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Study of Creep Recovery for Force Transducers Compared with Creep Behavior

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Abstract: As the creep and creep recovery are important characteristics for the selection of the force transducer, standard and supplementary calibration methods are focused on them. For both creep and creep recovery, the results will depend on how long the force applied has been at zero or at the rated value, respectively, before the change of force is made.

According to the new ISO 376-2011, creep/creep recovery values are measured at reached loads after time intervals from 30 to 300 seconds.

In this study, creep and creep recovery values are measured in the same calibration condition through the use of ISO 376 by waiting a time for creep/creep recovery measurements at each calibration step. The results reveal that for the transducers that have little creep value, there is no tangible difference between creep and creep recovery.

Keywords: Force transducer, Creep recovery, Creep, ISO 376.

1. Introduction

Force transducer/load cell selection can be either simple or complex, depending on whether one has the necessary background information. This information is freely available, but, as with all such data, the key is to know where to look for it. There are two routes for selecting it to suit certain criteria, either through standard calibration (ISO 376) or supplementary calibration (BS8422) [1, 2]. Supplementary calibration allows the user to select the calibration parameters to suit his application.

Since creep and creep recovery are important characteristics of the force transducer/load cell, these items are offered through the supplementary calibration.

Creep is the change in force transducer/load cell output occurring with time while under load, and with all environmental conditions and other variables remaining constant. Also, creep recovery is the change in no-load output occurring with time after removal of a load which had been applied for a specific period of time. Thus, this characteristic is more related to force transducer/load cell hysteresis behavior. So, it must be taken into consideration when evaluating any of them. A correction for creep is possible if the creep characteristics of the transducer are known and the time between the application of force and the reading of the indicator is controlled.

Most manufacturers specify creep as the maximum change of output over a specified time after increasing the force from zero to the rated force [3]. But according to the new ISO 376-2011, creep values are measured at maximum loads and are reached after time intervals from 30 to 300 seconds [1].

The manufacturer should normally supply 17 basic technical characteristics for each load cell. Normally, the following 9 properties should be calibrated: sensitivity S, linearity L, hysteresis H, repeatability R, zero output Z, influence of zero point temperature Z_t, influence of output temperature S_t, creep C_p (or creep recovery C_r) and stability S_b [4].

In order to obtain a quantitative understanding of the creep results, a rheological model was fitted to the data. This model is discussed by R. A. Mitchell and S. M. Baker [5].

2. Experimental Setup

Force transducers of different capacities from two different manufacturers (A and B) are used throughout this piece of research for creep/creep recovery experiments. The capacities used covered a wide range of forces starting from 20 kN up to 500 kN.

The experiments are conducted on Dead Weight Machines (DWMs) with maximum capacities of 20 kN, 100 kN and 1 MN and a combined relative uncertainty of 0.002 %.

DMP 40 readout is used as a load indicator with the filter setting at 1.7 Hz for creep experiments to decrease the noise level. The readout resolution is 1×10^{-6} mV/V.

The scheme to reach the maximum load is obtained through the calibration of the transducers according to ISO 376 (as shown in Fig. 1). Following the same ISO standard scheme, the set of experiments to determine creep/creep recovery values in the same calibration condition, are conducted. In this scheme of work, the waiting time for creep/creep recovery measurements is applied at all calibration steps before proceeding to the next step. The creep/creep recovery data is recorded at different load steps through DMP 40 readout software program every 0.2 sec for up to 5000 readings.

All experiments are carried out in controlled environmental conditions, namely at a temperature of 20 ^{o}C and relative humidity of 45% RH.

3. Results and Discussion

Some creep recovery of force transducers is displayed in the opposite direction from creep as shown in Figs. 2, 3 and 4 for the same transducer designated as A-100 kN. The measurements are performed through the ISO 376 scheme, but the three figures are focused on three steps only as a model. But in some other cases, both of them were found in the same direction, e.g. A-500 kN and B-500 kN as shown later in Figs. 7 and 8.

