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THE INFLUENCE OF TEMPERATURE AND HUMIDITY ON THE CREEP OF TORQUE TRANSDUCERS

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Abstract: This paper presents a study of the effect of temperature and relative humidity on the so-called short-term creep over 3 minutes as well as on the creep over 30 minutes using different torque transducers. The creep values increase with increasing temperature while it is decreased for increasing relative humidity. Using a linear assumption for the creep value change due to temperature/relative humidity change, the relevant coefficients are presented. The 30 minutes creep test is recommended rather than the 3 minutes test.

Keywords: torque transducers, creep, temperature, humidity

1. INTRODUCTION

Creep, as the change of a torque or force transducer's signal at constant load, is considered very important as a characteristic parameter for each transducer and for the uncertainty estimation of its indication as well.

The influence of temperature and humidity on the torque transducers characteristics, residual zero torque, reversibility and 3 minutes creep recovery, was studied earlier and found to have a small effect [1]. The influence of humidity on torque transducers was considered earlier for inter-laboratory comparisons [2-4] using a climate-controlled cabinet. The influence of humidity on the zero signal of torque transducers was investigated [5] and found to vary from +3.3 to -9 nV/V per % relative humidity. In [6], it was proposed to use a short creep test, so-called short-term creep, over only 3 minutes and to multiply the creep value found by 4 to obtain the creep over a 20 min interval.

In this investigation, the influence of temperature and relative humidity on the creep of torque transducers was studied for short-term creep, 3 minutes creep, and for 30 minutes creep.

2. DESIGN OF THE EXPERIMENTS

In these experiments the following equipment was used:

- PTB's 20 N·m dead weight torque standard machine
- a specially designed climatic cabinet with a temperature range of (15 – 40) °C ± 1 K and relative humidity range of (30 – 80) % ± 1 %.
- five torque transducers (three different types) from two different manufacturers
- DMP40 measuring amplifier; the settings of the amplifier were: filter of 0.22 Hz Bessel, the signal reading was "absolute", the measuring range was 2.5 mV/V, and the excitation voltage was 5 V.
- temperature and relative humidity sensor (Manufacturer: Rotronic, type: HygroPalm-HP21, uncertainty: ± 0.2 K for temperature and ± 1 % for relative humidity), set inside the cabinet.

Each torque transducer was placed inside the cabinet and assembled onto the machine individually. Thermal insulator couplings are used to couple torque transducers to the machine to reduce heat transfer along machine couplings and the transducer. Figure 1 shows the environmental sequence of the climatic cabinet while Figure 2 shows the transducer's loading regime, which was applied consistently along the environmental sequence line. The machine experimental setup is shown in Figure 3.

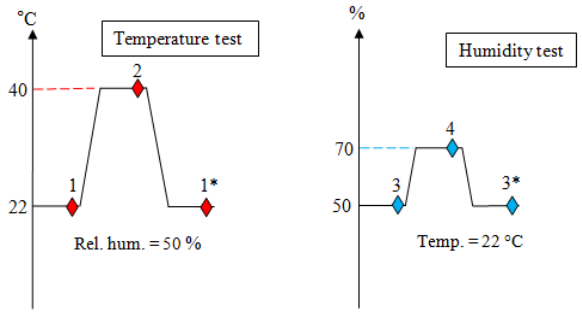

Figure 1: Environmental test sequence for (a) temperature (left) and (b) relative humidity (right)

The waiting time needed to reach signal stability for each torque transducer used here equal to the waiting time used in [1]. The warming up time for the DMP40 was observed thereby.All the experiments were conducted under laboratory environmental conditions of 21 °C ± 0.5 K and (45 ± 5) % humidity.

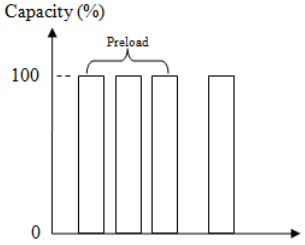

Figure 2: Torque loading regime

Figure 3: Experimental setup machinery/equipment for environmental tests

3. EFFECT OF TEMPERATURE ON THE TORQUE TRANSDUCER'S CREEP

Figures 4 to 8 show the effect of temperature changes on the creep of the investigated torque transducers. In the figures, the *x*-axis is the time in minutes, the *y*-axis is the creep and creep recovery at different temperatures in mV/V.

