COMPARISON BETWEEN THE CONTINUOUS AND STEP BY STEP CALIBRATION METHODS OF FORCE TRANSDUCERS

M. Ibrahim and G. Aggag

National Institute for Standards, El-Haram, Giza, Egypt

Abstract:

The continuous calibration method of force transducer represents a very helpful method since the calibration can be carried out in a short time compared with the step by step method. Another advantage of the continuous calibration method is the possibility of recording the responses of the standard force transducer and the force transducer to be calibrated synchronously. This could be done using two different channels of the displaying device. The disadvantage of this method is the difficulty to define exactly constant certain loads at each loading series during the calibration. The continuous method shows better measurement uncertainty than the step by step method, where as a lot of calibration points are considered in the analysis. One important factor for the results of the continuous calibration method is the response rate. Rates less then 0.08mV/Vs showed good agreement results of the two methods.

1. Introduction

The methods of calibration commonly used in the calibrated force transducers described a step-by-step procedure, which is natural in any case for stepwise load application. The result of the calibration using these method represents the best possible result with respect to the measurement uncertainty and is the best version for intercomparisons under well-known loading conditions [1-2]. However, the majority of applications of load measuring devices do not employ this kind of loading sequence. Therefore, the requirements for continues calibration method is needed in various industrial and research applications such as process monitoring, material testing and crash testing; where the load application is continuous. Consequently, it is important to carry out interpolation processes in order to analyze the calibration results, and evaluate the repeatability error. These interpolation processes affect the uncertainty of the results.

In this paper, the comparison between the continuous and step by step calibration methods of different force transducers, using a universal calibration machine have been studied at various loading rates. The calibrations are carried out according to ASTM E74 [3] for both the continuous and the step by step method.

2. Experimental Work

2.1 Universal Calibrating Machine

Morehouse calibrating machine was used in the experiments. Basically, the universal calibrating machine is a device for simultaneously applying a force to a high-accuracy calibration standard, and the transducer to be calibrated. Fig. 1 shows a photographic view of the universal calibrating machine. The machine consists of:

a) Stationary frame assembly which is composed of two platens connected by four tie bars, moveable yoke assembly. Four adjustable feet, together with a circular level mounted on the lower machine platen, provide the means for leveling the machine.
b) Moveable yoke assembly which consists of upper and lower yoke platens. The two platens are connected by two tension tie bars. The lower yoke platen is permanently fixed in position by means of the set screws and tension collar nuts. The tie bar locking

collars support the moveable yoke assembly on the upper machine platen. The upper yoke platen is adjustable to accommodate various test configurations.

c) Hydraulic jack and hand pump assemblies. High pressure hydraulic jack is specially designed and constructed so that its leak rate is low enough not to interfere with precise calibration work. The jack is attached to the top of the upper machine platen. The jack is activated by two-speed pump assembly which advances the ram with the desired speed. An auxiliary screw piston is provided for application of minute increments of load.

The reference transducer is inserted axially over the ram of the jack, and the calibrated transducer is inserted axially over the lower moveable platen (as shown in fig. 1).

Fig. 1 Photographic view of the universal calibrating machine.

2.2 Transfer Standards

Two types of transfer standards (force transducers) were used, GTM and Revere, with different capacities (5 kN, 10 kN and 50 kN). Two force transducers (load cells) with similar capacity were used in each experiment, one as a reference transducer and the other as a calibrated one. All the transducers used are of class 00. The experiments were carried out at environmental temperature of $21 \pm 0.5\,^{o}C$ and relative humidity of $60 \pm 5\%$.

2.3 Displaying Device

The displaying device used in the experiments was a VN-Digitizer with resolution of 1E-5 mV/V. Two channels were considered, channel 1 for the reference transducer and channel 2 for the transducer to be calibrated. For the continuous calibrations, the measured values for each channel were read every 60 ms.

