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50 N·m TORQUE STANDARD MACHINE AT SASO / NMCC

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Abstract:
A 50 N·m torque standard machine was established at National Measurement and Calibration Center (SASO / NMCC) in 2019 by TÜBİTAK UME. Realisation of torque unit is based on the definition of torque and directly traceable to the mass, length, and time units. It is performed by a lever arm and deadweight system. The lever arm is symmetrical and supported by an air bearing. Deadweights, which are under the influence of local gravity and air buoyancy, are freely hung on the lever arm ends to create right and left hand torques. This paper describes the mechanical structure of the machine and uncertainty assessment. The relative expanded measurement uncertainty is smaller than 1×10^{-4} in the range from 0.2 N·m to 50 N·m.

Keywords: torque standard machine; deadweight torque calibration machine; air bearing; uncertainty

1. INTRODUCTION

Developing technology and demand for economic solutions in torque calibration and measurements causes to increase the need of using torque measuring devices below 10 % of their capacity.

The torque calibration machine of 50 N·m offers the possibility of calibration of torque measuring devices in 12 steps between 2 % and 100 % of three main nominal capacities which torque measurements are frequently performed.

The machine is designed for static calibration of torque measuring devices (such as torque transfer standards and torque transducers) with high accuracy. It is mainly used for calibration of transducers with nominal capacity of 10 N·m, 20 N·m, and 50 N·m.

2. PRINCIPLE OF THE TORQUE STANDARD MACHINE

The torque calibration machine is realising the torque by using the torque arm and deadweights. The torque calibration machine has one symmetrical torque arm and a total of three deadweight sets for the calibration of torque measuring devices with nominal capacities of 50 N·m, 20 N·m and 10 N·m. For clockwise and counterclockwise calibration, the same deadweight set is used. To be able to use the same deadweights, the deadweight sets are moved from one end of the torque arm to the other to achieve clockwise and counterclockwise torques.

2.1. Mechanical Structure of the Machine

Realisation of torque unit is based on the definition of static torque and directly traceable to the main SI units of mass, length, and time. A schematic view of the torque standard machine is given in Figure 1.

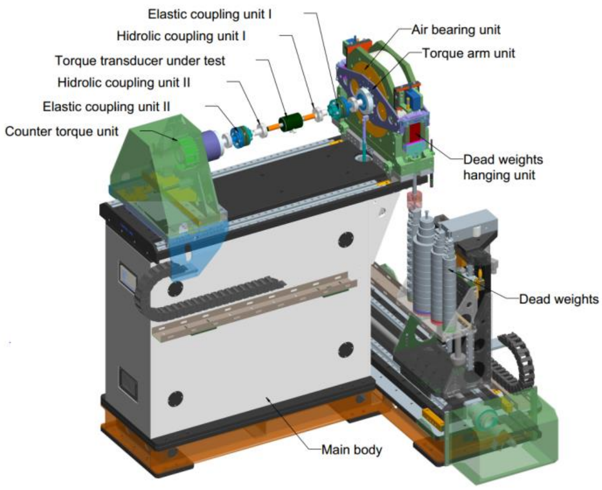

Figure 1: 50 N·m torque standard machine (drawing)

The main components are basically explained in the following sections;

Main Frame

The machine main body is made of a welded steel construction. On this body, there is an air bearing and a main plate that provides linear movement, on which the counter torque unit is mounted with bolts. All the parts and auxiliaries are mounted on that body by bolted arrangements (Figure 2).

