PERFORMANCE OF THE NEW PRIMARY TORQUE STANDARD MACHINE OF INMETRO, BRAZIL

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ABSTRACT

A new design of primary torque standard machines (TSM) with feedback-control of the lever support was described at IMEKO – XVI. World Congress in Vienna [1].
The purpose of this paper is to present the performance of a hand operated option model in the wide range from 2 N·m up to 3000 N·m. Influences of hand operation are estimated as well as ambient influences like temperature changes and air flow. A protection chamber against the ambient influences was built and the improvement is shown.
The TSM has three mass stacks to cover all transducer capacities from 20 N·m up to 3000 N·m in each ten steps. The masses are calibrated within $5 \cdot 10^{-6}$ by German DKD. The lever arms were precisely adjusted and also DKD-calibrated within $5 \cdot 10^{-6}$. The adjustment procedure is described.
The measurement uncertainty is calculated by the design data according GUM. In addition the best measurement capability of the TSM and the relative deviations are calculated by the results of several torque transfer standards, former calibrated at PTB. Both calculations are compared.
The next steps of the upgrade concept – from a hand-operated model to a full-automated model – are illuminated regarding the requirements in Brazil.

1. INTRODUCTION

The increasing level of industrialisation in Brazil demands an improvement in the National Torque Standard of INMETRO regarding the reduction of uncertainty and a better traceability. In order to reach an immediate implementation and to be in line with the budget, the decision was made to acquire a hand operated dead-weight-TSM with the possibility of a subsequent automation. The target relative uncertainty was fixed to $1 \cdot 10^{-4}$ ($k=2$).
From a metrological side of view the advantages of a completely automated standard machine are the possibilities to cover the lever and the mass handling against disturbing influences and to guarantee an asymptotically load change, independent of the operator.
In case of a hand-operated TSM, these points can’t be realised in the same way. Therefore the influences have to be investigated.

2. DESCRIPTION

The TSM consists of a T-formed base frame with a horizontal measuring axis. The test space may be varied from 10 mm to 1000 mm by moving the manual operated counter torque drive. The double-sided lever is supported by strain-controlled cross-hinges and wears on each end a strain-controlled mass-hinge to connect the masses. The masses are manually placed on one of the two scale pans, depending on the desired torque direction. The measured strain-sum of all hinges is scaled in unit “N·m” and indicated with a precision amplifier. The sensitivity is about 0,525 mV/V per N·m and the indicated resolution is **+/-** 0,00002 N·m. This enables to measure a torque of 2 N·m with a relative uncertainty of +/- $1 \cdot 10^{-5}$ ($k=2$).
With the hand-wheel on the counter torque drive the moment of the hinges will be adjusted to zero while loading. For this reason the influence of the lever support is negligible or the indicated very small value may be taken into account.

To avoid side forces and parasitic bending moments, the device under test is coupled to both the lever and the counter torque drive via elastic Rexnord-couples. For the lower torque range < 100 N·m some smaller couples will be added and the big couples were blocked.

