

DESIGN, DEVELOPMENT AND ESTABLISHMENT OF 1 kN FORCE CALIBRATION MACHINE IN FORCE LABORATORY OF TSE

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Abstract – A new dead weight type force calibration machine with a 1 kN loading capacity both in tension and compression is installed both in force laboratory of UME and TSE. This paper describes the preliminary results of the performance of the newly developed 1 kN dead weight force machine at the Force Laboratory. The machine is designed and manufactured by UME. The performance test results show that relative reproducibility error with rotation (b) $\pm 5,5 \times 10^{-3}$ and relative repeatability error without rotation (b') $\pm 3,5 \times 10^{-3}$ for a range of 0,2 kN to 1 kN of a new 1 kN machine of TSE.

Keywords: force calibration machine, dead weight, performance test

1. INTRODUCTION

Standard forces are obtained fundamentally on the base of static force measurement principle, corresponding to Newton's 2nd law ($F=m.g$). In most of the National metrology laboratories the generation and realization of forces with highest possible accuracy are made by the application of the dead weights under the influence of local gravitational field. A dead weight force-generating machine provides a convenient means of selection and application of precisely known static forces in the form of dead weights directly on the force-measuring device (i.e. proving rings, dynamometers, load cells, force transducers) being calibrated. There are different type force calibration machines: dead weights, hydraulic amplification, lever amplification and multiple transducer system.

In order to make precise and accurate force measurements using force measuring instruments are needed to calibrate them with high accuracy or with low measurement uncertainty. Force calibration machines developed for this purpose are the most important system to perform accurate and reliable measurement of the force-measuring devices.

Aim of this project, the force calibration machines will be designed and developed by UME (National Metrology Institute of Turkey) for the Calibration Center of TSE (Turkish Standardization Institute). TSE Calibration Center will establish traceability chain for the derived force unit in SI system. This will be the second chain of force standards after primary standards at UME in our country. This project is funded by 111G062 coded project by TUBITAK (Turkish Scientific and Research Council of Turkey).

In this study, a new 1 kN machine is described shortly and the pre performance test results realized by UME are given briefly.

2. DESCRIPTION OF THE MACHINE

The most important and needed specification of the force calibration machines is having an automatic load selection and application mechanism applying defined forces on the force measuring devices for the calibration process.

The procedure for calibration of force measuring device is based on ISO 376:2011 standard (Figure 1). The procedure includes the following steps:

- The digital indicator is switched on for 30 min. The no-load output (before taring) and the calibration signal are noted.
- Before application of the calibration forces, the force transfer standard is preloaded three times to its maximum capacity and kept at full load for 60 sec.
- Calibration is carried out by applying two series of calibration forces in ascending order at initial position, considered 0° (series 1 and 2).
- Two series of calibration forces have been applied at rotation positions 120° and 240° (series 3 and 4).
- The force transducer is subjected to the full load once for about 60 sec ants time before starting the calibration to the new position.
- Between the loadings, readings corresponding to no load after waiting at least 30 sec for the return to zero are noted.

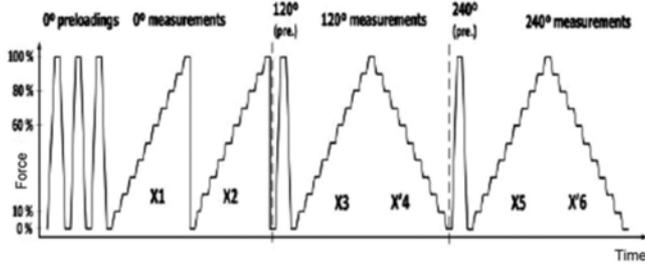


Figure 1. Schematic calibration procedure.

The 1 kN capacity dead weight force calibration machines should be designed specially according to their function. The careful design work is necessary for the masses and its selection mechanism for limitation of masses against swinging, preventing them hitting and touching to each other, protecting them from air flows and magnetic fields. Avoidance of as such is required for repeatable results.

The 1 kN capacity dead weight force calibration machines is developed and manufactured with computer controlled. These systems will be “solution-oriented” developments according to the needs of TSE and will be designed and manufactured by the knowledge and experience of UME.