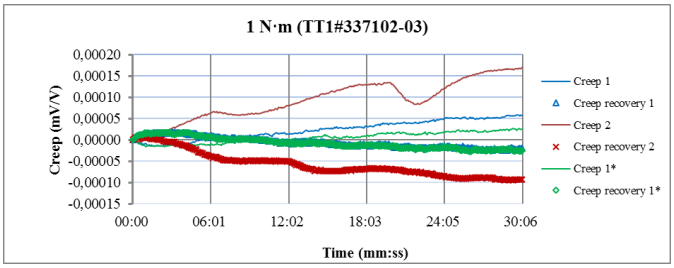

Figure 4: Effect of temperature on the creep of a 1 N·m torque transducer

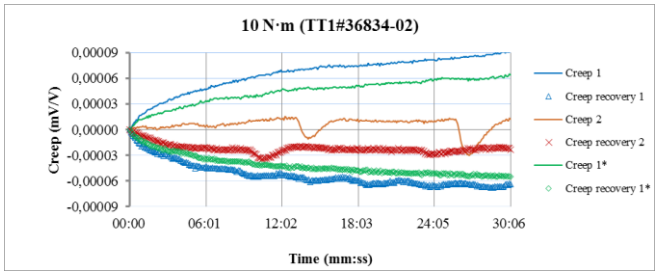

Figure 5: Effect of temperature on the creep of a 10 N·m torque transducer

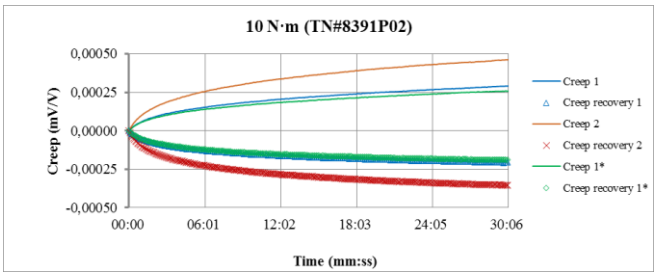

Figure 6: Effect of temperature on the creep of a 10 N·m torque transducer

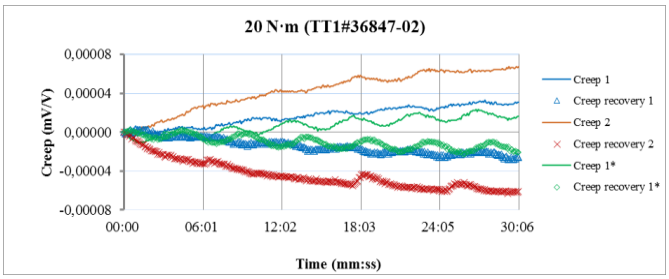

Figure 7: Effect of temperature on the creep of 20 N·m torque transducer

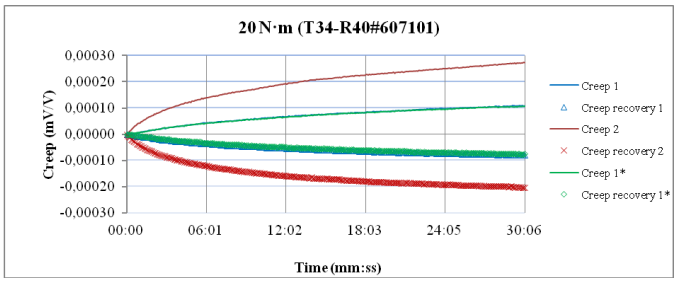

Figure 8: Effect of temperature on the creep of 20 N·m torque transducer

Table 1 shows the values of the effect of temperature on the creep of torque transducers. Different factors are used; K_1 is the temperature-creep ratio of the creep over 30 minutes relative to that over 3 minutes, K_2 in (% / K) is the change of the creep value due to temperature change; a linear relation is assumed, which is calculated following equation (1):

$$K_2 = \frac{\text{Creep}_{40\,°C} - \text{Creep}_{22\,°C}}{\text{Sensitivity}} \cdot \frac{100\%}{18\,\text{K}} \qquad (1)$$