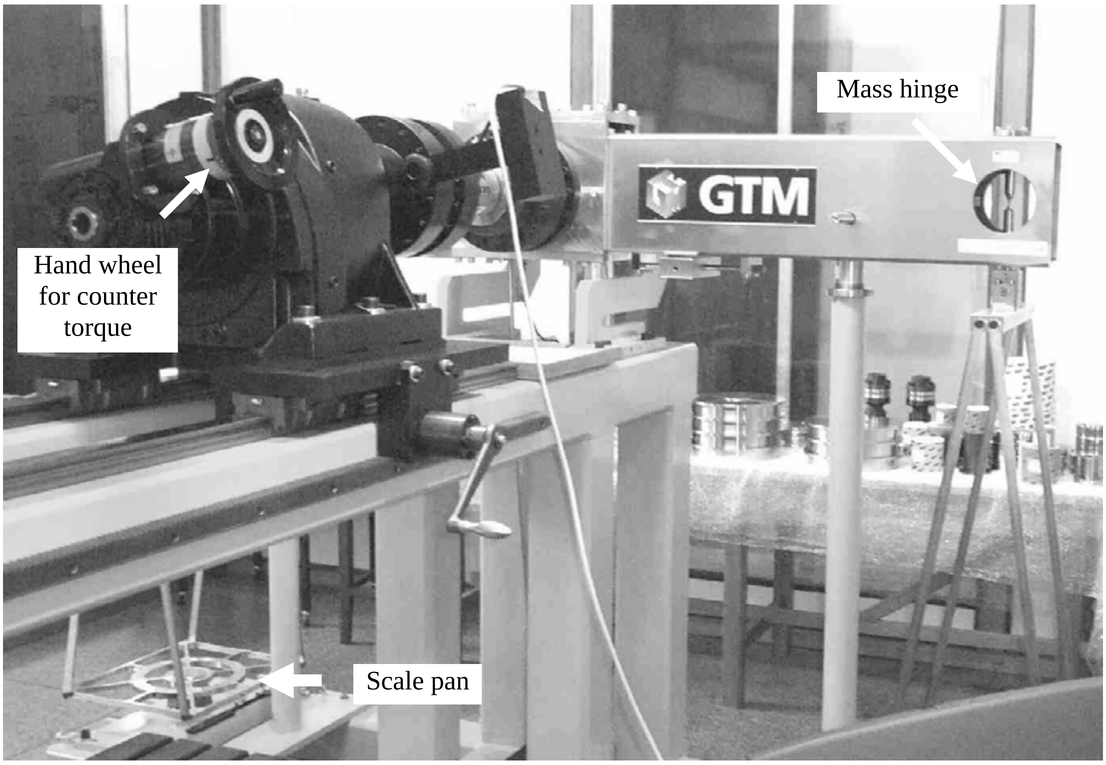

Figure 1: Torque Standard Machine 3000 N·m

3. LEVER ARM ADJUSTMENT

The lever length has been calibrated at a German DKD-laboratory. The distance between the two mass axes is 1999.995 mm with an uncertainty of 7 µm.

To achieve this exact value, an adjustment procedure was developed at GTM, particularly with regard to the fact, that GTM itself is not DKD-accredited in the physical quantity of length and has no high-tech measuring devices. A similar procedure was described in [2].

The mass-hinge thickness is 1 mm. The distance between the inner concave surfaces is about 1999 mm, the distance of the outer concave surfaces is about 2001 mm. To measure the real distance, GTM used a profile with two µm-indicating callipers on its ends. With this profile the mass-hinges were touched on each four points and the measured values were compared with gauge blocks of the desired length. Figure 2 shows the touching of the mass-hinge in one point. After calculating the real lever length, one mass-hinge was moved by usage of gauge blocks to adjust the length exactly.

The adjustment of the centre of the lever is checked with a balance test. This balance test can be performed by the operator at any time. So it is possible to have a monitoring of the lever ratio.

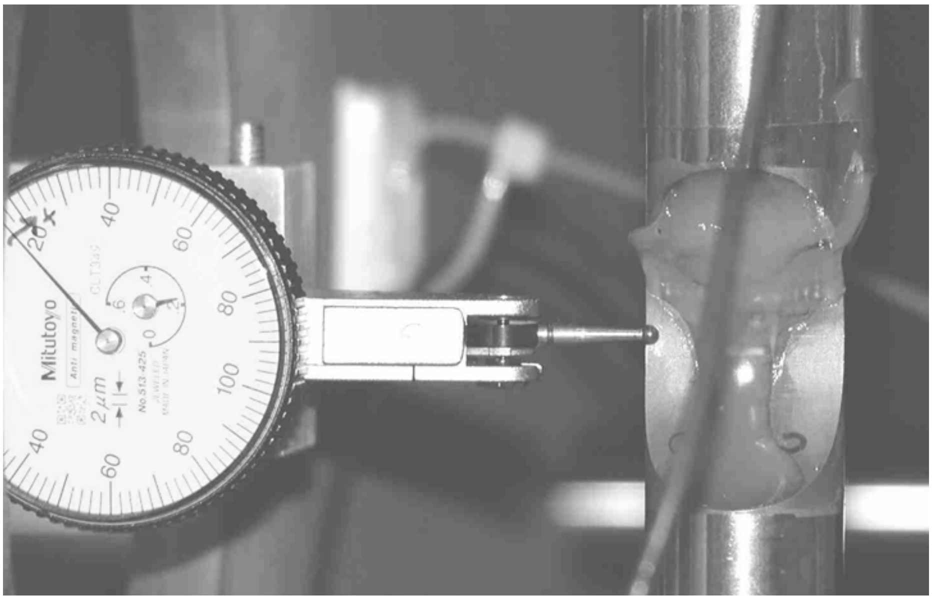

Figure 2: Adjustment of the lever length

4. AMBIENT UNCERTAINTY CONTRIBUTIONS

The following parameters make a contribution to the measurement uncertainty: masses, mass density, local gravity, lever length, lever support, temperature, air density, airflow, shocks and manual operation of the TSM. Some of the contributions are well known because of calibration results, e.g. the mass uncertainty. Others are estimated by additional tests, e.g. the influence of the air conditioning.