Figs. 5 and 7 indicate that the A transducer's behavior has the capacities of 20 and 500 kN at 50 % and 90 % of maximum capacity. Also, Figs. 6 and 8 indicate the B transducer's behavior has the same capacities at the same capacity levels.

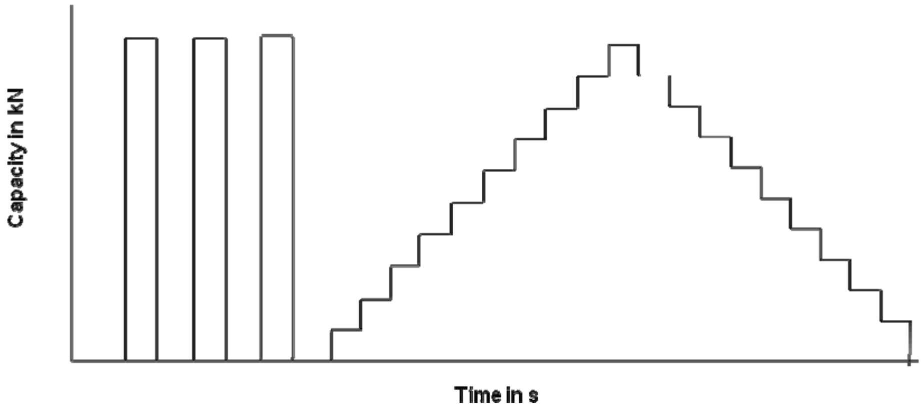

Fig. 1. Scheme for loading.

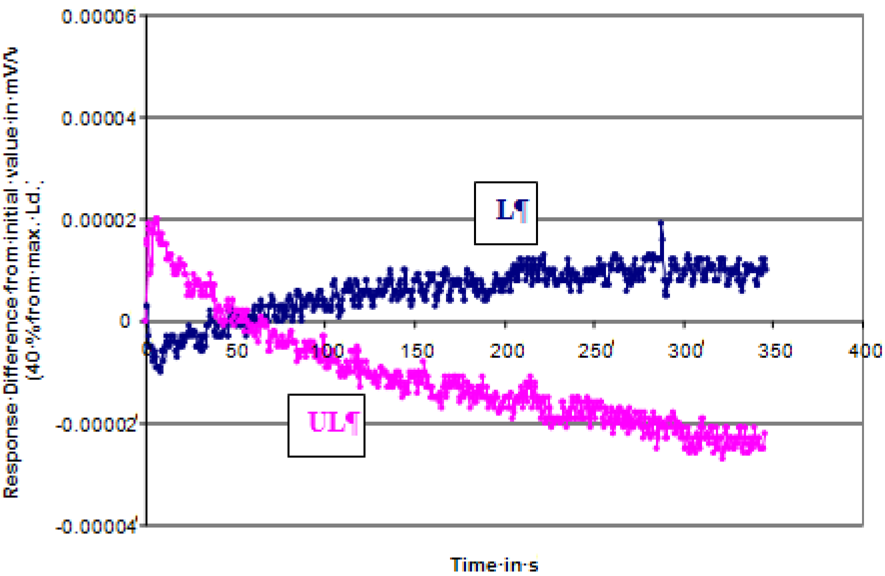

Fig. 2. Creep/Creep recovery behavior for the A-100 kN force transducer at 40 % of maximum capacity.

Although Figs. 5 and 6 indicate that the A-20 kN and B-20 kN force transducers have a little creep/creep recovery behavior, there is some slight small difference is observed between creep and creep recovery for the B-20 kN force transducer. According to the new ISO 376-2011 for creep phenomenon characterization in equation 1, the calculated creep value is approximately 0.0005% and the creep recovery value is approximately 0.0001 %. For the other force transducer A-20 kN there is no difference in creep and creep recovery values, which is approximately 0.0004 % for both:

$$c = \left| \frac{i_{300} - i_{30}}{X_N} \right| \cdot X \cdot 100, \quad (1)$$

where c is the relative creep error %; i_{300} is the reading of the indicator corresponding to the deflection 300 seconds after application or removal of force; i_{30} is the reading of the indicator corresponding to the deflection 30 seconds after application or removal of force; X_N is the deflection corresponding to the force.

