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EFFECT OF DIFFERENT LOADING SCHEMES ON CREEP AND CREEP RECOVERY FOR FORCE MEASUREMENTS

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Abstract – The creep and creep recovery are important characteristics of force transducers. Thus, this study is focused on the measurements of creep and creep recovery for transducers of different capacities.

Creep measurements are carried out according to three different loading schemes, revealed that the creep values measured at maximum loads and reached after time intervals from 30 to 300 seconds like proposed in a new draft of ISO 376 from the moment of load application. The effect was higher in direct loading (one step to reach the maximum load) than those obtained from the two other schemes (chosen loading steps distributed all over the full range up to maximum load and according to automatic machine calibration (M/C) software that designed to cover all the range up to maximum load). Effect of creep on hysteresis value is also investigated.

Keywords: creep – creep recovery – hysteresis - force transducer

1. INTRODUCTION

Force transducers are mainly calibrated according to ISO 376[1]. When the applied force acting upon a force transducer is changing rapidly to a new level and then remains constant, the force indicating system of the transducer yields a value that drifts, or creeps, with time before reaching equilibrium[2]. This creep is largely attributable to thermo elastic effects [3], namely the adiabatic heating and cooling of elastic load supporting elements within a force transducer as they undergo deflection in response to changes in the applied force.

In order to get 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 [4]. They represent the load cell as a network of springs and dashpots. In the combination of a spring and a dashpot in parallel, called a voigt element. For the results compared with this model, exponential curves fitted the creep data. In using the fitting to predict the creep response is not represented, one should take into account the non-linearity of the transducer.

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.

2. EXPERIMENTAL DESIGN

2-1.Equipments

Force transducers of different capacities and types from three different manufacturers (A,B and C) are used throughout this piece of research for creep experiments. The capacities used covered wide range of forces starting from 200 N up to 1000 kN.

The experiments are done on Dead Weight Machines (DWMs) with maximum capacities of 2 kN, 20 kN, 100 kN and 1 MN and combined relative uncertainty of 0.002%.

A DMP 40 readout is used as load indicator with the filter setting at 1.7 Hz for creep experiments to decrease the noise level. The readout resolution is $1x10^{-6}$ mV/V.

In order to investigate the creep behaviour, the data is obtained from the DMP 40 readout through a software program designed to record creep data every 0.2 seconds.

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

2-2. Loading schemes

In a group of creep measurements, the transducers are loaded to a maximum load by three schemes. Firstly, maximum load is reached in one step (direct loading). Secondly, the maximum load is reached through chosen loading steps randomly distributed all over the range (some steps loading). Third scheme the maximum load is reached passing by all steps in automatic M/C software for this load capacity (full steps loading).

For the three loading schemes, the creep data is recorded at maximum loads through software every 0.2 sec up to 5000 readings. The creep recovery data are then recorded through the same software at zero loads after unloading the force transducer (section 3-1).

Another group of creep measurements for the same transducers are carried out at different loading steps. At each step creep and creep recovery are evaluated as that occurring between 30 and 300 second from the moment of applying or removal of the load. For each loading step the load is reached directly from zero up to that step and back to zero to evaluate creep recovery. These data are presented as relative creep and relative creep recovery error (section 3-2).

To study the creep effect on hysteresis value, the transducers are calibrated according to ISO 376. Following the same ISO standard scheme, the set of experiments for determine creep value in the same calibration condition are done. In this scheme of work, the waiting time for creep measurements is applied at each calibration step passing by the full calibration steps (section 3-3).

3. RESULTS AND DISCUSSION

3-1. Creep at maximum load

Considering the new trend for creep measurements that defines the creep phenomenon as that occurring and measured between 30 and 300 sec after applying the load, the force transducers are used to study this creep criterion at maximum loads. Table No.1 shows the transducers creep behaviour data under three loading schemes to reach the maximum load capacity.