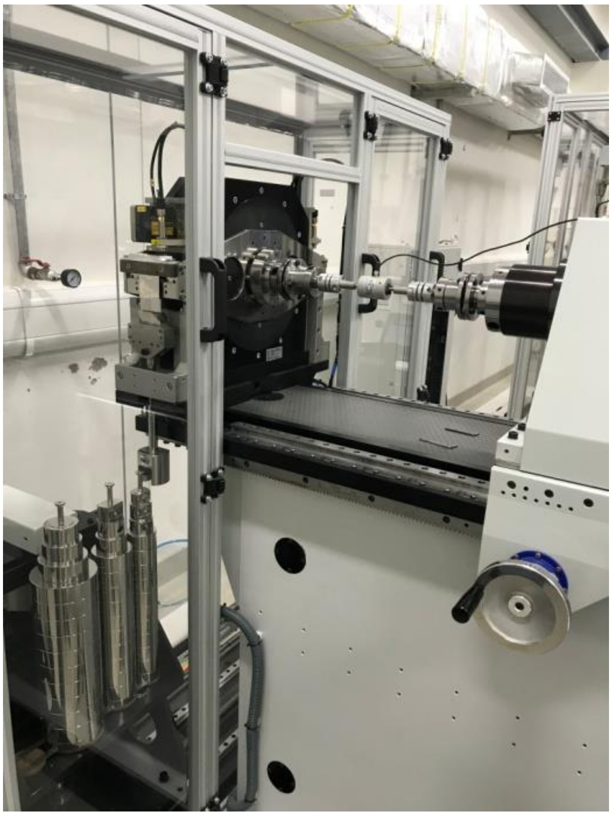

Figure 2: 50 N·m torque standard machine

Air Bearing

Aerostatic bearing unit is used to meet for two main goals. Primarily, in order to be able to eliminate the parasitic effect on torque transducer, and to support the lever arm and secondarily minimising the torque loss because of the fulcrum friction.

Air bearing is manufactured by Intop GmbH. Operational air pressure of the bearing is about 6 bar. Axial and radial run-out of the bearing is less than 5 µm and its frictional moment is less than 15 µN·m.

Torque Arm

The torque arm is a symmetrical construction and consists of two main Invar plates connected to each other.

The nominal length of the lever is 250 mm for each side. Traceability of torque arm to national standards of length is supplied by certification of dimensional laboratory using 3D coordinate measuring machine (CMM). The uncertainty of length measurement is better than ±4 µm.

For the position of the torque arm, two distance measuring sensors, one at each end of the torque arm, are used. With the help of these sensors, the torque arm can be controlled within a ±10 µm band without any contact (Figure 3).

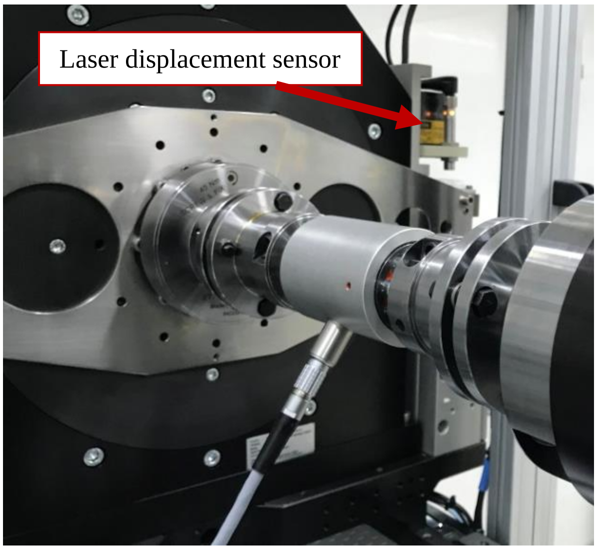

Figure 3: Laser displacement sensor, for torque arm positioning

To be able determine the torque arm length and force application point, an adjustment pin and a steel metal foil with 20 µm thick and 50 mm wide is used (Figure 4).

