THE METROLOGICAL CHARACTERISTICS OF FORCE TRANSDUCER UNDER LOADS LESS THAN 10% OF ITS CAPACITY

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ABSTRACT

In many circumstances some one may be compelled to use a force transducer under loads less than 10% of its capacity. It is so important to know the metrological characteristics of the force transducers at this small range in order to be aware how much these characteristics are poor under this force range. Two different types of class 00 force transducers are used. For each type different transducer capacities are considered. The force transducers are calibrated according to ISO 376 in compression within two ranges. These ranges are 10% and 100% of the transducer capacity. The transducer linearity, repeatability, reproducibility and reversibility are compared for the two applied ranges. For the same force transducer each rang is considered as a separate force transducer, so each parameter is evaluated as a ratio from the full range capacity.

1. INTRODUCTION

We use metrology to make sure that measurements are correct and give appropriate values, under all circumstances. Three characteristics of a measurement system are very important : Resolution (a quantitative expression of the ability of an indicating device to distinguish meaningfully between closely adjacent values of the quantity indicated, resolution is also measure of readability), Precision (indicates a measuring system ability to always give the same reading when measuring the same thing) and Accuracy (indicates how close a measurement of a quantity comes to the accepted value of the characteristic). Force measuring devices should be calibrated to guarantee their test results.

Load cells, one type for the force measuring devices, have found numerous and diversified uses in the areas of force weight measurement. They are used to measure the thrust of jet and rocket engines, weight of aircraft, tension in cables and numerous other functions. Their electrical output makes them extremely adaptable as monitors or control sensors to limit loading of materials, and in process weight measurement of any item where total or maximum weight is required.

There are two basic calibration techniques used for calibrating force measuring instruments, Direct and Substitution. If the force instrument is calibrated using weights to generate a known force, then the calibration is direct (dead weight). If the force instrument is compared to another instrument, then the calibration process is named substitution. It becomes obvious that the dead weight or direct method is the preferred method of calibration when errors are calculated. It may be impossible to use the dead weight in all applications; however, the reference standards have to be calibrated using the dead weight. The reference standards are then used to calibrate the working standards.

The instruments should be calibrated regularly and the re-calibration period should be determined depending upon the following factors by the end usre, 1) conditions of storage 2) work load 3) kind of abuse it is subjected to 4) overall performance of the unit depending upon the specifications of the unit and its expected performance.

The last thinking in the area of using load cell is preferred to use it above 10% of full capacity. May be this is due to some characteristics of the elastic member and strain gauges used in manufacture of load cell. Now, we take in our consideration the behavior of load cell in the different characteristics related to different type of analysis that includes the actual behavior of load cell under applying loads.

Every day, millions of force measurements are made across a diverse range of industries and applications. Different applications will have different uncertainty requirements, but for the measurement and the associated uncertainty to have meaning, traceability back to recognized standard is essential. As the Egyptian national standards laboratories, NIS provided such traceability with appropriates uncertainties.

In many circumstances, the need necessitate the use of a force transducer under loads less than 10% of its maximum rated capacity. Nothing wrong with that if, and only if the characteristics of the transducer is well studied, experimented and the associated uncertainties are determined.

2. EXPERIMENTAL

The experimental programmed laid down to achieve the goal of this work is dictated by the availability of force transducers and the capabilities of the available force standard machines. However, it covered a good range of capacities used in different applications.

The force standard machines used are the 50 kN and the 500 kN pure dead weight machines in addition to the mechanically amplified 1 MN force standard machine (FSM). As for the force transducers under study two different types of class 00 are used. Different capacities are considered to cover a reasonable range of force measurements needed in different applications. Four force transducers of 1 MN, 1 MN, 500 kN and 50 kN capacities are chosen for the study.

Both the 1 MN load cells are calibrated on the 1 MN FSM for the full range (100%) in steps of 100 kN starting form 100 kN . They are then recalibrated on the same machine for the 10% of their full rated capacity starting from 10 kN in steps of 10 kN up to 100 kN.

The 500 kN cell is calibrated on the 500 kN dead weight machine for the full range in steps of 50 kN starting from 50 kN up to 450 kN . It is then recalibrated on the same machine for 10% of its full capacity in steps of 5 kN starting from 10 kN up to 45 kN. The 50 kN cell is calibrated on the 50 kN dead weight machine for both the full capacity and 10% of its range. It is calibrated for the 100% range in steps of 5 kN starting from 5 kN and recalibrated the 10% of its full capacity in steps of 0.5 kN starting from 0.5 kN.