Table 1: Creep measurements in mV/V at max. load capacity (between 30 to 300 sec)

Force Transducer	Direct Loading	Some steps Loading	Full steps Loading
A- 100 kN	0.000012	0.000013	0.000007
A- 20 kN	0.000151	0.000129	0.000131
B- 16 kN	0.000033	0.000022	0.000024
A-10 kN	0.000011	0.000000	0.000002
C-2 kN	0.000051	0.000027	0.000032
A- 1000 N	0.000042	0.000019	0.000027
A- 200 N	0.000024	0.000026	0.000024

For the majority of Force Transducers, as indicated in the table 1, the creep values at maximum load between 30 sec to 300 sec in case of direct loading to reach the maximum capacity are higher than the two other cases (loading steps chosen randomly and loading following the full steps according to M/C automatic software to maximum load capacity). Also, the creep values for the lowest capacities Force Transducers have a little difference between the three loading cases.

3-2. Creep at different load steps

Figure 1 shows the scheme for creep measurements at each load step capacity. In this scheme, each step load capacity is reached to maximum value direct from zero load.

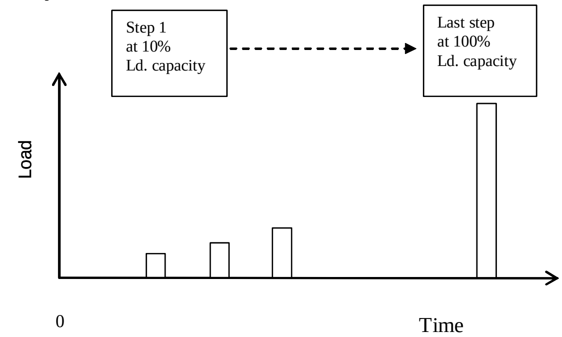

Figure 1: Scheme for loading each step from zero to max. Ld.

One typical result of creep and creep recovery for the force transducer at load steps are presented in the figures 2&3 respectively.

These figures indicate the comparing values in loading and unloading scheme for the force transducer. Another example is shown in the figure 4. The different behaviours of creep could be correlated with the type of force transducer construction with the variety of mechanical and electrical processes involved for the transducer.

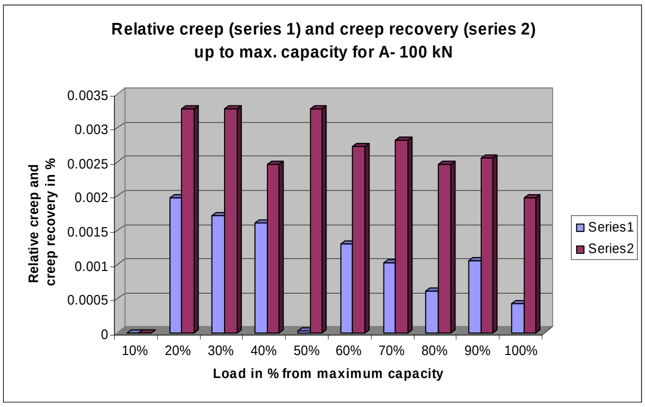

Figure 2: Relative creep and relative creep recovery in % versus Load in % for A-100kN

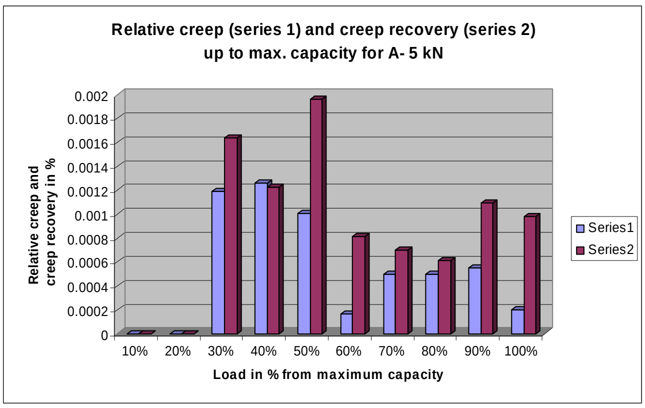

Figure 3: Relative creep and relative creep recovery in % versus load in % for A-5kN

