

## **A New 500 Kg Dead-Weight Machine for Test Load Cell According to OIML R60 and Performance Tests Realised by UME**

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### **Abstract**

In order to test load cells used according to OIML R60 regulation in different temperature such as  $-10$ ,  $20$  and  $40^{\circ}\text{C}$  with increasing and decreasing loading conditions, dead-weight machine and good temperature control cabinet are necessary. ESIT Company has been manufacturing different type and capacities load cells in the last 12 years in Istanbul. In order to improve product quality and accuracy of ESIT load cells, a new dead-weight machine was designed and manufactured in ESIT Factory. This machine is capable to testing the compression load cells up to 500 kg. In this machine, quick loading and unloading for creep test purposes is realized by newly developed lever arm mechanism. Since temperature control cabinet restricts the movement of load cells up and down, this mechanism was developed to move loading frame of machine. UME Mass Laboratory calibrated to each dead weight. UME Force Laboratory realized a performance test of this machine using UME transfer force transducer.

### **1. Introduction**

Load cells are directly used for quality control in process, weighing systems, safety engineering, in optimal design works, in industrial application point of view. Especially, load cell is widely used in weighing system and in the subject of legal metrology field. Since the weighing system established in different environmental conditions, their protections against to change of humidity and temperature must be done carefully and great

attention should be paid by manufacturer. Otherwise they are not used in weighing purposes. OIML regulations oblige to test these load cells in changing temperature and humidity conditions. For the accurate testing of load cells, main parameter, which directly affects the test results, is application of unchanged and stable known forces or loads on the load cells. This is managed only using the dead weight force

machines. This is necessity for the load cell producer for both the satisfaction of customer and development of load cell quality. In this circumstances, ESIT Company was produced a new dead weight machine to test their load cells in production line.

Normally load cells can be tested in different type of machines. These are divided into four groups according to the order of magnitude and the accuracy of the generated forces. These are dead weight, lever amplification, hydraulic amplification and built-up machines. Dead weight force standard machines (DWM) get the best measurement uncertainty at between the levels of  $1-5 \cdot 10^{-5}$  and can be used under the forces between 10 N and 4.4 MN [1]. Rest of them has lower accuracy due to some mechanical effects [1].

ESIT has been producing different types and capacities of load cells for 12 years in Istanbul. To get the best quality in load cell production, ESIT engineers have designed and manufactured a new dead-weight machine to test the load cells according to OIML R60 recommendation. In general, ESIT dead weight machine has the features as follows:

- Step by step loading or unloading for making load tests according to OIML R60 with the weights calibrated by UME Mass Laboratory.
- Being able to set quick load or unload for creep test by using lever special arm mechanism in the machine.