2.4 Methodology

The force transducers are calibrated in compression for step by step and continuous methods using ASTM E74-03. Before applying the calibration forces, the maximum force is applied to the force transducers three times [4]. In step by step method, the calibration is carried out by applied one serie of the calibration forces to the force transducers with increasing force only. Then apply two further series of increasing values. Between each of the two further series of forces, the force transducer is rotated symmetrically around its axis to positions uniformly distributed over 360° (i.e 0°, 120°, 240°). Before the two future series the transducer is preloaded once after each rotation. The number of applied forces in each series of step by step method is ten with equal steps (i.e 10%, 20%, 30%,……..until 100% of the transducer capacity). The response of calibrated force transducer and reference force transducer for each applied load is recorded by VN-Digitizer.

In the continuous method the sequence of the calibration is preformed as step by step method without loading step. The load is applied gradually with different loading response rate using the hydraulic jack of the universal calibration machine.

The evaluation analysis of uncertainty of experimental results follow the method given in " the Guide to the Expiration of Uncertainty in Measurement" [4] and "The Expression of Uncertainty and Confidence in Measurement – M 3003" [5]

3. Results and Discussion

The continuous calibration method is a powerful method since it gives the opportunity to collect a lot of calibration points in a short time. It is very difficult to consider the same collected loading values in each series as the step-by-step method. So, it is important to make the repeatability test to check the consistency of the results. Figures 2 and 3 show the relative repeatability error of the 5 kN and 50 kN force transducers respectively.

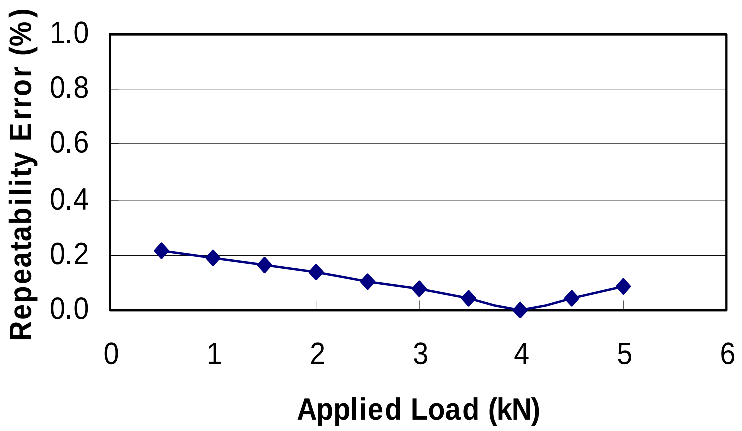

Fig. 2 Repeatability error of the 5 kN force transducer.

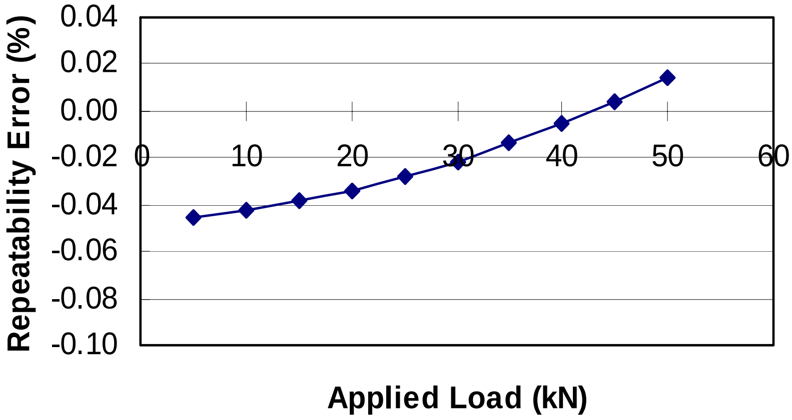

Fig. 3 Repeatability error of the 50 kN force transducer**.**

The two figures show a good consistency of the results for the continuous calibration method. The average value of the repeatability error is about 0.06%.

To compare the new method with the step-by-step method, the relative deviation of the calibration results of the two methods are calculated and represented. Figures 4 and 5 show the relative deviation of the calibration results using step-by-step method versus the continuous method with rate of response equals to 0.08 mV/Vs for the transducers with capacities of 5 kN, and 10 kN respectively.

