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# A PORTABLE SYSTEM FOR THE CALIBRATIONOF TRANSDUCERS AND TORQUE WRENCHES: THE CALIBRATION BELL

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**Abstract** – In the industry, in the assembling production lines, in mass production, very often are popular special dedicated systems, so-called ***calibration benches,*** with which it is possible to ensure the correct performance and calibration of production torque tools, pneumatic, electric or electronic power tools and torque wrenches. Most important problems are encountered during the transfer of the torque unit from the accredited laboratories to the industrial laboratories. For this purpose was designed a portable calibration system named ***Calibration Bell,*** particularly dedicated to calibration of torque transducers installed in the calibration benches of its production. In the paper the main metrological characteristics of these systems, evaluated during the assessment of the Calibration Centre are reported.

**Keywords:** torque, calibration, torque wrench

## 1. FOREWORD

In recent years we have observed a noticeable increase in the demand for torque measurements, for the extension of measurement ranges and for a reduction of measurement uncertainty: in other words, for an improvement of primary, secondary and transfer standards.

INRiM provides for traceability to the standards of mechanical, thermal and electrical quantities all over the country, so as to allow high-quality measurements and tests to be made.

At present the number of SIT centres is **194 in total, plus 24 for force and torque quantity** (load cell, testing machines, impact pendulum, torque, extensometer).

One of the most important activities of the National Accreditation Body (NAB) is the organisation of a series of comparisons (ILC), at the National level, to verify the measurements capability of the accredited laboratories.

The results of participating laboratories are evaluated against calibration results from pilot laboratory.

Most important problems are encountered during the transfer of the torque unit from the accredited laboratories to the industrial laboratories.

In the industry, in the assembling production lines, in mass production, very often are popular special dedicated systems, so-called ***calibration benches,*** with which it is possible to ensure the correct performance and calibration of production torque tools, pneumatic, electric or electronic power tools and torque wrenches.

The calibration benches, generally mobile with rechargeable batteries have various rotating torque transducers connected to rotating braking systems linked to a PC which simulate the behaviour of a real joint reproducing the stiffness from hard to soft.

Machine capability (Cm, Cmk) can be tested quickly and easily under real shop floor conditions without the need to run tests on the product on the line that would interfere with production.

This testing should be performed prior to using a tool in production. If the tool test is OK, and is placed in production, it should be periodically tested to make sure that it is performing correctly. If a tool is out of tolerance all the tightenings done before the test may be inaccurate. Keeping the tool under control avoids this situation.

Difficulties can arise in moving such equipment that needs to be calibrated to guarantee traceability of the measures.

Generally the use of calibration beams and dead weight are not fit for the purpose due to the difficulties of handling the calibration standard and for the fact that is not always possible the transducer's location with horizontal axis, unless than take them from the bench, operation not always possible or unsuitable.

Therefore the best solution will be a calibration device that uses as reference a series of reference transducer, with which to calibrate:

- torque transducers installed on calibration benches with vertical axis
- rotating torque transducers, as removable units from tightening equipments
- torque wrenches, mechanical and electronic

**Atlas Copco BLM** has designed for this purpose a portable calibration system named ***Calibration Bell,*** particularly dedicated to calibration of torque transducers installed in the calibration benches of its production, and that with appropriate accessories and adapters allows also the calibration of rotating transducers and torque wrenches of any type.

The system consists of a so-called ***bell*** which keeps inside a reference torque transducer mounted with hydraulic bushing and a two couplings to ensure the alignment of the connection to the transducer to be calibrate through

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appropriate adapters, operated by a gearbox that with an appropriate transmission ratio give to the operator the possibility to develop high torque with a minimum effort to the hand wheel.

For the direct calibration on the bench are available flanges of adaptation which allow to set the bell vertically on the drive of the transducers, generally arranged with a male square drive for the connection to power tools, and allow the reference transducer of the bell to be connected tanks to appropriate reductions and adapters.

The calibration bell has been designed in three different models, to cover the calibration range from 2 to 3000 Nm.

## 2. THE CALIBRATION BELL mod. 500

The main documents for the calibration and evaluation of the uncertainty of measurement are the references [2] and [12].

