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A NEW 200 N DEAD WEIGHT FORCE STANDARD MACHINE

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Abstract – In this paper, newly developed 200 N capacity dead weight force standard machine which is established at UME and TSE will be summarized. The 3 different mass stacks are used for calibrating the force-proving instruments together with 3 different loading frames. In the first mass stack, there are two force ranges which are 10 N and 20 N. In the second mass stack, there is only one force range is 50 N and the last one, there are also 2 force ranges are 100 N and 200 N. Each loading frame generates the first force step. This machine is developed as computer controlled system for automatic calibration. Each force range is generated by 10 steps loading and has an additional mass for 110 % overloading test. The main advantage of this machine is that it has newly developed hanging and centering mechanism during both loading and unloading process of the masses. The measurement uncertainty of both systems is 5 x 10^{-5} which can be achieved theoretically.

Keywords: dead weight, force standard machine, mass stack

1. BASIC INFORMATION

The force proving instruments which are force transducers, dynamometers, load cells, proving rings are widely used in many industries for the measurement of force or weights and also for control process. For the reliable measurement they should be calibrated according to ISO 376 by known forces. The well known and high accurate forces are generated by the action of gravity on the weights with an air buoyancy correction in field of primary force metrology. This type of system is called dead weight force standard machines (FSMs) [1-2].

A newly developed 200 N capacity dead weight force standard is completely computer controlled system and has 5 different force ranges with 3 different weight stacks are 10 N, 20 N, 50 N, 100 N and 200 N and each one has 10 force steps and 3 loading frames to obtain for first force step with 10 % increment. At the same time, additional masses in each force range satisfy the 110% force for overloading test. All masses are capable be to canter with each other due to special design. The mass stacks and generating force values are given in Table 2.

The new 200 N dead weight force standard/calibration machine is developed both National Metrology Institute (TUBITAK UME) of Turkey and Calibration Canter of Turkish Standardization Institute (TSE) of Turkey. Ths machine has been developed in the scope of 1007 TUBITAK project. It name is "Design, development and establishment of force calibration machines in the range of 10 N to 100 kN" and Project no is 1007 KAMAG-111G062.

2. 200 N DEAD WEIGHT FORCE MACHINE

This machine covers 10 N, 20 N, 50 N, 100 N and 200 N force ranges with 3 mass stacks. Each range has also 10 steps and has an additional mass for overloading test. Three separate loading frames generate the first force values of related force ranges. The first frame generates 1 N force value of 10 N ranges. The second one generates 5 N force values of 50 N ranges and the last frame generates 10 N force of 100 N ranges. These machines include the quick loading and unloading to apply creep test according to ISO 376. The characteristics of the developed 200 N FSM is given in Table 1.

Table 1. Characteristics of the 200 N dead weight FSM

Type of force generation	Dead weight
Rated Capacity	200 N
Force Ranges (each one have 10 step with 10 % increment)	10 N 20 N 50 N 100 N 200 N
Compr. Space (vertical)	100-500 mm for diff.pans
Tension space (vertical)	200-500 mm for diff. Pans
Quality of masses	Stainless steel
Operating	Manuel and PC Controlled

This machine can be operated both manually and automatically depending upon the operator's decision. In any

case movement of table is driven by electrical motors. In case of undesired mass contacts between the masses in weight stacks occur during loading and loading processes, the lamp indicates this error. Undesired movement of the lifting table and crosshead is limited by limit switches to protect the machine from damage.