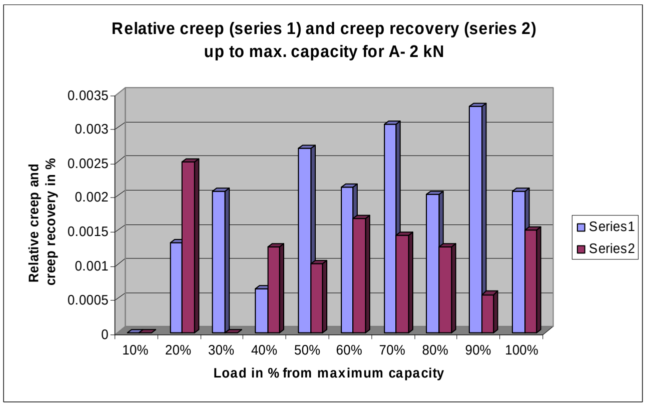

Figure 4: Relative creep and relative creep recovery in % versus load in % for A-2kN

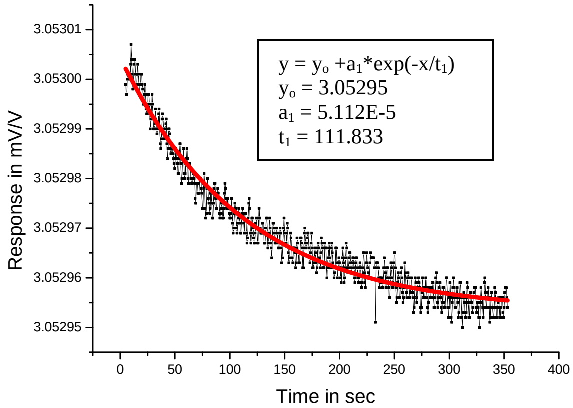

Figure 6: Creep behaviour for the transducer A-100kN at max. Ld.

3-3. Creep effect on hysteresis

Five force transducers type A and three transducers from type B are used for this part of study. Exponential fitting is used to calculate the creep value at maximum capacity according to draft of ISO 376 requirement. The exponential fitting is expressed by the following equation :

$$y = y_o + a_1 * \exp(-x/t_1)$$

since y is force transducer response

y_o is a constant depends on force step value&elastic behaviour& viscoelastic behaviour

a_1 is a constant depends on force step value&elastic behaviour

t_1 is a constant depending on elastic&viscoelastic behaviour of force transducer

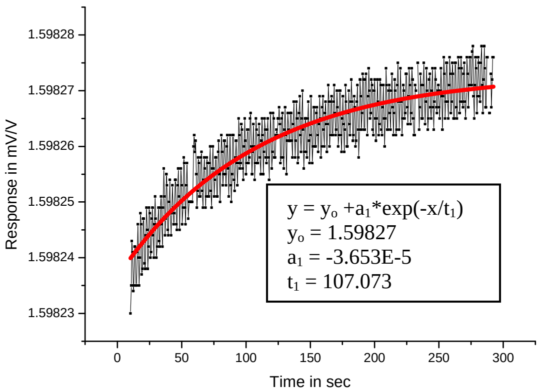

Figure 5: Creep behaviour for the transducer B-2.5kN at max. Ld.

Figures 6 and 7 indicate the creep behaviour for the B-2.5 kN and A-100 kN respectively at maximum capacity through the normal scheme for the ISO 376. The contribution of creep on hysteresis in both transducer slightly different. The effect of creep in case of 2.5 kN is more than the other transducer. Although there is some difference, the results show the effect of creep on hysteresis reaches to 18% which is not so big effect for the hysteresis value as shown in table No.2. This table presents the creep contribution on hysteresis value for the force transducers under this study.

Hysteresis is calculated from the normal calibration procedure according ISO 376. For example, figure 7 and figure 8show the hysteresis behaviour for the 2.5 kN (type B) and 100 kN (type A) respectively.