All calibrations are conducted according to the international standards specification ISO 376 "Metallic materials – Calibration of force – Proving instruments used for the verification of uniaxial testing machines". They are all calibrated in the compression mode. The readout device used is the HBM manufactured DMP 40s2 with of 1 x 10^{-6} mV/V. Readings of the device corresponding to the applied load are recorded after 30 seconds from the load application.

All force transducers are pre-loaded at least three times, to their maximum capacities, prior to calibration. Warm up time required for the readout device is strictly observed. All calibrations are carried out under the same environmental conditions, namely 23 degrees Celsius ± 1 degree and 45-55 RH.

Since the transducers linearity, repeatability, reproducibility and reversibility are to be compared for their two ranges, namely the 100% and the 10% of the full rated capacity, each range for the same transducer resembles a transducers on its own. Hence, each parameter is evaluated as a ratio from the full range capacity.

3. RESULTS AND ANALYSIS

The linearity analysis of the force transducers used shows that the 100% range of the transducer gives better linearity than the 10% range. Figures 1 and 2 show two examples which demonstrate the linearity behavior (at 10% and 100% ranges) of type 1 and type 2 force transducers (both of 1 MN capacity).

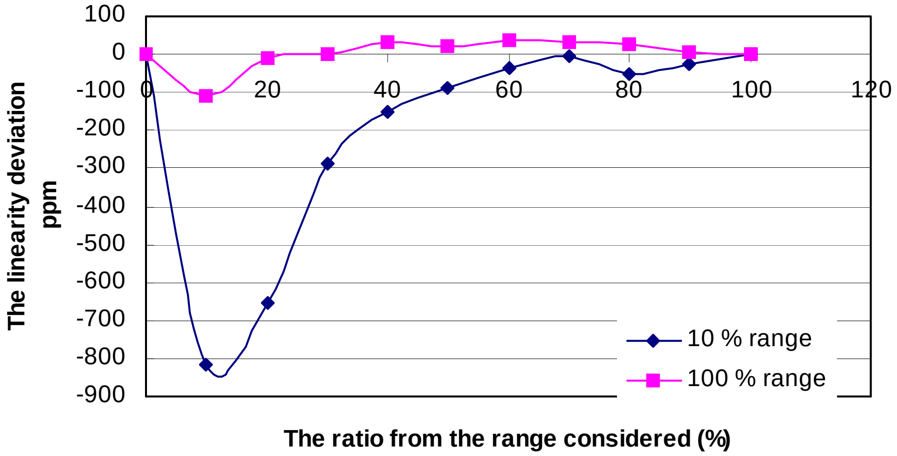

Fig. 1 Linearity behavior of type 1 force transducer (with capacity of 1 MN).

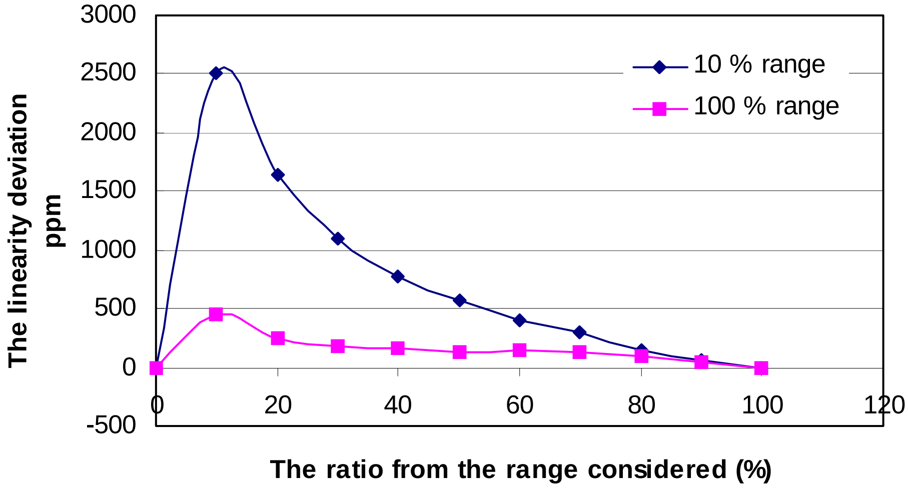

Fig. 2 Linearity behavior of type 2 force transducer (with capacity of 1 MN).