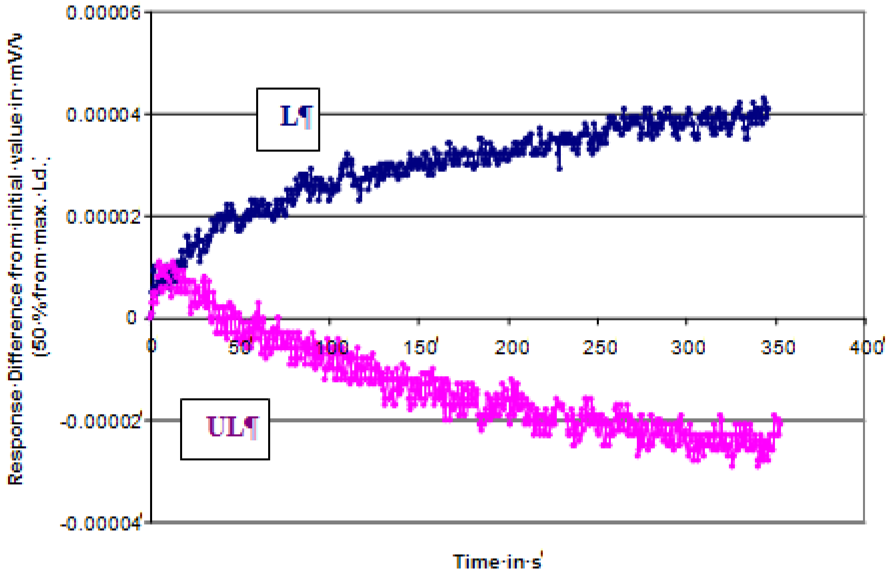

Fig. 3. Creep/Creep recovery behavior for the A-100 kN force transducer at 50 % of maximum capacity.

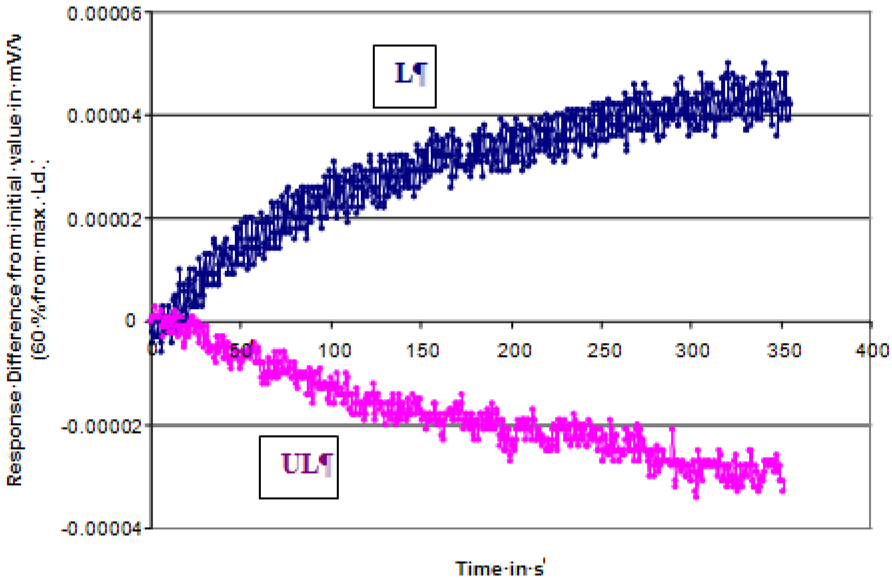

Fig. 4. Creep/Creep recovery behavior for the A-100 kN force transducer at 60 % of maximum capacity.