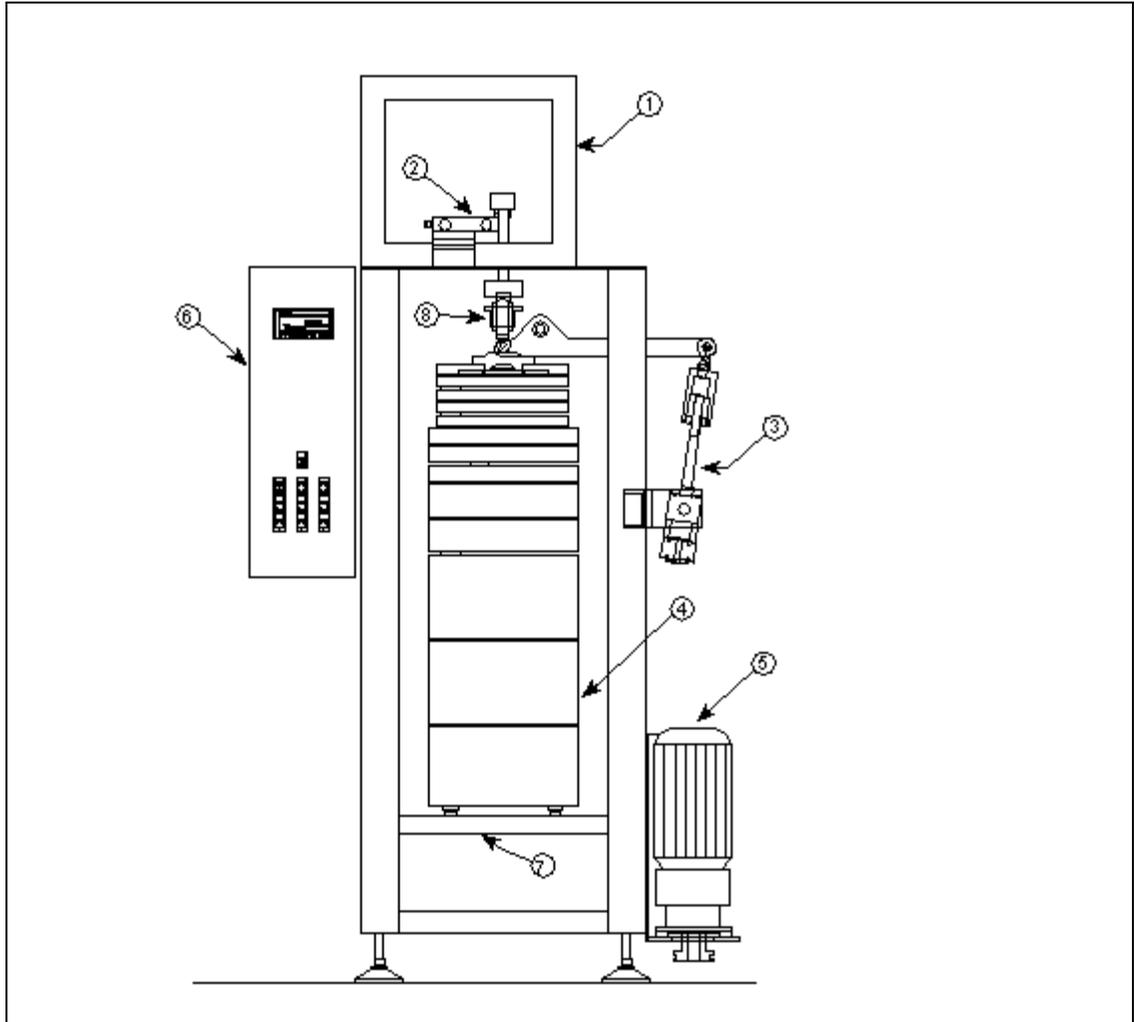
- The temperature chamber enables making tests at different temperatures between  $-10^{\circ}\text{C}$  and  $40^{\circ}\text{C}$ , as seen in the structure of the machine.
- This test machine is capable of testing the compression load cells up to 500 kg.

In this study, this machine is described shortly and performance test results realized by UME are given briefly.

## 2. Description of the ESIT Dead Weight Machine

Compression forces are generated through a direct application of a dead weight, under a force transmitted directly on the load cell. This force is generated from the acceleration caused by gravity, air buoyancy and mass of the dead weight [2]. Figure. 1 shows the schematic diagram of ESIT dead weight machine where the parts are numbered as follows:

1. Temperature chamber
2. Test load cell
3. Lifting lever (lever arm)
4. Test weight
5. Loading motor
6. Control panel
7. Lifting table
8. Flexible joint



**Figure 1:** Schematic diagram of the ESIT dead weight machine

Temperature chamber enables to test the load cells at any temperature between  $-10^{\circ}\text{C}$  and  $40^{\circ}\text{C}$ . BBS type 50 kg, 100kg and 200 kg; SBS type 200 kg, 500 kg; and SP type 100 kg, 200 kg, 500 kg load cells are tested in this machine. UME Mass Laboratory calibrated all of weights for the ESIT machine. It is possible to load and unload of load cells to the maximum capacity directly or step by step with increasing or decreasing load

steps. This machine has one stack of 14 weights composed of:

$$100 \text{ kg} * 3 = 300 \text{ kg}$$

$$40 \text{ kg} * 2 = 80 \text{ kg}$$

$$20 \text{ kg} * 3 = 60 \text{ kg}$$

$$10 \text{ kg} * 6 = 60 \text{ kg}$$

$$\text{Total: } 500 \text{ kg}$$

Three different capacities that are 50 kg, 100 kg, 200 kg and 500 kg load cell can be tested in this machine with 20 % load increment. Loading frame having a nominal value of 10 kg bears directly on the load cell and realizes first step of load. All weights are positioned over the lifting table during unloading position. In this stage, it is also possible to hang all or selected weight stacks in unload position for the purpose of creep test. After hanging the selected weight stack on the loading frame, quick loading and unloading is possible for creep test by means of lever arm located under the loading frame of the machine. This lever arm is newly developed and enables to make creep test of load cells by using complete lever arm system and the loading motor in reverse order shown in figure 1. After selection of applied load value on the computer screen in manual or automatic mode, first the lever arm goes down to load first step of load having weight of loading frame and then the lifting table moves down and selected weights hangs up to the loading frame and other weights hung up to each other.