The calibration of torque transducers installed on calibration benches Atlas Copco BLM is performed with the method of comparison by the use of reference torque transducers (calibration bell).

The picture (Fig. 1) illustrates the calibration bell and its components: this is a specific equipment for the calibration of torque transducers mounted on calibration benches family models JSB (Joint Simulator Bench) and derived, by the use of reference transducers.

Particularly, to cover the needs of calibration for the most popular models in the market were foreseen four transducers (mod. TCR) of capacity respectively 15 – 50 – 250 – 500 Nm, provided with SIT certificates with an expanded uncertainty of measurement below to 0.1%.

In any case, also to keep account the operator uncertainty is assumed an expanded uncertainty of 0,2%.

Transducers are mounted into the bell for means of hydraulic bushings: alignment of the system to the transducer to calibrate is guaranteed by two couplings and by specific adaptor flanges used for connecting the calibration bell to the bench (Fig. 2).


Fig. 1. Calibration bell and its components (Serial 031): specific equipment for the calibration of torque transducers mounted on Atlas Copco BLM JSB benches by the use of reference transducers.

Torque transducers mounted on Atlas Copco BLM calibration benches are normally used only for increasing torque. *For this reason only some of the directions contained in EA-10/14 for static torque devices are considered valid and applicable*: particularly the chapter 4.4.2 related to various position of the transducer (usually is controlled only the position at 0°) and is not included the evaluation of the hysteresis.

The procedure can be used for the calibration of other types of transducers, provided that it is possible to install an element of support of the calibration bell (connecting flange) for allowing the application of torque to the transducer in calibration in coaxial way and therefore without introducing to measurement uncertainties not quantifiable.

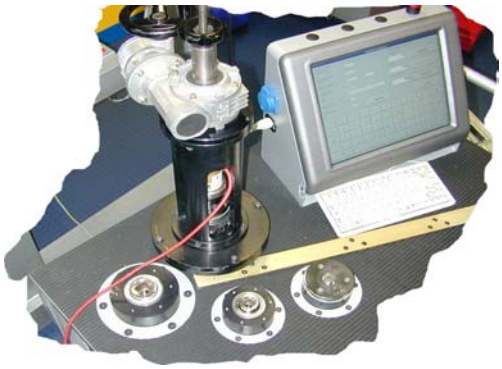

Fig. 2. Example of calibration bell mounted on a bench using a connecting flange.

The analysis of uncertainty as stated in the procedure was carried out by assessing the more significant contributions. The contributions of type A are determined by means of tests experimental. The contributions of Type B are determined on the basis of technical information on the band of uncertainty of the instruments used.

To check the metrological characteristics of the calibration bell was carried out the calibration of a reference transducer (mod. TCR) of capacity 250 Nm using the first line calibration bench of the SIT Laboratory (Fig. 3), equipped with air bearing and with uncertainty of 0.01%.

For installation of the transducer on calibration bench have been used the same couplings and the same ETP bushings and adapters used in combination with the calibration bell.

The transducer was linked to his amplifier mod. MP-10 S/N 6123-2004, 200.000 division readings.

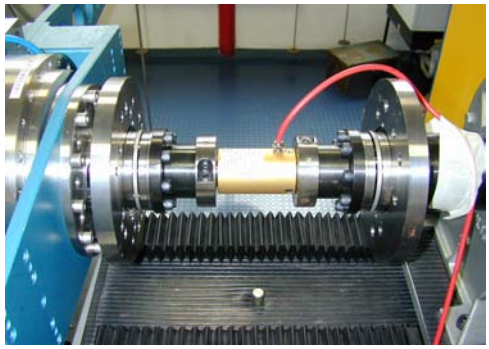

Fig. 3. The transducer mounted directly on first line calibration bench, using the joints and adapters of the bell.

The calibration of the reference transducer was repeated by using the calibration bell BLM mounted on special adapter assembled directly in the calibration bench.

Before mounting the bell it was verified the perfect alignment of axes and only after this control the bell was fitted, coupling the reference transducer to the bench with the same square drive which will be used during the calibrations procedures.