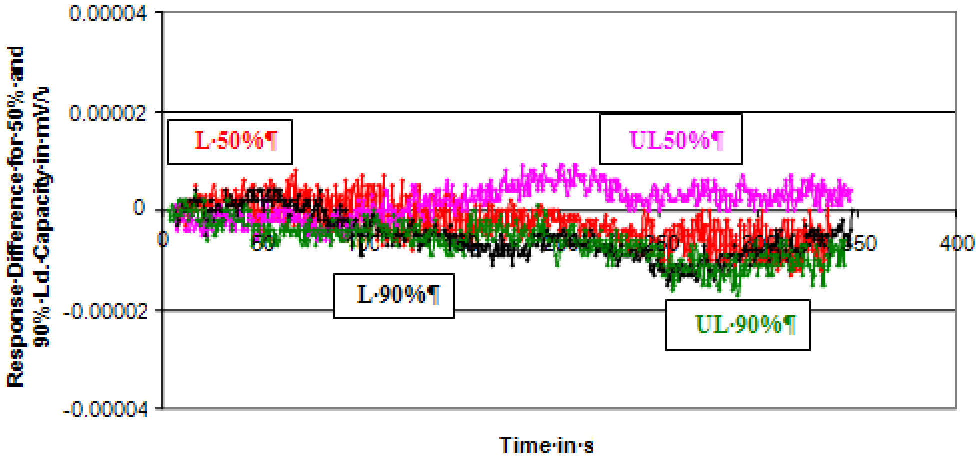

Fig. 5. Creep/Creep recovery behavior for the A-20 kN force transducer at 50 % and 90 % of maximum capacity.

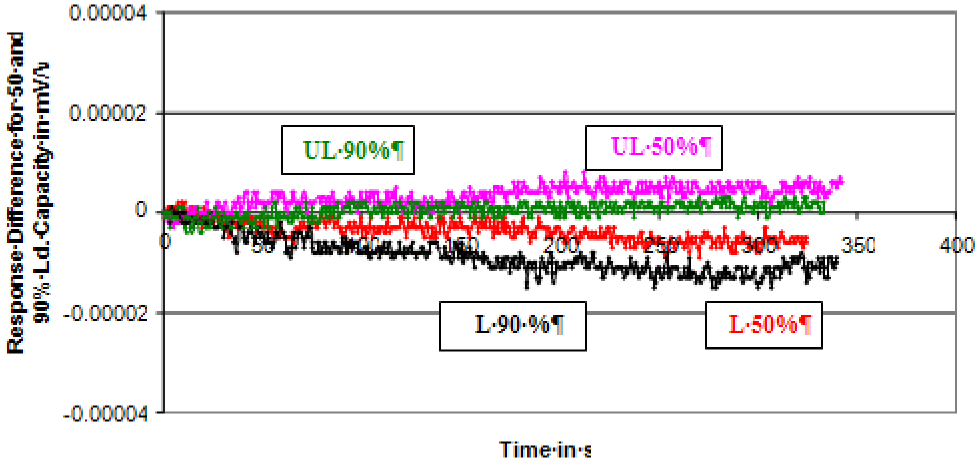

Fig. 6. Creep/Creep recovery behavior for the B-20 kN force transducer at 50 % and 90 % of maximum capacity.