The two figures show that the deviation from linearity is not exceeding 500 ppm for the 100% range where as it exceeds 2500 ppm for the 10% range. This indicates that for some needs the transducer behavior can be approximated to be linear for the full range capacity with reasonable uncertain results allover that range. On the other hand, This approximation may lead to catastrophic uncertain results for the range under 10% of the transducer capacity.
For the proper use, a suitable curve fitting polynomial equation has to be chosen in order to fit the calibration results of the force transducer. Reference 1, describes how to estimate the interpolation error of the calibrated force transducer. Figures 3 and 4 show the interpolation error of two force transducers (types 1 and 2) with capacity of 1 MN. The two figures show that the interpolation error does not exceed 250 ppm for the full range capacity, while as it exceeds 600 ppm for the 10% range. This may indicate that not only the behavior of the transducer under the 10% of its capacity is poor in linearity compared with its full scale range but also the results of the 10% range have more scattered values around its fitting polynomial equation than the full scale range behavior.

This result will also contribute rising the uncertainty of the calibration data obtained for the scale range under 10% of the transducer capacity.

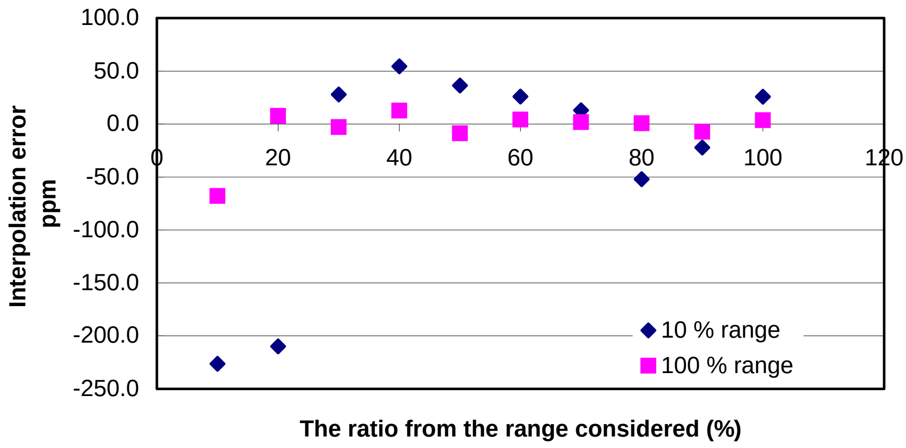

Fig. 3 Interpolation error of type 1 force transducer (with capacity of 1 MN).

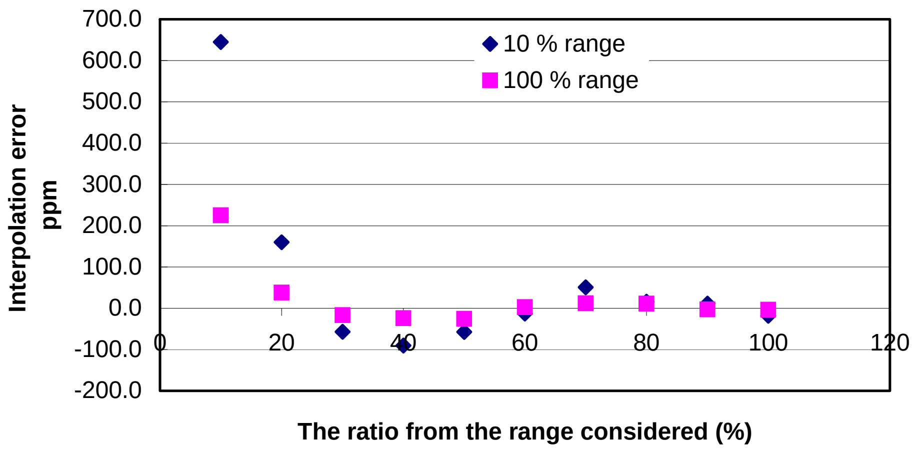

Fig. 4 Interpolation error of type 2 force transducer (with capacity of 1 MN).

