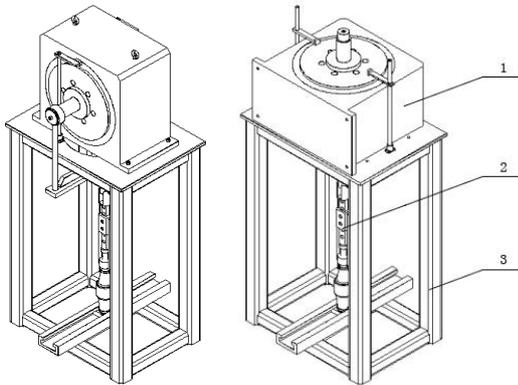
maximum radial bearing capacity	6000N
maximum axial bearing capacity	2000N
sensitivity	2×10^{-5}

3. TEST AND SIMULATION ANALYSIS

In order to ensure the performance of machine computer simulation was carried out before the machining process.

3.1 Test of air bearing support capacity

An air bearing is used on the machine. Here we use an experimental device to do the test of air bearing support capacity. The performance test of air bearing is shown in Figure 9.



1. Air-bearing 2. Hydraulic loading mechanism 3. Frame

Figure 9. Air bearing test

The left part of Figure 9 is radial bearing capacity test. The air bearing is mounted vertically on the test device. With hydraulic mechanism we can load to different loads smoothly. The maximum radial bearing capacity is 6000 N. The right part of Figure 9 is axial bearing capacity test. The maximum axial bearing capacity is 2000N. The sensitivity of this air bearing is 2×10^{-5} .

3.2 The calculation and analysis of reaction arm

Because the measurement range of this machine is from 10 Nm to 5000 Nm, so the reaction arm design needs to consider the range of needs. Figure 10 to Figure 12 is the analysis of reaction arm, here only when the maximum load 5000 Nm is analyzed.

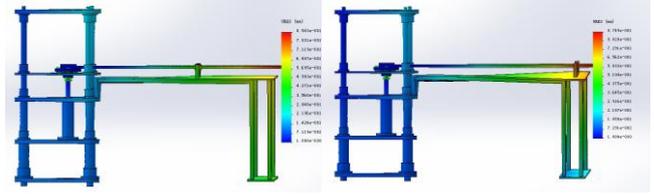


Figure 10. Displacement analysis

From the Figure 10 we can see the maximum displace of the reaction mechanism is 0.5 mm when the reaction point at 60 % length and at 90% points the maximum displace is 0.7 mm. When loaded into 5000 Nm.

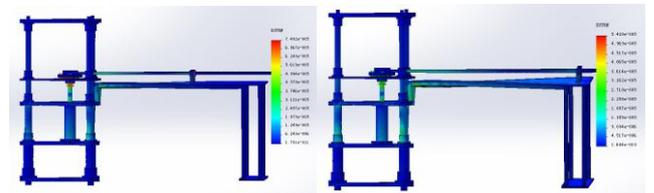


Figure 11. Strain analysis

From the Figure 11 we can see when the reaction point at 60 % length the maximum strain of the reaction mechanism is 1.8×10^{-5} micro strain. And at 90 % points the maximum strain is 2.2×10^{-5} micro strain. When loaded into 5000 Nm.

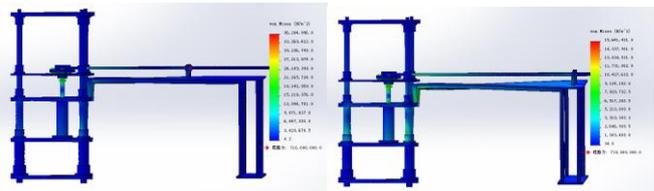
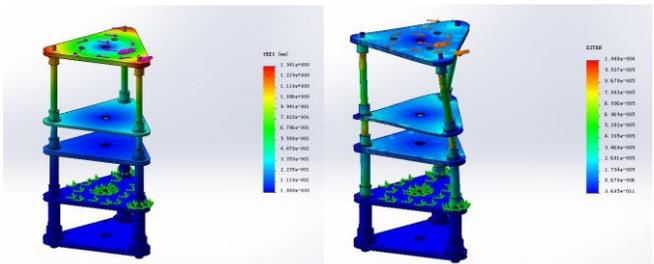


Figure 12. Stress analysis

From the Figure 12 we can see the actual stress is much lower than the yield stress of the structure when loaded into 5000 Nm.