The values of K_2 show that the change of the creep values due to temperature change from 22 °C to 40 °C varied from 0.00015 % / K to 0.00062 % / K which is larger than the results presented from short-term creep in [1] by (24 - 97) %, which considered a reason to apply a creep test over 30 minutes.

Table 1: Effect of temperature on the creep of two torque transducers

Torque trans-ducer	Rel. humidity		%	50	50	50	K_2
	Temperature		°C	22	40	22	
	Conditions code			1	2	1*	% / K
20 N·m (TT1#36847-02)	Creep	mV/V	3 min	0.000003	0.00001	-0.000001	0.00015
			U, 3 min	0.000003	0.000003	0.000003	
			30 min	0.000031	0.000066	0.000016	
			U, 30 min	0.000004	0.000005	0.000004	
			K_1	10.3	6.6	-16	
	Creep recovery	mV/V	3 min	-0.000004	-0.000023	-0.000004	-0.00015
			U, 3 min	0.000003	0.000004	0.000003	
			30 min	-0.000025	-0.000062	-0.000021	
			U, 30 min	0.000005	0.000006	0.000006	
			K_1	6.2	2.7	5.2	
20 N·m (T34-R40#607101)	Creep	mV/V	3 min	0.000024	0.000096	0.000023	0.00062
			U, 3 min	0.000003	0.000006	0.000004	
			30 min	0.000107	0.000274	0.000106	
			U, 30 min	0.000007	0.000011	0.000009	
			K_1	4.5	2.9	4.6	
	Creep recovery	mV/V	3 min	-0.000022	-0.000087	-0.000019	-0.00046
			U, 3 min	0.000003	0.000005	0.000004	
			30 min	-0.000079	-0.000203	-0.000076	
			U, 30 min	0.000007	0.000008	0.000006	
			K_1	3.6	2.3	4	

4. EFFECT OF RELATIVE HUMIDITY ON THE TORQUE TRANSDUCER'S CREEP

Figures 9 to 13 show the effect of relative humidity changes on the creep of the investigated torque transducers. In the figures, the *x*-axis is the time in minutes, the *y*-axis is the creep and creep recovery at different humidities in mV/V.