It is clear that the reliability of the results also depends on the resolution error which may deeply affect the uncertainty of the calibration result. The resolution error for loads greater than 10% range certainly has values less than for loads under that range. For example, The resolution error for the load 1% of the transducer capacity is 10 times as the error at 10% of the transducer capacity and 100 times as the error at the full capacity. This can easily be seen from the definition of the resolution error (Ref. 1). Thus, it is worth to mention that the using of the force transducers at the small load ranges; the resolution error represents a predominating factor of the measurement uncertainty.

Figures 5 and 6 show that the repeatability error for the transducers of types 1 and 2 respectively. The two figures show that the repeatability error increases with the lower force range, whereas, the 100 % range of type 1 force transducer with capacity of 1 MN gives repeatability error better than its 10% range by about 40 ppm. The same clear difference is also observed in Fig. 6 for type 2 force transducer with capacity of 50 kN.

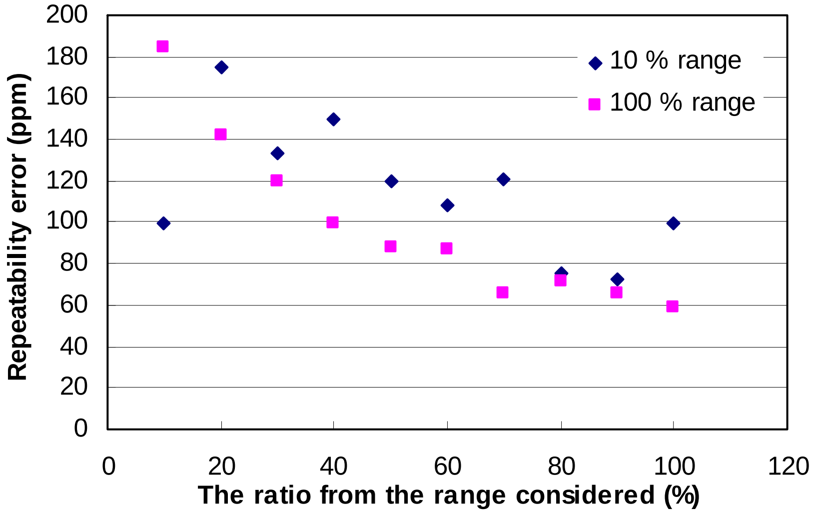

Fig. 5 Repeatability error of type 1 force transducer (with capacity of 1 MN).

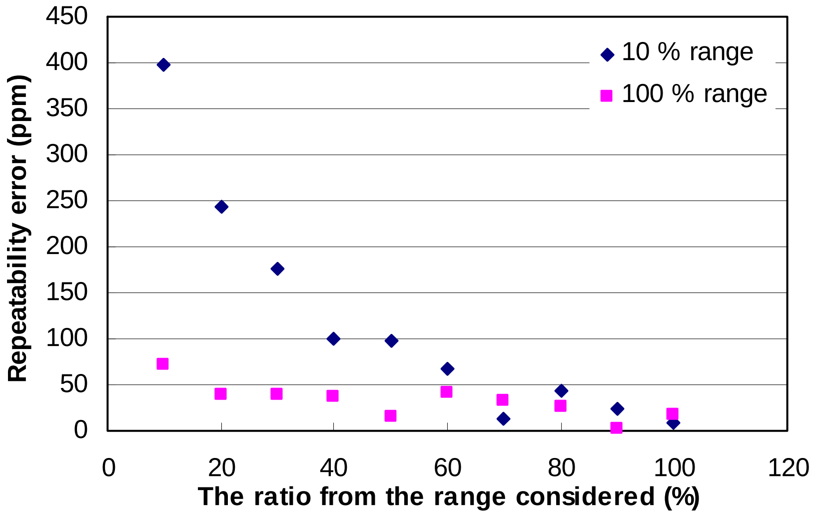

Fig. 6 Repeatability error of type 2 force transducer (with capacity of 50 kN).

4. CONCLUSION

The experiments show better results of the 100% force range rather than the 10% range for the linearity, interpolation error, resolution and repeatability analysis. For usual applications and for accurate measurements like inter-laboratory comparisons it is recommended to use the transducer with its full capacity range. For compel circumstances, the usage of the transducer with low force ranges will affect the uncertainty of the measurements.

5. REFERENCE

1. International Standard ISO 376 "Metallic materials-Calibration of force proving instruments used for the verification of uniaxial testing machines".