Automation software is allow flexibility to do step by step and continuous calibration, rapid loading and unloading conditions of force measuring instruments, making creep tests. The software is suitable for automatic calibration without attendance of a person according to world needed conditions in the year of 2011 and beyond.

3. PERFORMANCE TEST

The comparison measurements for performance test were made to determine the relative deviations between the various forces realized by TUBITAK-UME and TSE. For this measurements, 1 kN force transducer belonging to TUBITAK-UME were used in the comparison. The purpose of the performance test is to determine repeatable load application capability and mass contacts during loading and unloading of the machine.

The measurement procedure for performing the comparison measurements is described as below.

The 1 kN capacity of GTM force transducer was used as force transfer standard in this preliminary performance tests.

Before starting each measurement, the indicating instruments used in comparison, model DMP 40, were calibrated by calibrator, model BN 100.

All weights of TSE machine were calibrated to UME Mass laboratory with 5×10^{-6} measurement uncertainties.

To minimize the effect of creep, it was taken that 1 minute time delay between the initiation of the loading (or unloading) and the actual reading is adequate. However, after the force transducer is loaded or unloaded, some drifts due to mechanical, thermal and electrical effects may occur in the output of the transducer for longer time.

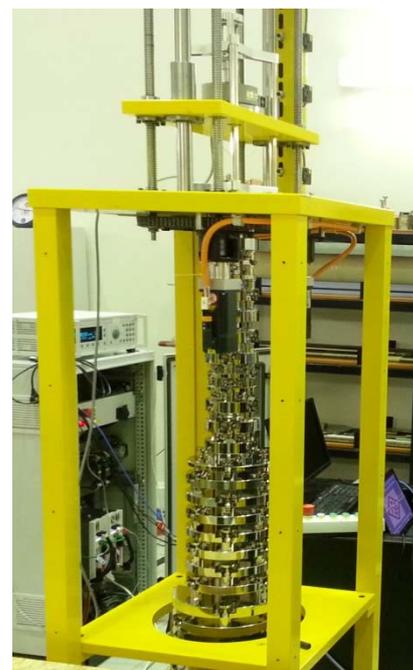
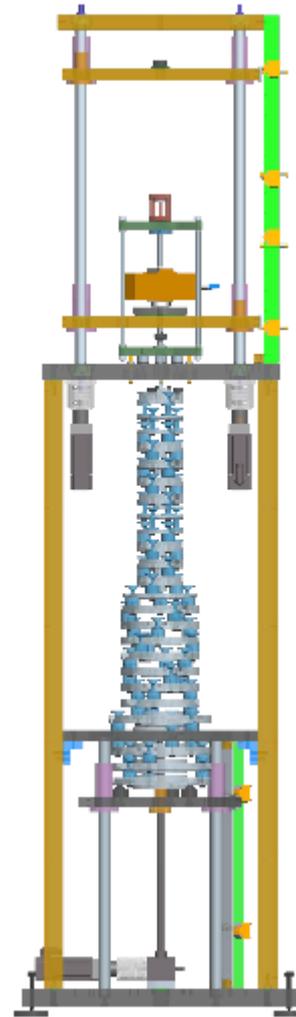


Figure 2. 1 kN dead weight machine figure

Machine-transducer interactions can significantly influence measurement accuracy. To minimize the errors due to these non-axial components of deformation, the response of each force transducer was obtained at five symmetrically distributed positions relative to the axis of the machine (0°, 90°, 180°, 270°, 360°). In order to get better results, prior to start of a measurement cycle, the force transducer was loaded with maximum test load three times at the 0° position. Measurements took each position two series.

The performance test was performed in five force steps that are 0,2, 0,4, 0,6, 0,8 and 1 kN. The reason for the selection of five steps is that all weights are included to these weight steps. The detailed performance test will be carried out later between UME and TSE.

All measurements were carried out at laboratory conditions a temperature range of (±1) °C and relative humidity (±10) %.

4. MEASUREMENT RESULTS

As stated before, UME was selected as a pilot laboratory. That's why the force transducer was measured first at UME. These measurements were followed by measurements performed at TSE.

Performance tests performed to compare rotation effect, repeatability and hysteresis errors of 1 kN UME force transducer measured at UME and TSE machines.