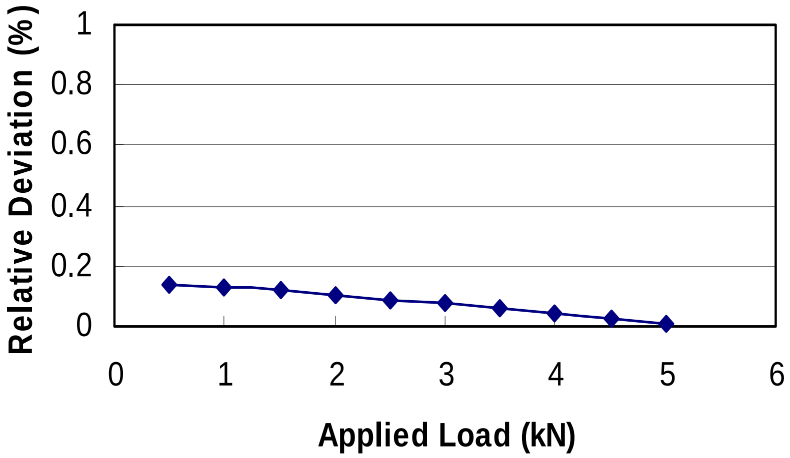

Fig. 4 The relative deviation of the calibration results using step-by-step method versus the continuous method with rate of response equals to 0.08 mV/Vs for the transducer with capacity of 5 kN.

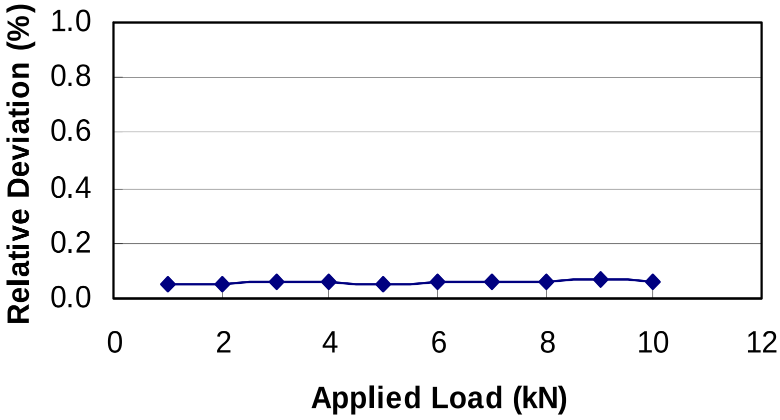

Fig. 5 The relative deviation of the calibration results using step-by-step method versus the continuous method with rate of response equals to 0.08 mV/Vs for the transducer with capacity of 10 kN.

The two figures show good agreement for the method of continuous calibration compared with the step-by-step method, where as, the relative deviations are ranged from 0.007% to 0.14%. The calculated relative expanded uncertainty values using the continuous method were better than the values calculated using the step-by-step method by about five times, since a lot of calibration points can be collected by the displaying device throughout each calibrated range. Statistically, more data means more reliability of the results. One disadvantage of this method is the sensitivity of the calibration to the loading rate. Since, there is time delay between the collected responses from the two channels of the displaying device. The calibrations with high loading rates may lead to erroneous calibration results. The situation may be out of our prediction for the high load rates, since not only the synchronization time will be affected the results, a complicated situation; due to the dynamic effect and the creep behavior of the transducer beside the synchronization time will exist. Figures 6 and 7 show the relative deviation of the calibration results using step-by-step method versus the continuous method with rate of response equals to 0.08 mV/V and 0.12 mV/V for the transducers with capacities of 5 kN, and 50 kN respectively. The two figures show that the high response rates lead to increase the relative deviation. Increasing the response rate to 1.2 mV/Vs leads to increase the relative deviation to reach 0.68 % and 0.33 % for the 5 kN and 50 kN force transducers respectively.