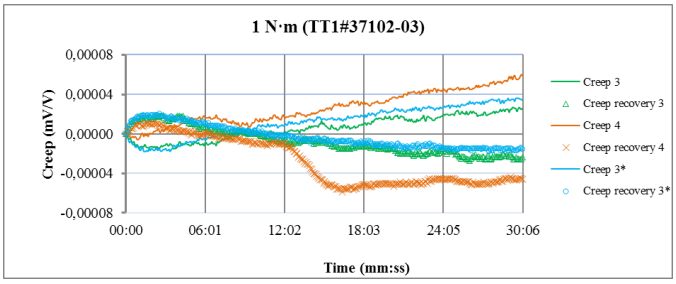

Figure 9: Effect of humidity on the creep of a 1 N·m torque transducer

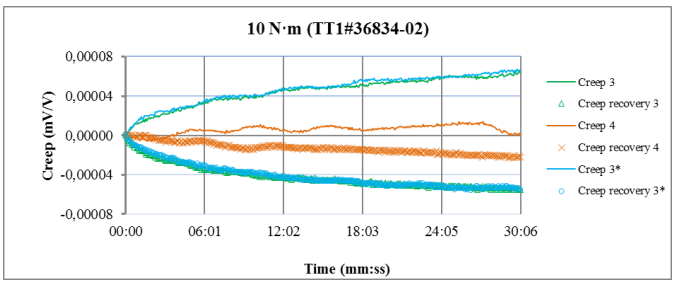

Figure 10: Effect of humidity on the creep of a 10 N·m torque transducer

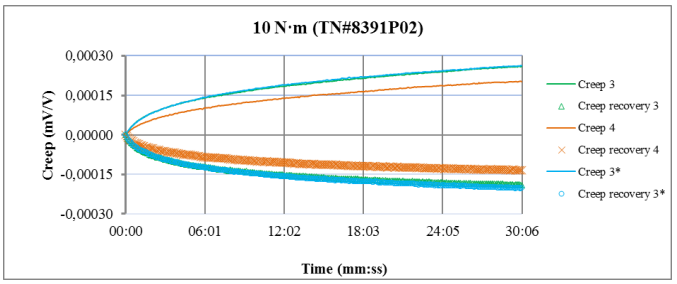

Figure 11: Effect of humidity on the creep of a 10 N·m torque transducer

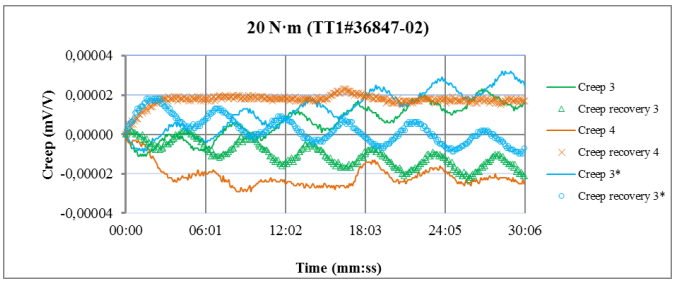

Figure 12: Effect of humidity on the creep of a 20 N·m torque transducer

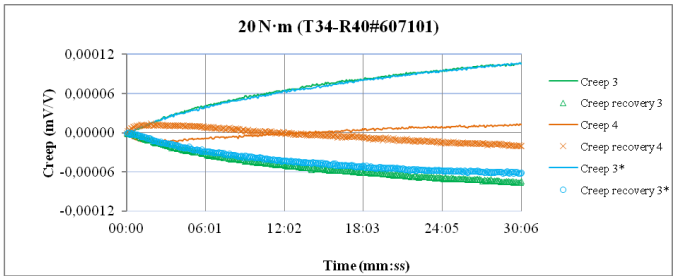

Figure 13: Effect of humidity on the creep of a 20 N·m torque transducer

Table 2 shows the values of the effect of the relative humidity on torque transducers. Different factors are used; K_3 is the humidity-creep ratio of the creep over 30 minutes relative to that over 3 minutes, K_4 in % / (% R. H.) is the change of the creep value due to relative humidity change; a

linear relation is assumed, which is calculated following equation (2):

$$K_4 = \frac{\text{Creep}_{70\,\%\,\text{R.H.}} - \text{Creep}_{50\,\%\,\text{R.H.}}}{\text{Sensitivity}} \cdot \frac{100\%}{20\,\%\,\text{R.H.}} \qquad (2)$$

The values of K_4 show that the change of the creep values due to relative humidity change from 50 % R. H. to 70 % R. H. varied from 0.00006 % / (% R. H.) to 0.0003 % / (% R. H.) which is different than the results of [1] by about 35 %, which considered another reason to apply 30 minutes creep test.