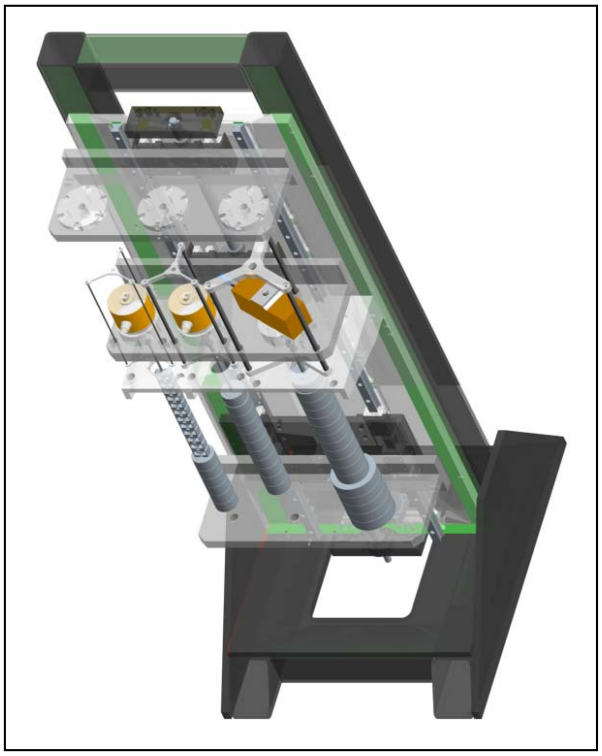


Fig. 1. General view of 200 N dead weight FSM

All masses are in the shape of circular discs and are hanged up to each other by means of newly developed hanging system. The advantage of this system is exact centering of masses during hanging to each other and also during collecting the masses. This causes less oscillation of masses during calibrations because of eccentricity protection.

Fig. 2. The mass stacks of 200 N dead weight FSM

The mass stacks of 200 N dead weight FSM is shown in Figure 2. Lifting table moves in the direction of up and down with a servo controlled screw mechanism. After the selection of the applied force value on computer screen, the lifting table moves down and first weight hangs up to the loading frame and other weights hang up to each other step by step.

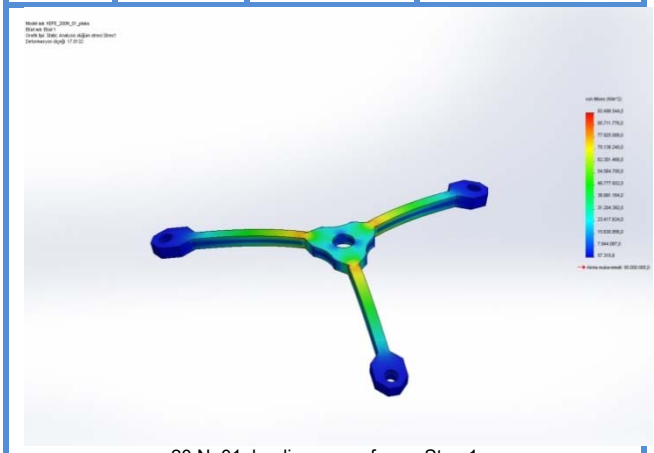
Table 2. Generated force ranges of the dead weight machine

	Force capacities of each force ranges				
Force steps	**10 N**	**20 N**	**50 N**	**100 N**	**200 N**
1	1	2	5	10	20
2	2	4	10	20	40
3	3	6	15	30	60
4	4	8	20	40	80
5	5	10	25	50	100
6	6	12	30	60	120
7	7	14	35	70	140
8	8	16	40	80	160
9	9	18	45	90	180
10	10	20	50	100	200
11	11	22	55	110	220

The critical parts which are the upper parts of the loadig frames have been analysed using FEM (Finite Element Method). After designing the loading frames, all upper and lower parts of each frame have been analyzed. The analysis of the upper part of the 20 N loading frame is given in Figure 3.

Fig. 3. FEM analysis of the upper part of 20 N loading frame

Name	**Type**	**Min**	**Max**
Stress1	VON: von Mises Stresi	57318.6 N/m^2 Mesh: 7369	9.34985e+007 N/m^2 Mesh: 283



20 N_01_loading upper frame-Stres1

Three Loading frames having a nominal value of 1 N, 5 N and 20 N bears directly on the instrument being calibrated and realizes first step of force. All weights are positioned over the lifting table during unloading position. In this stage, it is also possible to hang all or selected weight stack in unload position for the purpose of creep test. After hanging the selected weight stack on loading frame, quick loading and unloading is possible for creep test by means of moving upper and lower cross heads in tension and compression

respectively. The photo of the loading frames is shown in Figure 4.

Fig. 4. The loading frames of 200 N dead weight FSM

3. PERFORMANCE TEST

The measurement procedure is applied during the performance test of the machine is similar to calibration of force proving instrument according to ISO 376 standard for the comparison of dead weight force standard machines. The purpose of the performance test is to determine friction and mass contacts during loading and unloading of the machine. Normally machine produces the loads by direct application of dead weights on the load cell. All weights were calibrated to UME Mass laboratory with 5 $x10^{-6}$ measurement uncertainties.