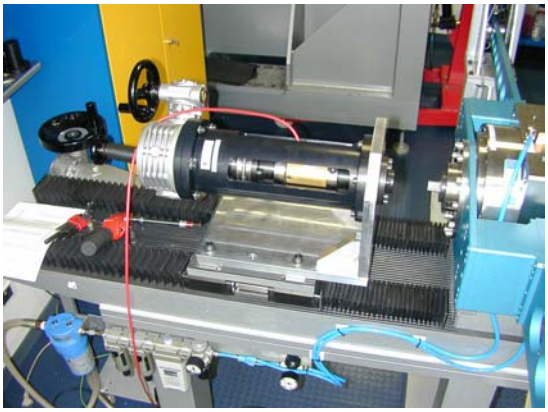

Fig. 4. Calibration bell mounted on first line calibration bench using the special adaptor.

A summary of the results of the experimental verification are reported in table. 1.

The differences between the tests carried out during the experimental verification directly using the first line calibration bench or through the calibration bell, are largely within the tolerances required by the guidelines EA-10/14 for the evaluation of transducers in class 1.

The permissible deviation between the torque value read on the indicator using the first line bench and the values determined with the use of the calibration bell result less than 0, 2% (table 1).

Table 1

| Applied torque on test bech Nm | Readings MP10 Nm Test 1 | Test 2 | Test 3 | Average Nm | Deviation Nm | % |
|---|---|---|---|---|---|---|
| 0 | 0,000 | 0,000 | 0,000 | 0,0000 | 0,0000 | - |
| 25 | 24,984 | 24,982 | 24,981 | 24,9823 | -0,0177 | -0,071 |
| 50 | 49,974 | 49,972 | 49,973 | 49,9730 | -0,0270 | -0,054 |
| 100 | 99,977 | 99,976 | 99,977 | 99,9767 | -0,0233 | -0,023 |
| 150 | 150,002 | 150,001 | 150,002 | 150,0017 | 0,0017 | 0,001 |
| 200 | 200,045 | 200,043 | 200,048 | 200,0453 | 0,0453 | 0,023 |
| 250 | 250,098 | 250,099 | 250,102 | 250,0997 | 0,0997 | 0,040 |

In the present paper the main results obtained for the calibration bell up to 500 Nm during the comparison are discussed, in particular the differences on the repeatability and accuracy given are compared and evaluated.

The results obtained were evaluated using the En number according to the EA guideline and ISO 43

$$E_n = \frac{|C_1 - C_2|}{\sqrt{U_1^2 + U_2^2}}$$

The compatibility index is defined as:

where $C_1$ = torque values given by the reference transducer calibrated directly on the first line calibration bench

$C_2$ = torque values given by the reference transducer calibrated directly on the first line calibration bench using the calibration bell

$U_1$ = uncertainty of first line calibration bench (0,01 %)

$U_2$ = uncertainty declared by the SIT Centre No.59 (≤ 0,2%) for the use of calibration bell based on reference norms fort the calibration of torque transducers

The compatibility index results $\mathbf{E_n \leq 0,3}$ for every calibration points.

## 3. THE CALIBRATION BELL mod. 2000

Calibration benches up to 500 Nm are the most popular in mechanic industries and represent approx. 80% of standard use.

In heavy mechanical industries, for example, manufacturers of bus, trucks, ground moving machinery, are required tightening torques very high, often up to 2000 Nm: these high tightening torques are obtained by means of electrical, pneumatic or hydraulic power tools, which must be constantly monitored to verify their performances or deviations from the calibration values for a possible adjustment.

Especially in similar cases where, in general, the equipments are difficult to handle, it is very useful a mobile calibration bench that allows the calibration of these power tools directly in the workstation.

The calibration benches series BLM joint simulator are equipped with hydraulic joint simulators driven by PC which can simulate with very high precision the behavior of a bolt tightened up to 2000 Nm.

The torque and angle measures are carried out through rotating torque and angle transducers integrated in the various brakes-joint simulators on the bench that give through strain gauges an electrical signal proportional to the measured torque.

The torque transducers on the benches must be subjected to regular calibration directly on the line of production, possible thanks to a model of calibration bell that allows the calibration up to torques of 2000 Nm.