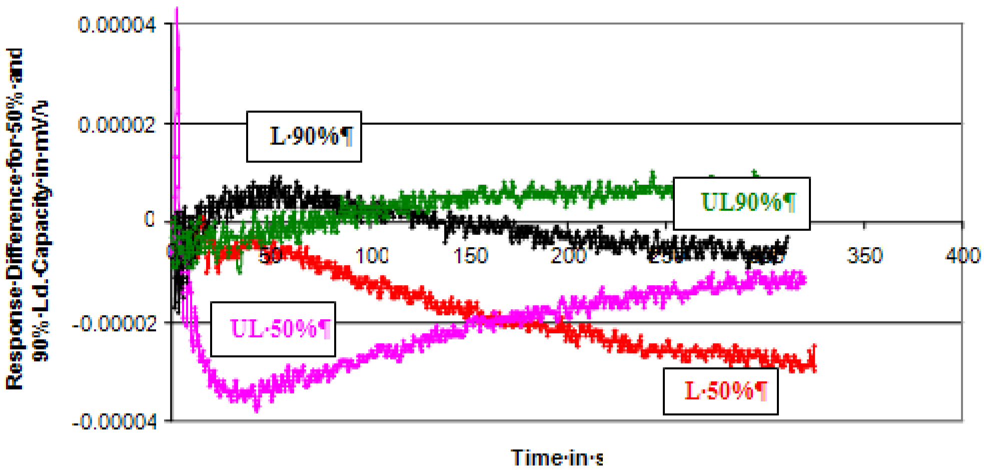

Fig. 7. Creep/Creep recovery behavior for the A-500 kN force transducer at 50 % and 90 % of maximum capacity.

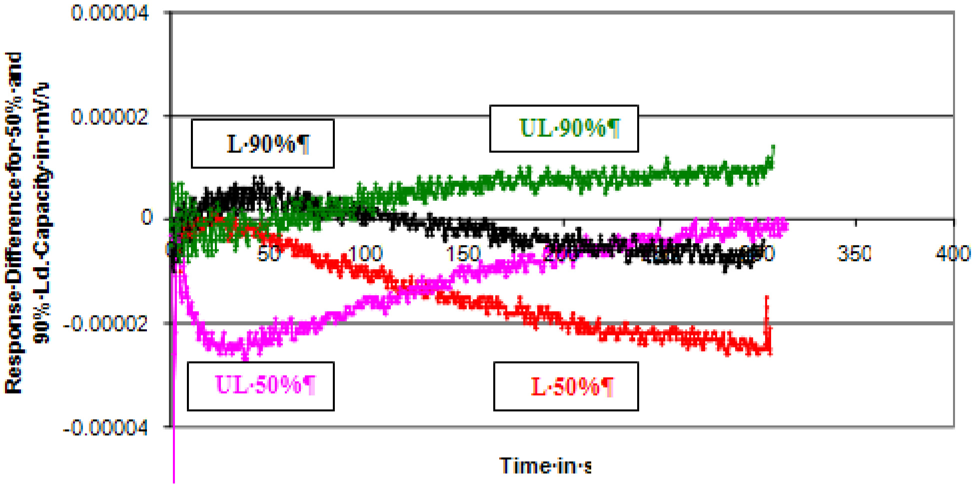

Fig. 8. Creep/Creep recovery behavior for the B-500 kN force transducer at 50 % and 90 % of maximum capacity.

According to the new ISO 376-2011 standard, the creep limit is found to be higher than the calculated values in these force transducers, so the creep effect may be negligible here.

Fig. 9 shows the curve fitting the creep behavior for the A-100 kN force transducer at near full capacity (90 % of maximum capacity, for example). The differentiation of the curve fitting equation with respect to time is plotted in Fig. 10 to indicate at what time the behavior for the transducer may be stable for the creep response.

