BIPM Capacity Building & Knowledge Transfer Programmed
2021 BIPM - TÜBİTAK UME Project Placement
Report

Project Name	Establishment of a force laboratory at the Ethiopian National Metrology Institute (NMIE) and this laboratory's primary traceability service in the field of force metrology
Description	The aim of this Project is to understand the system required to carry out accredited calibration service of force proving instruments using force standard machines, and to published the NMIE force standard machine's CMC in KCDB data base
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Motivation and Introduction

National metrology Institute of Ethiopia ordered different force standard machine from the supplier GTM to expand the scope of force calibration and planned to establish new Force Laboratory and serving Traceability at the Primary Level in the Field of Force Metrology in Ethiopia in the coming years. So the main objective of this Project is to understand the system required to carry out calibration of force proving instruments using force standard machines, to prepare uncertainty budget, Skills development to perform accredited force calibration and to publishes the NMIE force standard machine's CMC in KCDB data base

Research

My project focus theoretical and practical training on international standards ISO 376:2011:- calibration of force-proving instruments used for the static verification of uniaxial testing machines (e.g. tension/compression testing machines), ISO 7500-1:2018: Part 1:- Calibration and verification of the force-measuring system and EURAMET Calibration Guide No.4:-Guidelines on the Uncertainty of Force Measurements. Here below the activities and the results explained one by one.

1. **ISO 376:2011: calibration of force-proving instruments used for the static verification of uniaxial testing machines**

Here for my project I used an international standards as reference ISO 376:2011 (fourth edition) was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*. An ISO/TC 164/SC 1 working group has developed procedures for determining the measurement uncertainty of force-proving instruments, and these procedures have been added to this fourth edition as a new annex (Annex C).

This International Standard specifies a method for the calibration of force-proving instruments used for the static verification of uniaxial testing machines (e.g. tension/compression testing machines) and describes a procedure for the classification of these instruments.

TÜBİTAK UME Force laboratory provided training on how to calibrate force proving instruments according to ISO 376:2011. After the training 20kN force proving instrument taken for calibration and one day is given for the force-proving instrument to attain a stable temperature.

For the determination of the interpolation curve, eleven discrete forces was taken, and these forces are distributed uniformly over the calibration range and according to ISO 376 calibration procedures data is taken step by step

Step 1 before the calibration forces are applied, in a compression mode, the maximum force applied to the instrument three times and the value were recorded on the data sheet (preloading data)

Step 2 the data were recorded by applying two series of calibration forces to the force-proving instrument at 0°positions with increasing values only.

Step 3 Rotated the force-proving instrument symmetrically on its axis to positions 120° then maximum force is applied to the instrument as preloaded and increasing and decreasing force value were recorded.

Step 4 Finally rotate the force-proving instrument symmetrically on its axis to positions 240° then maximum force applied to the instrument as preloaded and increasing and decreasing force value were recorded. And the temperature was recorded before and after calibration.

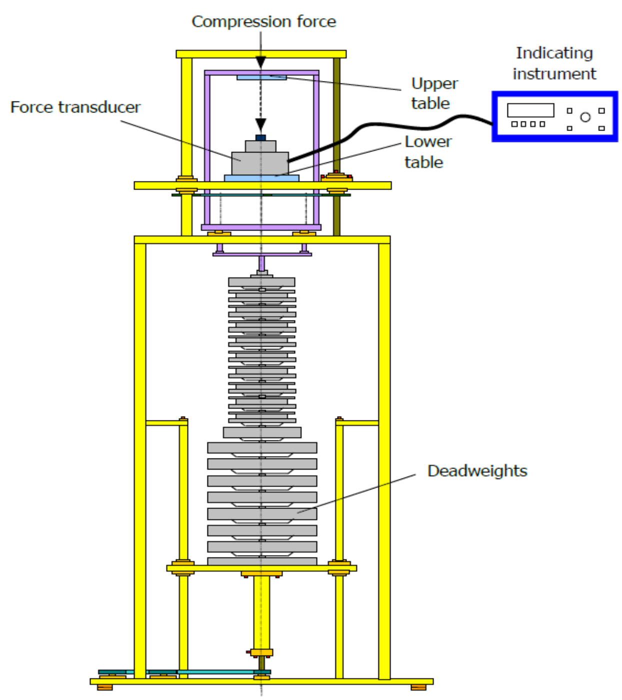

Figure 1 Typical deadweight force standard machine

After the data collected I have developed excel sheet for the calculation of uncertainties and relative errors according to ISO-376 and the excel sheet is approved by the TUBTAK UME force laboratory. By using this excel sheet Relative reproducibility and repeatability errors, *b* and *b*′, Relative interpolation error, *f*c, Relative zero error, *f*0, Relative reversibility error, *v and* Relative creep error, *c were calculated for the* Classification of the force-proving instrument according to Classification criteria. And relative standard uncertainty associated with applied calibration force, w_1 ; reproducibility of calibration results, w_2; repeatability of calibration results, w_3; resolution of indicator, w_4; creep of instrument, w_5; the drift in the zero output,w_6; the temperature of the instrument,w_7; and interpolation,w_8 were calculated by using the excel. Finally I compered the result with TUBTAK UME force laboratory and it is with in the accuracy.