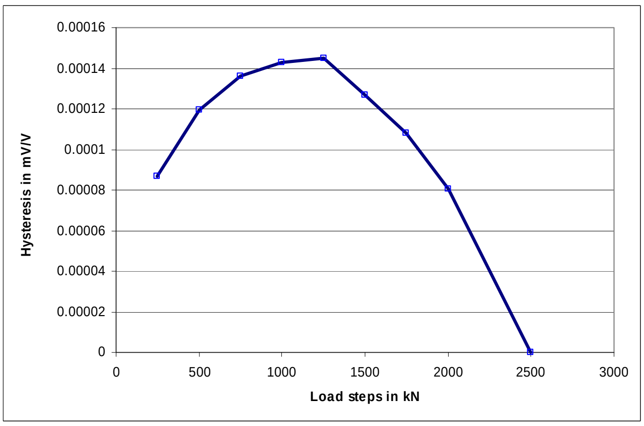

Figure7: Hysteresis behaviour for the transducer B-2.5kN

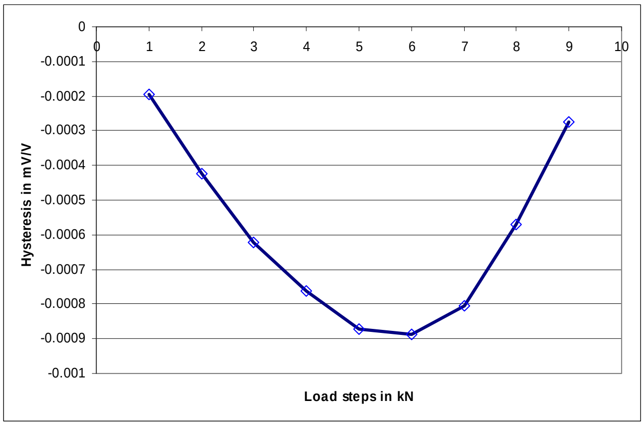

Figure8: Hysteresis behaviour for the transducer A-100kN

Table 2: Creep contribution on hysteresis

Transducer Type/Capactity	Creep at max. load in mV/V according to draft ISO 376	Max. hys. Value in mV/V	Creep/hys in .%
A - 2 kN	0.000014	0.000161	8.70
A – 5 kN	0.000002	0.000061	3.28
A – 20 kN	0.000005	0.000056	8.93
A – 100 kN	0.000036	0.000888	4.05
A – 500 kN	0.000026	0.000640	4.06
A – 1000 kN	0.000030	0.000172	17.44
B – 2.5 kN	0.000025	0.000145	17.24
B – 20 kN	0.000008	0.000190	4.21
B – 100 kN	0.000008	0.000174	4.60
B – 500 kN	0.000002	0.000112	1.79

4. CONCLUSIONS

The results of tests on different force transducers indicate a wide variety in the magnitude, direction and complexity of the creep/creep recovery response. This is not surprising if one considers the variety of interrelated mechanical, thermal and electrical processes involved as the force transducer system creeps toward a equilibrium state.

Force transducers can show larger creep and creep recovery values at the initial loads, then theses values are coming smaller until to be almost steady all over the range up to maximum load capacities.

It could be also concluded from this study that creep values for the force transducers have less value in routine work since they work under the condition of loading steps.

This study is included also the contribution of creep value on transducer hysteresis value. The creep effect is ranging approximately 20% for the hysteresis value.

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REFERENCES

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

[2] P. E. Pontius and R. A. Mitchell, Inherent Problems in Force Measurement, Exper. Mech. 22, 81-88 (1982).

[3] Thomas W. Bartel and Simone L. Yaniv, "Creep and Creep Recovery Response of Load Cells Tested According to U.S. and International Evaluation Procedures", Journal of Research of the National Institute of Standards and Technology, Volume 102, Number 3, May–June 1997.

[4] R.A.Mitchell and S.M.Baker, “Characterization the creep response of load cells”, VDI-Berichte Nr. 312, 1978, pp43-48.

[5] M.I.Mohamed, Ebtisam H. Hasan and G. Aggag, “study of creep behaviour of load cells”, Measurement Journal-ELSEVIER, Measurement 42, 2009, pp1006-1010.

[6] A. Stoian, T. Kuberczyk and G. Schultes, “A new type of force sensor”, IMEKO 20th TC3, 3rd TC16 and 1st TC22 International Conference, 27th to 30th November, 2007. Merida, Mexico.

[7] “Load Cell accuracy in relation to the conditions of use”, Revere Transducers Application Note 07/7-11/01.