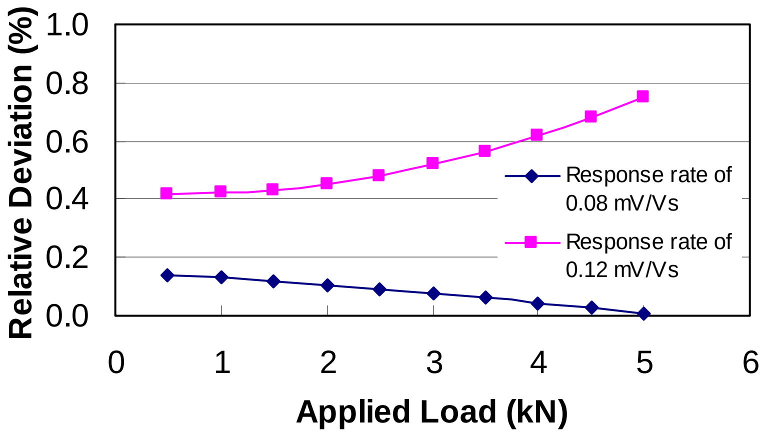

Fig. 6 The relative deviation of the calibration results using step-by-step method versus the continuous method with rates of response equal to 0.08 mV/Vs and 0.12 mV/Vs for the transducer with capacity of 5 kN.

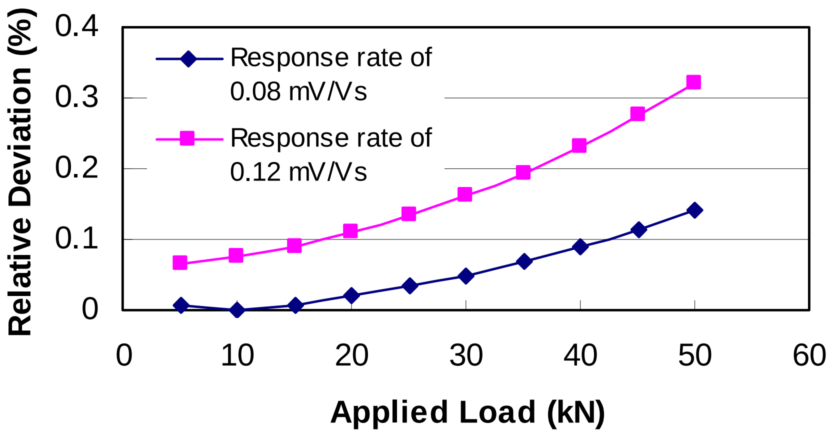

Fig. 7 The relative deviation of the calibration results using step-by-step method versus the continuous method with rates of response equal to 0.08 mV/Vs and 0.12 mV/Vs for the transducer with capacity of 50 kN.

4. Conclusion

This study presents a new method for secondary force transducers calibrations. The continuous force calibration using the universal calibrating machine with the aid of multi-channel displaying device is an easy and reliable method. The method gives better measurement uncertainty than the step by step method, since a lot of calibration points are considered in the polynomial curve fitted equations. Good consistency for the different calibration series were showed. One important factor is the response rate used during the calibration. Response rates less than 0.08 mV/Vs gives good agreement results of the continuous calibration with respect to the step by step calibration.

5. References

1- M. I. Mohamed, H.M.Abdel-Hakeem and A.A.El-sayed, "Evaluation of Measurement Uncertainty of Universal Calibration Machines" , Proceeding of the 17th International Conference of IMEKO, Istanbul, 2001 pp. 104-110

2- El-Dorry M., Expermintal Evaluation of universal calibration machines used as secondary standard for force calibration", Master Thesis: Mechanical Engineering Department, Al-Azhar University 1997.

3- ASTM Standard practice of calibration of Force-Measuring instruments for Verifying the force Indication of testing Machines, ASTM E73-03.

4- The Expression of Uncertainty and Confidence in Measurement M 3003, UKAS, 1997.

5- Uncertainty of Calibration Results in Force Measurements, EAL-G22, 1996