2. **ISO 7500-1:2018: Part 1: Tension/compression testing machines - Calibration and verification of the force-measuring system.**

Here I used an international standard ISO 7500-1:2018 as reference. This document specifies the calibration and verification of tension/compression testing machines. After theoretical training one universal strength testing machines its capacity 250KN calibrated according to the ISO 7500-1 calibration procedures. For the calibration I used 200KN Load cell as reference and one day is given for the force-proving instrument to attain a stable temperature near to the testing machines and calibration data is taken step by step.

Step 1 mounted the force-proving instruments in the machine in such a way as to minimize any effects of bending

Step 2 the force-proving instrument in position 0° in the machine preloaded three times between zero and the maximum force to be measured (200kN) and one series of measurements data with increasing force taken approximately equal intervals between 20kN and 200kN.

Step 3 the force-proving instrument rotated through an angle of 120° and preloaded then one series of measurements data with increasing force taken

Step 4 the force-proving instrument rotated through an angle of 240° and preloaded then one series of measurements data with increasing force and one series of measurements data with decreasing force taken And the temperature has been recorded before and after calibration.

After the data collected I have developed excel sheet for the calculation of uncertainties and relative errors and the excel sheet is approved by the TUBTAK UME force laboratory.

By The help of this excel sheet for each discrete force, the relative indication error, the relative repeatability error, the relative zero error, the relative resolution error and the relative reversibility error, in addition to this uncertainty, of the force-measuring system of the testing machine calculated. Finally I compered the result with TUBTAK UME force laboratory and it is with in the accuracy.

3. **EURAMET Calibration Guide No.4:-Guidelines on the Uncertainty of Force Measurements**

This document was developed by the EURAMET e.V., Technical Committee for Mass and Related Quantities and produced to enhance the equivalence and mutual recognition of calibration results obtained by laboratories performing calibrations in the field of force.

I used this document to estimate the force measurement uncertainty in common types of force standard machines, namely, deadweight, hydraulic amplification, lever amplification, reference (single or multiple) transducer system.

Deadweight force standard machines

I used the model equation given below to estimate the uncertainty of the force generated by 1kN deadweight force standard machines.

$$F = mg(1 - \frac{\rho_a}{\rho_m})$$

Each uncertainty contribution from Calibration of mass m, Local gravitational acceleration, g, Density of deadweights, ρ_m and Density of air ρ_a combined to calculate the standard uncertainty.

Lever amplification force standard machines

In a lever amplification machine, 110kN deadweight force is amplified by the use of one mechanical lever systems, increasing the force by a factor approximately equal to the ratio of the lever arm lengths Here I used the model equations given below to estimate the uncertainty of the force generated by the lever amplification machine its capacity equal to 1100kN.

$$F = mg\left(1 - \frac{\rho_a}{\rho_m}\right)\frac{L_1}{L_2} + \frac{M_b}{L_2}$$

In this the uncertainty components are Calibration of mass, local gravitational acceleration, Density of deadweights, Density of air, Lever ratio (Dead weight side), Lever ratio (Lever side), elastic distortion of lever system, Instability of control system, Alignment and Response sensitivity of lever system. I used these uncertainty contributions to calculate the standard uncertainty.

Reference transducer system force standard machines

This machine is based on three reference force transducers each 1MN that have previously been individually calibrated in lever amplification force standard machine in force laboratory. These reference transducers are then loaded in parallel as a build-up system and in series with the instrument being calibrated. The generated force is calculated as the sum of the forces being measured by the individual transducers that is equal to 3MN.

For this machine, the uncertainty contributions that I used to calculate the standard uncertainty are the following: Calibrations of the individual transducers, use of transducers subsequent to their calibration, Alignment of transducers with the measuring axis of the transducer under calibration and stability/performance of control system.

Conclusions and future work

Participation in this project permitted me to build capacity and knowledge on calibration of force proving instruments by using force standards machines (primary standards), calibration of material testing machines by force proving instruments and to evaluation its uncertainty in addition to this estimate the force measurement uncertainty in force standard machines. These knowledge and skills will assist me to serving Traceability at the Primary Level in the Field of Force Metrology in Ethiopia and to produce a project plan to participate in an inter laboratory comparison and to register CMCs in KCDB data base.

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