While commissioning it was detected, that the airflow in the lab is notable for the torque. To minimise the influence, a chamber was built around the TSM. The chamber works well on minimising the airflow, but some additional points must be considered. Before and during a calibration it is important to have the temperature variation in the chamber completely under control, as the lever length depends on this element. Therefore some parts of the chamber can be opened during the calibration, what generates no influence to the stability of the lever.

To avoid an undue influence, the mechanical end stops of the lever have to be adapted to the stiffness of the torque axis. With the use of this end stops there is no influence of the operator if he pushes the lever on the end stop. The quality of the load change sequence is equal to automatic load change systems.

Before starting a calibration, the sequence for changing the masses must be defined according to the range it will work. For example: while calibrating a 3000 N·m capacity transducer, the operator should have the last steps (after 2400 N·m) with masses of 100 N and not with masses of 200 N or 300 N, because the mass stack is higher and it is easier to operate with smaller masses on that height.

5. MEASUREMENT UNCERTAINTY

To verify the estimated uncertainty, the Standard Machine was calibrated with a set of torque transfer standards. The nominal values are 50 N·m, 100 N·m, 500 N·m, 1000 N·m and 5000 N·m. The transfer standards were calibrated according DIN 51309 and the best measurement capability was calculated considering the calibration results of German PTB according [3].

Figure 3 shows exemplary the calculated bmc of the clockwise torque in the range from 100 N·m to 3000 N·m. Both results, clockwise and anti-clockwise torque, are comparable in bmc and relative deviation. The relative uncertainty of the TSM is $1 \cdot 10^{-4}$ (k=2) in the range from 100 N·m to 3000 N·m.

Figure 4 and 5 show exemplary the deviations in intercomparison tests with PTB. In the range from 2 N·m to 2000 N·m the best measurement capability is in good accordance with the specified relative uncertainty of $1 \cdot 10^{-4}$ (k=2).