Table 2: Effect of humidity on the creep of two torque transducers

Torque transducer	Rel. humidity		%	50	70	50	K_4
	Temperature		°C	22	22	22	
	Conditions code			3	4	3*	% / (% R. H.)
1 N·m (TT1#37102-03)	Creep	mV/V	3 min	-0.000011	0.000005	-0.000015	0.00012
			U, 3 min	0.000003	0.000002	0.000003	
			30 min	0.000025	0.00006	0.000035	
			U, 30 min	0.000004	0.000002	0.000003	
			K_3	-2.3	12	-2.3	
	Creep recovery	mV/V	3 min	0.000014	0.000006	0.000017	-0.00006
			U, 3 min	0.000004	0.000002	0.000004	
			30 min	-0.000026	-0.000045	-0.000014	
			U, 30 min	0.000004	0.000003	0.000003	
			K_3	-1.9	-7.5	-0.8	
20 N·m (T34-R40#607101)	Creep	mV/V	3 min	0.000023	-0.000013	0.000023	-0.00031
			U, 3 min	0.000004	0.000005	0.000004	
			30 min	0.000106	0.000013	0.000107	
			U, 30 min	0.000006	0.000008	0.000006	
			K_3	4.6	-1	4.7	
	Creep recovery	mV/V	3 min	-0.000019	0.000012	-0.000016	0.00019
			U, 3 min	0.000004	0.000005	0.000005	
			30 min	-0.000076	-0.00002	-0.000062	
			U, 30 min	0.000008	0.000006	0.000006	
			K_3	4	-1.7	3.9	

5. CONCLUSIONS

The effect of temperature and relative humidity on 3 minutes short-term creep and 30 minutes creep of torque transducers, is studied. The creep values increase with increase temperature while it is decreased for increasing relative humidity. The 22 °C temperature effect on the 3 minutes creep varies from 0.00001 mV/V to 0.000112 mV/V, while the 40 °C temperature creep varies from 0.000003 mV/V to 0.000187 mV/V. The 22 °C temperature effect on the 30 minutes creep varies from 0.00016 mV/V to 0.000290 mV/V, while the 40 °C temperature creep varies from 0.000013 mV/V to 0.000459 mV/V.

The 50% relative humidity effect on the 3 minutes creep varies from 0.00001 mV/V to 0.000103 mV/V, while the 70% relative humidity creep varies from 0.000002 mV/V to 0.000134 mV/V. The 50% relative humidity effect on the 30 minutes creep varies from 0.00009 mV/V to 0.000262 mV/V, while the 70% relative humidity creep varies from 0.000013 mV/V to 0.000204 mV/V.

With a linear model for the creep value change due to temperature change from 22 °C to 40 °C, the relevant coefficient (K_2) varied from 0.00015 % / K to 0.00062 % / K. With a linear model for the creep value change due to relative humidity change from 50% to 70%, the relevant coefficient (K_4) varied from 0.00006 % / (% R. H.) to 0.0003 % / (% R. H.). The 30 minutes creep test is recommended due to the large differences regarding to the 3 minutes creep test.

6. REFERENCES

[1] K. M. Khaled, D. Röske, A. E. Abuelezz, M. G. El-Sherbiny, "The influence of temperature and humidity on the sensitivity of torque transducers", Measurement 94 (2016) 186–200.

[2] D. Röske, "Key comparisons in the field of torque measurement", 19th International Conference on Force, Mass and Torque (IMEKO TC3): "Theory and Application in Laboratories and Industries", 19-23 February 2005, Cairo, Egypt. Link: http://www.imeko.org/publications/tc3-2005/IMEKO-TC3-2005-036u.pdf.

[3] D. Röske, D. Mauersberger, "On the stability of measuring devices for torque key comparisons", IMEKO XVIII World Congress and IV Brazilian Congress of Metrology, "Metrology for a Sustainable Development", 17-22 September 2006, Rio de Janeiro, Brazil. Link: http://www.imeko.org/publications/wc-2006/PWC-2006-TC3-040u.pdf.

[4] D. Röske, "Final report on the torque key comparison CCM.T-K1. Measurand torque: 0 N·m, 500 N·m, 1000 N·m", Metrologia, Volume 46, Tech. Suppl. 07006, Link: http://dx.doi.org/10.1088/0026-1394/46/1A/07002, 2009.

[5] K.M. Khaled, D. Röske, A.E. Abuelezz and M.G. Elsherbiny, "Humidity and temperature effects on torque transducers, bridge calibration unit and amplifiers", Measurement 74 (2015) 31–42.

[6] D. Peschel, D. Röske, "Determination of Creep Value Using Short-Term Creep", Proceedings of the XVth IMEKO World Congress, June 13-18, 1999, Osaka, Japan, vol. III, pp. 245-249.