The test machine control system consists of a PC and a PLC (programmable logical controller) in the control panel. With the PLC, test weight value is increased or decreased by the movement of the lifting table up or down, by the power transmitted from the loading motor. There is a special program developed by ESIT to perform the test, according to OIML R60 recommendation running in the computer. Load, creep and span tests can be performed and the operator easily enters the tests parameters such as stabilization

time, weight steps to the PC software. This feature makes the load application and data collection processes to be completely automatic. After the test is started, measured values by the indicating instrument are recorded at the actual time.

All weights must be on the same direction of the earth gravity, and the loading point of the load cell and the center of gravity of all weights must be on the same axis [3]. Paying attention to this rule, loading point of each load cell is mounted to special apparatus on the machine table at first to coincide weight axis of the machine. The concentric circles are made on the loading pad to ease the centering of the load cell. The machine can be used to evaluate the hysteresis by the application of the load both in ascending and descending order.

### **3. Performance Test Procedure**

The measurement procedure is applied during the performance test of the machine is similar to comparison measurement between force standard machines. The purpose of the performance test is to determine repeatable load application capability and determination of 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  $5 \times 10^{-6}$  measurement uncertainties.

A GTM force transducers having capacity of 5 kN were used as force transfer standard in this

preliminary performance tests. This had been used by UME in previous intercomparisons with the national laboratories of other countries in five years. To minimize the uncertainty associated with the indicating instrument a high resolution, HBM DMP 40, indicator having good stability was used in the tests.

To minimize the effect of creep, the force transducer included in the performance test, the time required achieving a stable response, following loading and unloading was determined prior to the start of the tests. In most cases, it was found that a 3 min. time delay between the initiation of the loading (or unloading) and the actual reading was adequate. Machine-transducer interactions can significantly influence measurement accuracy. Normal imperfections in alignment of loading machines and force transducers can result in significant bending, shear and twist components of deformation in the force transducers. To minimize the errors due to these non-axial components of deformation, the response of each force transducer was obtained at four symmetrically distributed positions relative to the axis of the machine (0°, 120°, 240°, 360°). 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 measurements at four rotation positions except 0° position (one set of measurements) was obtained, each separated by 3 min. interval [1].

The preliminary performance test was performed in five force steps that are 1, 2,3,4 and 5 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 ESIT.

The measurements were carried out at approximately equal temperature condition as  $21\pm 1^\circ\text{C}$  at ESIT and UME Laboratories. Due to equality of laboratory conditions, effect of temperature difference on results was eliminated.

#### **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 ESIT.

Normally ESIT machine produce the forces in kgf unit. Comparison measurements performed to check the measurement capability of ESIT force machine for the load cell tests according to OIML R60. In this case, it is not necessary to compare produced force values between UME and ESIT machines. Because, OIML R60 tests need the application of forces on the load cell at least five increasing and five decreasing load points [5]. However it does not oblige to producer for making test in kgf, lbf and N force units. For this reason, performance tests performed to compare rotation effect, repeatability and hysteresis errors of 5 kN UME

force transducer measured at UME and ESIT machines.

11 kN UME dead weight machine established at UME Force Laboratory in 1995. Two intercomparison measurements were performed between UME and PTB in 1995 and 2000. The best measurement uncertainty was achieved with dead weight force standard machine in the level of between  $\pm 1$  and  $4 \cdot 10^{-5}$ . [1,6]. Dead weight force standard machines exhibit approx.  $\pm 5 \cdot 10^{-5}$  relative deviations from PTB machine in international comparison measurements which have a theoretical uncertainty on the order of  $\pm 2 \cdot 10^{-5}$  [7].

Fig.2 shows the comparison graphs of repeatability error of of 5 kN UME force transfer transducer measured at UME and ESIT. As it seen in this figure that repeatability errors are very close to each other.

Fig.3 and Fig. 4 show the comparison graphs of hysteresis error error and rotation effect of of 5 kN UME force transfer transducer measured at UME and ESIT respectively

In the Fig.3, hysteresis error of force transducer measured in two different machines are also very close two each other. However rotation effects are not close to each other. This shows that force transducers are not good centered to load axis of force machine.