3.3 Device frame design analysis

The frame structure of the device is subject to 5000 Nm load, and the frame structure is simulated in the design process.



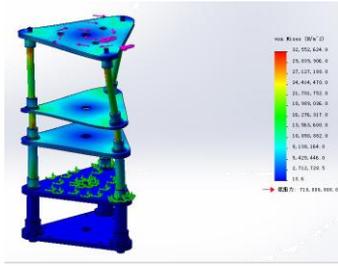


Figure 13. Analysis of frame

As shown in the Figure 13, the force analysis is performed in the case of the maximum load of 5000 Nm. including stress analysis, strain analysis, displacement analysis.

Table 3. The analysis result of frame

load	stress	strain	displacement
5000 Nm	32Mpa	1×10^{-4}	1 mm

4. ELECTRICAL CONTROL SYSTEM DESIGN

The control system of new multi-function standard torque machine is computer and PLC control system. We can see the diagram of the control system from Figure 14.

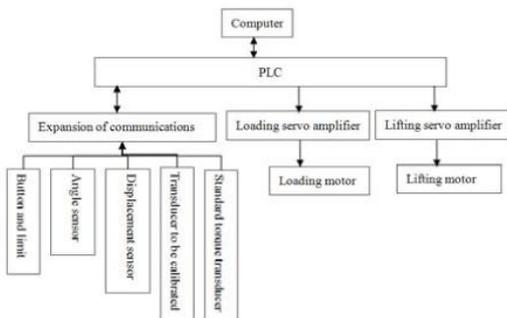


Figure 14 Control system

With the control system realize the control of the servo motor. The working state in various parts of the machine under operation condition can be displayed on the computer screen in real time. Using displacement transducer detects the lifting platform position. Using angle encoder detects the rotation angle of input shaft. The control system has two control modes.

4.1 Torque control

Torque control uses the signals of standard torque transducer as feedback signal. The signals of torque transducer amplified by the torque meter and transmitted through the serial port to control system. Torque control with PID control; continue to monitor the set torque value, so a long time to keep the torque within the set range, the

fluctuations in the torque value can be stabilized within ± 0.02 Nm.

4.2 Angel control

Use the absolute rotary optical angle encoder as spindle angle detecting sensor; we can get the angle signal of spindle at anytime. Absolute rotary optical encoder has an absolutely unique for their every position, well anti – interference. Before each angle position control, the target angle sensor value should be written to coordinate; Rotation range of $\pm 450^\circ$, corresponding to the encoder readings $\pm 180\ 000$.

4.3 Design of loading system

At the bottom of the machine is the loading system of the device, wide range, and stable loading system design is a challenge. The device adopts large speed ratio reducer; the speed ratio is 1:30000. When the maximum load is 5000 Nm, the input of the speed reducer is 0.16 Nm. The load stability is 0.02 Nm/min.

4.4 Design of lifting system

The upper part of the machine can be fitted with a higher standard torque transducer, and can also be fitted with a calibrated torque transducer. In order to adapt different transducer, the lifting system was designed. The top fixing part can be adjusted by the lifting mechanism. Work space can be adjusted from 100mm to 500mm.

The lifting mechanism is consisting of a servo motor and a reducer.

5. CONCLUSIONS

The new machine is a multi-function machine, with this machine we can carry out the calibration of reference torque wrench, this machine can also be used for calibration of torque transducer. When we calibrate the reference torque wrench with this machine the calibration status is same as the using status. So use this device calibration reference torque wrench is more scientific. The machine is currently in the processing stage, will be completed in August this year.

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