This bell, conceptually similar to the model 500 illustrated in Fig. 1, use two transducers with full scale respectively 1000 and 2000 Nm and is used in the range 200 – 2000 Nm with extended uncertainty contained within 0.2% of the measures (Fig. 5).

The couplings, hydraulic bushes and the gear box of this model of calibration bell are largely designed to apply in safety, and without fatigue the torque steps of the calibration procedure: the reference transducers (mod. TCR) are calibrated on calibration bench in our SIT Calibration Centre with an expanded uncertainty less than 0, 1% of the readings.

Fig. 5. Calibration bell mod. 2000.

Generally the bell is mounted directly on the bench, in line with the transducer to calibrate, using specific anchorage points for that purpose. If necessary, may be used appropriate adaptors flanges for assembling in cases out of standard.

Fig. 6 is an example of calibration using the 2000 Nm calibration bell.

Fig. 6. Calibration bell 2000 mounted on a bench for calibration

## 4. CALIBRATION BELL FOR TORQUE TRANSDUCERS

Both bells models 500 and 2000 can be equipped with a small bell extension with which it is possible the calibration of rotating transducers. Fig. 7 is a schematic for this application.

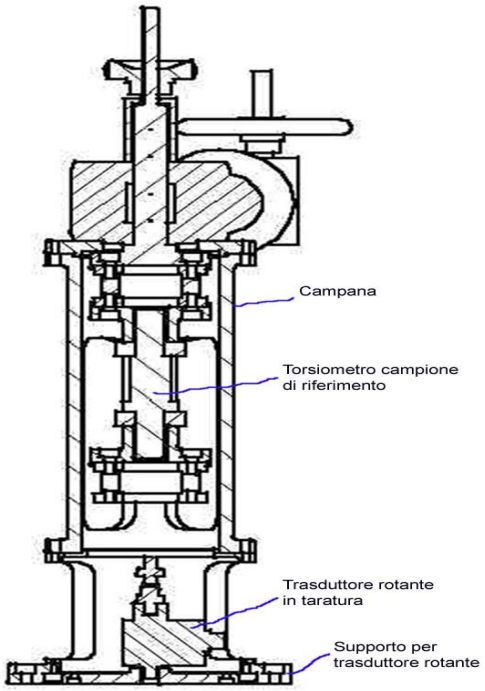


Fig. 7: Schematic of calibration for rotating torque transducers.

Torque transducers generally have a square drive (or exagon 1/4" for the smaller models, up to 25 Nm). The lower bell extension is provided with a female square flange where it is possible mounting various square or exagon adapter for the different transducer's driver size.

A set of adapters is provided giving the possibility to calibrate various models from different manufacturers.

## 5. CALIBRATION BELL FOR TORQUE WRENCHES

A particular use of the calibration bells is the calibration of torque wrenches to the norm ISO 6789. To this purpose have been provided specific adapters that allow to mount the bells to a support that keeps the bell with horizontal axis and allows you to mount the torque wrench to calibrate in vertical position, as required by ISO 6789.

Given the presence of ball bearings in the adapter, which have the task of absorbing the components lateral forces that occur when to the torque wrench the torque is applied, the expanded uncertainty is considered to be 0,5% of the measures, largely in the limits of ISO, expected in 1% max.

Fig. 8 shows how to proceed for the calibration of a torque wrench using the bell mod. 500.

Fig. 8. Calibration of torque wrench

The torque necessary to rotate the handle is very low: calibration is made comparing the readings on the reference display with the readings on the wrench under calibration.

## 6. CONCLUSIONS

A system for the calibration of portable transducers and torque wrenches has been described, a system simple, practical and versatile that allows the calibration under shop floor conditions with a good accuracy. Many Calibration Centers or Industrial Laboratories over the world are equipped with such equipment ensuring to customers the maintenance under control of their systems of torque measurement.

The most important cars manufacturers have chosen to be equipped with Atlas Copco calibration benches in different versions suitable to their specific needs: this benches are regularly subjected to calibration of transducers installed to guarantee the quality in torque tightening.

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