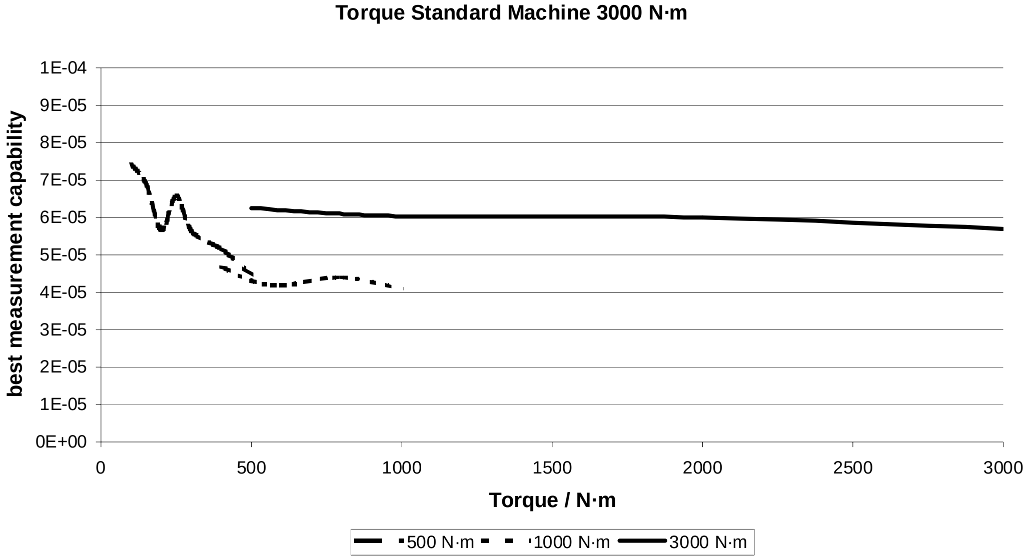

Figure 3: Calculated Best Measurement Capability

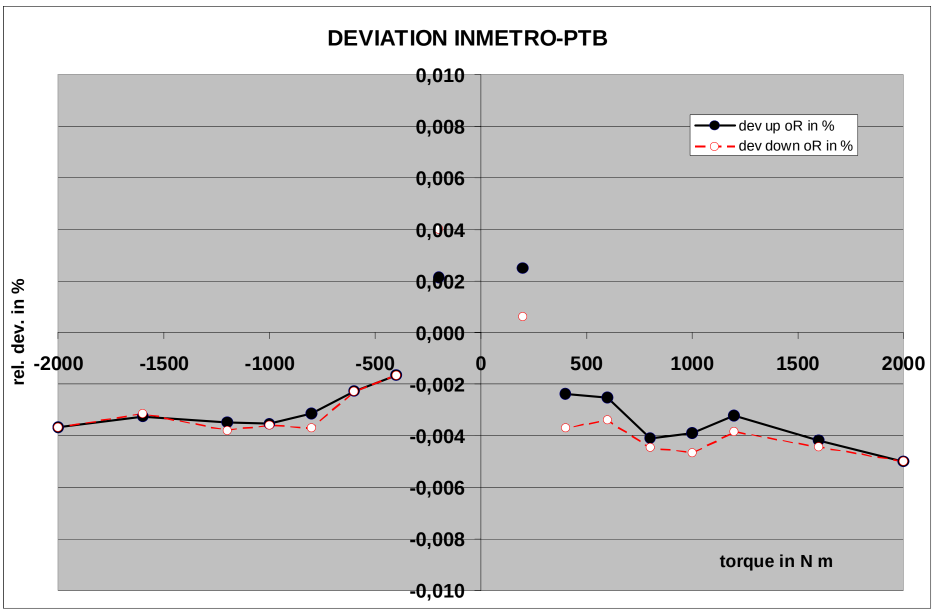

Figure 4: Relative deviation to PTB (range 2000 N·m)

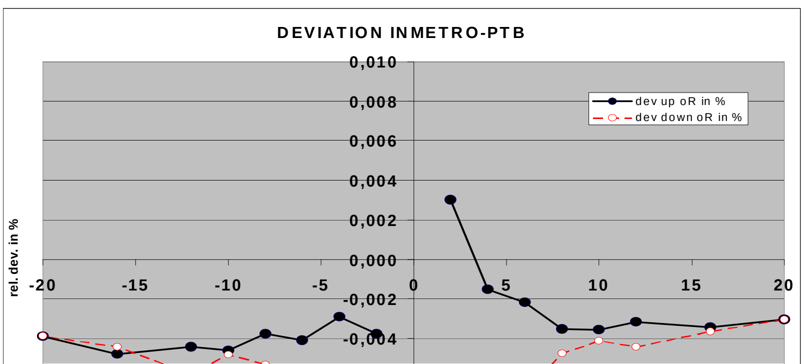

Figure 5: Relative deviation to PTB (range 20 N·m)

6. EXTENSION CONCEPT

Base frame, lever and counter torque as well as the coupling parts are constructed for a maximum load of 5000 N·m. If the torque situation in Brazil demands for higher torque than 3000 N·m, an upgrade of the masses will be realised.
First step in automating the standard machine may be a closed loop controller and an electric drive for the counter torque. At present the machine is operated with two persons, one for changing masses and the other to operate the counter torque. With an automated counter torque only one person can operate the machine.
An important point in traceability of torque is the possibility of calibrating torque transfer wrenches on the new torque standard machine. Side forces of considerable amount are working at torque wrenches. If these side forces are acting out of the measurement axis, a disturbing torque results and deviations of the applied and the indicated torque are detectable. For that, an extension of the standard machine will be used to bear the side forces without effect to the applied torque.

7. CONCLUSION

The improvement in the National primary torque standard with the reduction of the relative uncertainty to the limit of $1 \cdot 10^{-4}$ ($k=2$), reflects an improvement in the whole traceability of the torque unit in Brazil.
The implementation of the Torque Standard Machine in INMETRO's Torque Laboratory (LAFOR), provides a reference structure that allows to attend the metrological demands and needs of national industry, research centres and accredited laboratories, with higher accuracy and great reliability.
A compatible budget and possibility of upgrade for a higher range and automated operation made the decision of INMETRO in favour of this manual operated 3000 N·m TSM, with simple construction and high availability.

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