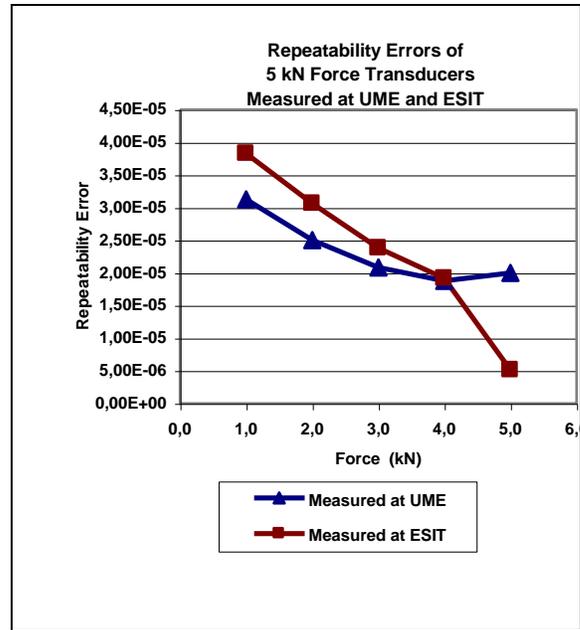


Fig.2 Comparison graphs of repeatability errors

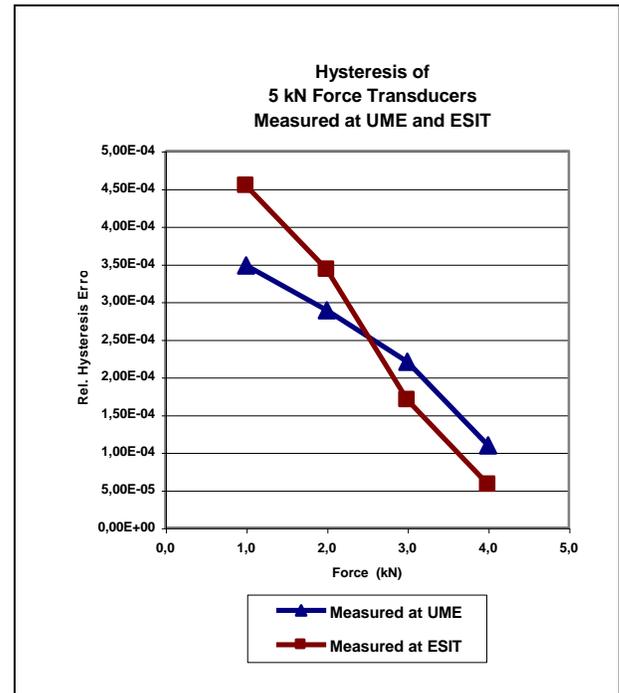


Fig.3. Comparison graphs of hysteresis errors

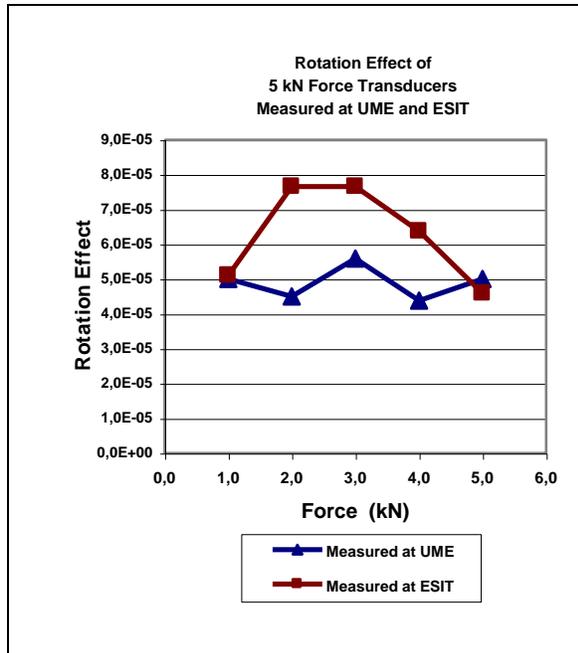


Fig.4. Comparison graphs of rotation effects

## 5. Conclusions

The repeatability error, hysteresis error and rotation effect or reproducibility error of 5 kN UME transfer transducer measured by the UME force standard machines over a range of 1 kN to 5 kN was compared with ESIT force machine. The results of comparison show that the agreement between UME 11 kN dead weight force standard machine and ESIT 500 kg dead weight machine is better than  $\pm 1 \times 10^{-5}$  for repeatability error,  $\pm 1 \times 10^{-4}$  for hysteresis error and  $\pm 3 \times 10^{-5}$  for rotation effect over a range of 1 kN to 5 kN. This ranges is in the error band of 5 kN force transducer. As a result of that ESIT dead weight machine can be used in load cell tests according to OIML R60 regulations.

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