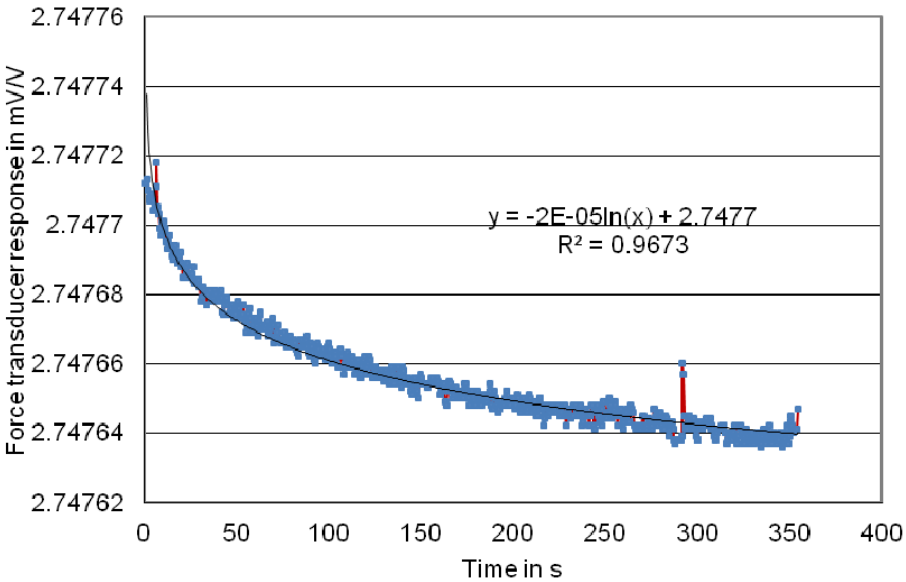

Fig. 9. Curve fitting response for the A-100 kN force transducer at 90 % of maximum capacity in the loading condition.

Fig. 10 shows that the creep behavior for the transducer is more stable after a time of around 30 seconds. This means the mechanical and electrical processes for manufacturing are acceptable for improving this phenomenon. The calibration measurements are always taken after 30 seconds, but the effect of creep must be included in our consideration in the uncertainty evaluation. In the case of intercomparisons, the measurement protocol usually recommends taking the measurements after 6 min to remove the creep effect from the readings. So, in this case there is no need to include the creep effect in the uncertainty evaluation.

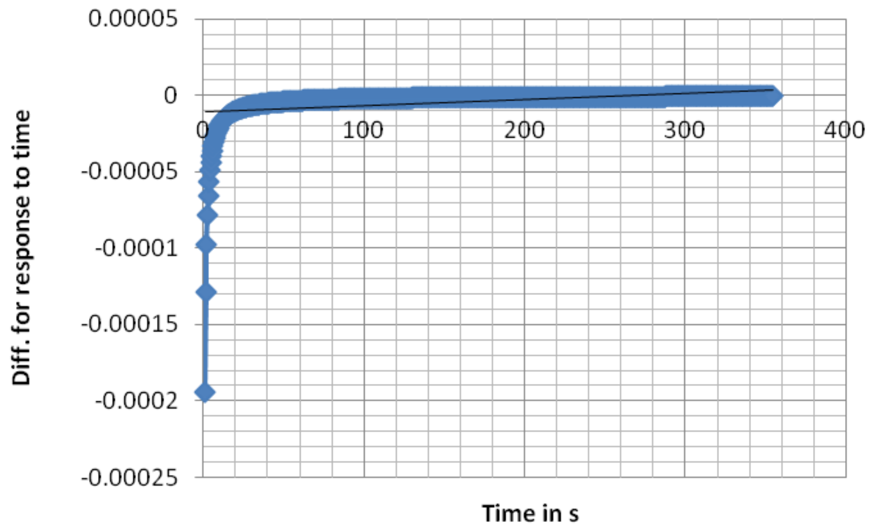

Fig. 10. Differential relation between response and creep time for the A-100 kN force transducer at 90 % of maximum capacity in the loading condition.

4. Conclusion

The different behaviors of creep and creep recovery could be correlated with the type of force transducer construction with the variety of mechanical and electrical processes involved for the transducer.

This is because the spring material not only has an effect on creep/creep recovery behavior for the transducer but also on the strain gauges and adhesive used.

For the majority of force transducers, creep and creep recovery almost have the same values but in opposite direction. But sometimes due to the transducer construction, this behavior is slightly a little different. In this case, creep and creep recovery have somewhat different values.

Force transducers have a small amount of creep behavior; there is a tangible difference between creep and creep recovery values.

The creep limit range specified in the ISO 376 draft standard for most cases covers the actual creep measurements in the practical technical work.

The experimental design must be performed at least once to know the limits for the creep stability with time. In this case, the procedure for the use of this transducer must be undertaken within this time limit for taking the measurements.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

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Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

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