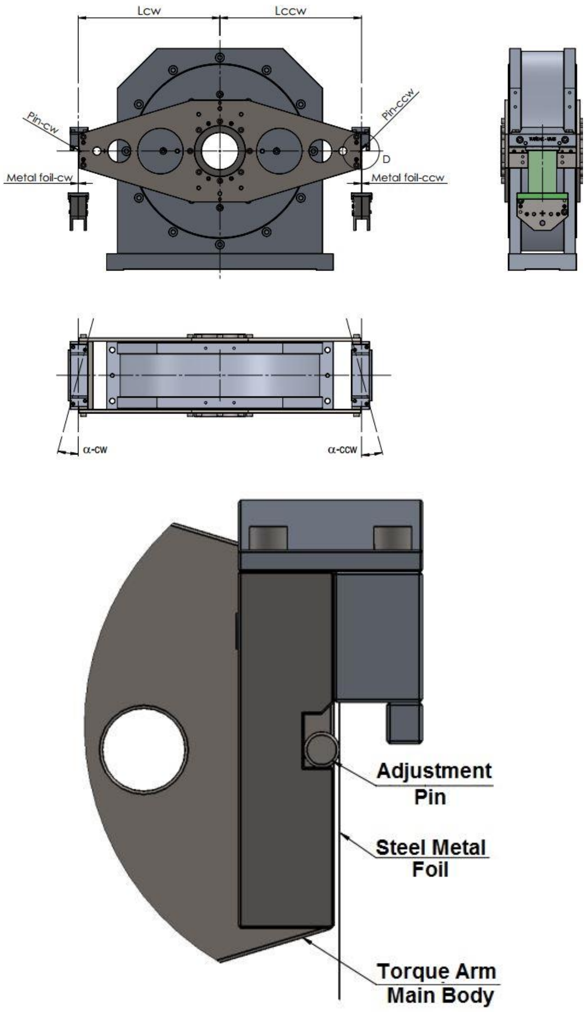

Figure 4: Adjustment of the torque arm length

Deadweights

There are three different deadweight sets and each of them has a chain type construction and consists of 13 masses (Figure 5). All the weights are traceable to the national mass standards and relative uncertainty is better than 7 ppm. Details of each set are given in Table 1.

Table 1: Weight sets of the torque standard machine

		Set I 50 N·m	**Set II 20 N·m**	**Set III 10 N·m**
1	2 %	1 N·m	0.4 N·m	0.2 N·m
2	5 %	2.5 N·m	1 N·m	0.5 N·m
3	10 %	5 N·m	2 N·m	1 N·m
4	20 %	10 N·m	4 N·m	2 N·m
5	30 %	15 N·m	6 N·m	3 N·m
6	40 %	20 N·m	8 N·m	4 N·m
7	50 %	25 N·m	10 N·m	5 N·m
8	60 %	30 N·m	12 N·m	6 N·m
9	70 %	35 N·m	14 N·m	7 N·m
10	80 %	40 N·m	16 N·m	8 N·m
11	90 %	45 N·m	18 N·m	9 N·m
12	100 %	50 N·m	20 N·m	10 N·m
13	110 %	55 N·m	22 N·m	11 N·m

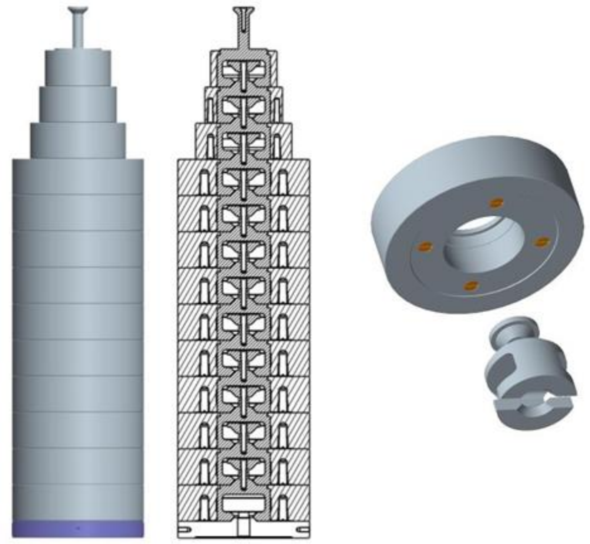

Figure 5: Schematic views of 50 N·m deadweights set

Counter Torque

Counter torque application is used to balance the torque arm after loading or unloading is applied. For this purpose, a servomotor with a harmonic drive gear box is used as a part of the machine. The reduction ratio of the gearbox is 1:10 000 and a 13-bit absolute encoder is used with the servomotor.

Couplings

The main connection of torque measuring devices can be done mainly via hydraulic couplings (ETP). It is possible to mount a torque transducer to the machine with a diameter of up to 50 mm and length of up to 500 mm.

2.2. Operational System of the Machine

Operational control of the machine is primarily management of servomotors. Positioning the mass stacks and balancing the lever arm are critical and it should be done highly accurate and adequately quick. All commands could be given to the torque standard machine easily by highly capable PLC control algorithm and system specific user interface program (HMI), Figure 6.