A 200 N capacity dead weight calibration machine of the TSE and 1 kN primary dead weight force standard machine of TUBITAK UME has been compared using 200 N capacity force transfer standard in this preliminary performance tests. To minimize the uncertainty associated with the indicating instrument a high resolution, HBM DMP 40, indicator having good stability was used in the tests.

The transfer force transducer was obtained at three symmetrically rotation positions relative to the axis of the machine (0°, 120°, 240°). Prior to start of a measurement cycle, the force transducer was loaded with max. test load three times at the 0° position, returning to zero after each maximum load application. Two sets of increasing measurement series at 0° position and one set of increasing and decreasing measurement series at 120° and 240° positions were obtained according to ISO 376 standard[3-4].

The measurements were carried out at approximately equal temperature condition as 22±1°C at TSE and TUBITAK UME Laboratories. Due to equality of laboratory conditions, effect of temperature difference on results was eliminated.

Transfer force transducer was measured first at TUBITAK UME. These measurements were followed by measurements performed at TSE.

Fig. 5 and Fig. 6 show the comparison graphs of repeatability error and rotation effect of of 200 N force transfer transducer measured at TUBITAK UME and TSE respectively. As it seen in these figures that repeatability and reproducibility errors are very close to each other measured in different dead weight force machines at UME and at TSE.

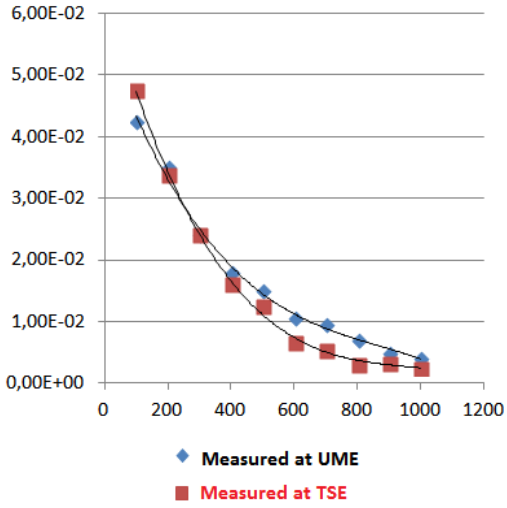


Fig. 5. Comparison graphs of repeatability errors

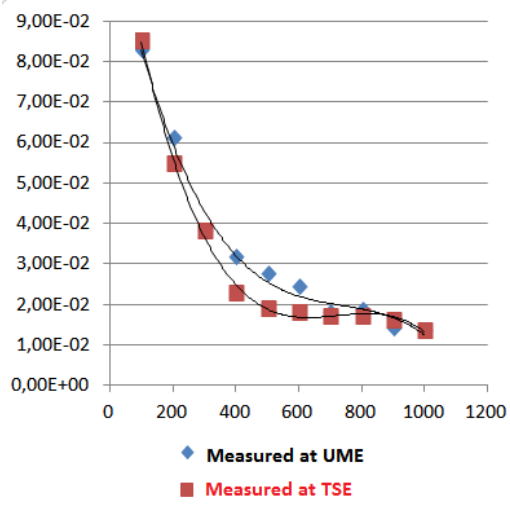


Fig.6. Comparison graphs of rotation effects

6. CONCLUSIONS

The repeatability error and reproducibility error 200 N UME transfer transducer measured by the UME dead weight force standard machines over a range of 20 N to 200 N was compared with TSE 200 N dead weight force calibration machine. The results of comparison show that the agreement between UME 1 kN dead weight force standard machine and

TSE 200 N dead weight calibration machine machine is better than ± $4x \cdot 10^{-5}$ for repeatability error and ± $5\ x \cdot 10^{-5}$ for reproducibility error over a range of 20 N to 200 N. As a result of that TSE 200 N dead weight calibration machine can be used in force proving instruments according to ISO 376 standard.

The systems realize the force calibration standards of TUBITAK UME and TSE in the stated range. The newly designed and manufactured 1 N - 200 N dead weight force standard/calibration machine will give service to industry for the calibration of force proving instruments in Class "00" acc. To ISO 376 with a measurement uncertainty of 5×10^{-5}.

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