11 kN UME dead weight machine established at UME Force Laboratory in 1995. There are a lot of intercomparison measurements. The best measurement uncertainty was achieved with dead weight force standard machine in the level of between ± 1 and 4·10⁻⁵. [1,5]. Dead weight force standard machines exhibit approx. ± 5·10⁻⁵ relative deviations from PTB machine in international comparison measurements which have a theoretical uncertainty on the order of ± 2·10⁻⁵ [2].

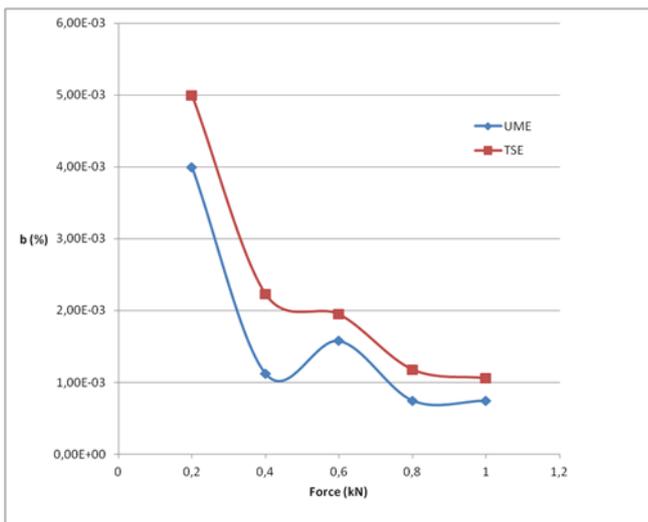


Fig.3 Comparison graphs of relative reproducibility error with rotation (b)

Figure 3 shows the comparison graphs of relative reproducibility error with rotation (b) of 1 kN UME force transfer transducer measured at UME and TSE. Its errors were seen very close to each other in this figure.

In the Figure 4, relative repeatability error without rotation (b') of 1 kN UME force transfer transducer measured at UME and TSE. Its errors were seen very close to each other in figure 4.

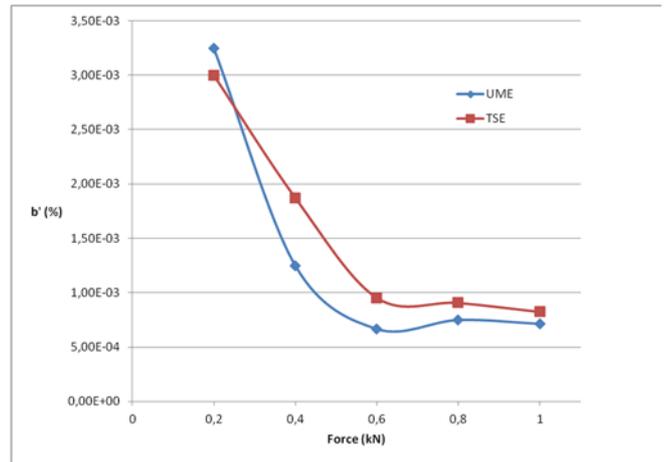


Fig.4 Comparison graphs of relative repeatability error without rotation (b')

4. CONCLUSIONS

The repeatability error and reproducibility error of 1 kN UME transfer transducer measured by the UME force standard machines over a range of 0,2 kN to 1 kN was compared with TSE force machine. The results of comparison show that the agreement between UME 11 kN dead weight force standard machine and TSE 1 kN dead weight machine is better than ± 5,5 x 10⁻³ for relative reproducibility error with rotation (b) and ± 3,5 x 10⁻³ for relative repeatability error without rotation (b') over a range of 0,2 kN to 1 kN. This range is in the error band of class '00' force instruments according to ISO 376.

As a result of TSE 1 kN capacity dead weight calibration machine can be used in the calibration of class '00' force proving instruments according to ISO 376 international standards

ACKNOWLEDGMENTS

1 kN force standard machine project is funded by 111G062 coded project by TUBITAK (Turkish Scientific and Research Council of Turkey).

During the design, manufacturing, montage, automation system and software of the machine, we would like to thank all colleagues working at UME and at TSE.

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