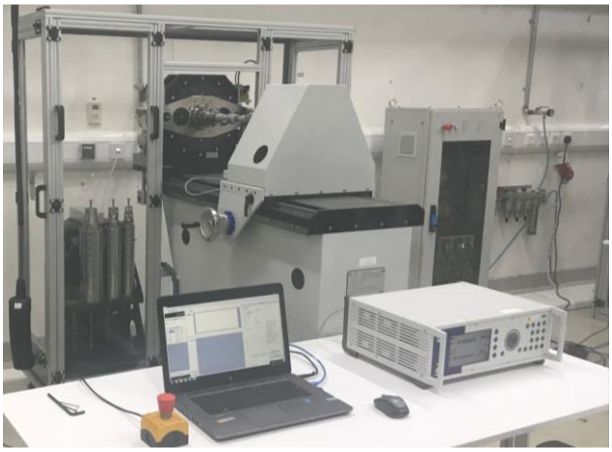

Figure 6: Control of 50 N·m torque standard machine

The software allows the operator to select all the relevant variables such as transducer capacity, direction of rotation, amplifier options, and load steps. Moreover, the calibration sequence can be defined by macros or individual commands and all measurement-related data can be recorded on the HDD simultaneously. The software has options to make either fully-automated calibration by configurable auto macros or a half manual operation of the machine. Furthermore, in any exceptional case, the operational system keeps the safety conditions for both the machine and the transducer by a PLC unit using certain safety switches and algorithms.

3. UNCERTAINTY OF THE TORQUE STANDARD MACHINE

The measurement uncertainty of the machine is substantially dependent upon the uncertainty of force realised by deadweights, torque arm length, torque arm position, and the friction losses in the air bearing. The mathematical model of torque generated by torque calibration machine can be taken as in equation (1), see [1], [2].

$$M = m\, g_{\mathrm{local}} \left(1 - \frac{\rho_{\mathrm{air}}}{\rho_{\mathrm{mass}}}\right) l \sin(\alpha) + \delta M_{\mathrm{fric}} + \delta M_{\mathrm{other}} \qquad (1)$$

The measurement uncertainty parameters of the machine are summarised in Table 2 and combined relative expanded measurement uncertainty can be calculated according to equation (2) and equation (3), see(2) [3], [4].

$$w = \sqrt{w_1^2 + w_2^2 + \cdots + w_n^2} \quad (2)$$

$$W = k \times w \quad (3)$$

Table 2: Uncertainty evaluation of the torque calibration machine

Uncertainty component	**Distribution function**	**Contribution to relative uncertainty**
Mass	normal	$\leq 4.3 \times 10^{-5}$
Density of mass	rectangular	$\leq 5.5 \times 10^{-7}$
Density of air	rectangular	$\leq 3.6 \times 10^{-6}$
Local gravitational acceleration	normal	$\leq 5.0 \times 10^{-7}$
Torque arm length	normal	$\leq 8.0 \times 10^{-6}$
Torque arm position	rectangular	$\leq 9.0 \times 10^{-8}$
Temperature of torque arm	rectangular	$\leq 1.1 \times 10^{-6}$
Deflection of torque arm	rectangular	$\leq 1.4 \times 10^{-8}$
Air bearing friction	rectangular	$\leq 2.8 \times 10^{-5}$
Combined relative standard measurement uncertainty (k = 1)		$\leq 5 \times 10^{-5}$
Combined relative expanded measurement uncertainty (k = 2)		$\leq 1 \times 10^{-4}$

4. SUMMARY

The 50 N·m torque standard machine of SASO / NMCC has been put into use for a measuring range of 0.2 N·m to 50 N·m. The measurement uncertainty is declared as 1×10^{-4}, due to the air bearing effective at small torque value below 1 N·m. For torque values above 1 N·m, the measurement uncertainty is expected to approach 5×10^{-5} and it would be useful to wait for the results of the comparison measurements to clarify the measurement uncertainty.

In order to meet the demand to use torque transducers in a wider measuring range, 50 N·m torque standard machine give chances to start the calibration process from 2 % of the capacity of torque measuring devices within a single calibration process.

5. REFERENCES

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