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The influence of temperature and humidity on the sensitivity of torque transducers

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ABSTRACT

This paper presents a study of the effect of temperature and relative humidity on the sensitivity and the characteristics of torque transducers such as residual zero torque, reversibility and creep. Temperature and humidity coefficients of the sensitivity take positive as well as negative values. Linear dependence is found between the influence of temperature/relative humidity and the applied load. For some torque transducers, under temperature change the sensitivity has a transient overshoot reaching up to 3 times the steady amplitude. Also there is a small effect of temperature/relative humidity on the transducer's parameters such as residual zero torque, reversibility and creep. Equations are presented to predict the effect of temperature/relative humidity changes on the sensitivity of torque transducers.

1. Introduction

For many years, manufacturers of precision torque transducers have paid attention to the influence of temperature on the sensitivity and the zero signals, in order to provide the customer with a correction factor within the transducer's data sheet, whenever the temperature changes. This correction factor is presumed to have a linear time-sensitivity relation which is not the case for all torque transducers. Usually this factor does not provide information about the time needed to reach stability or its applicability for both increasing and decreasing temperature variations. Each manufacturer uses its own internal procedure to test the temperature effect. Dissimilar procedures could yield different results due to dissimilar test factors such as the maximum temperature, temperature rate of change, time, application of torque, and analysis of data. Users of torque transducers who have transducers without a correction factor, or even have old transducers, and want to know the stability of their correction factors need a reliable and acceptable testing protocol. Therefore, the present work considers these parameters to provide a temperature test procedure for conformity between manufacturers, calibration laboratories, as part of the calibration of torque transducers.

The influence of humidity on torque transducers is quite new. Manufacturers of torque transducers have not provided humidity correction factor so far. The significance of humidity was considered earlier for interlaboratory comparison [1–3] using a climate-controlled cabinet. The basic idea of the cabinet is to infuse water steam into the cabinet and then measure the induced relative humidity and the corresponding sensitivity change without providing closed loop automatic feeding or controlling the rate of changing humidity. The climatic cabinet used in this investigation is provided with a closed loop control system for controlling both the rate of humidity change and the humidity level which should provide better results. The influence of humidity on the zero signal of torque transducers was investigated [4] and found to vary from +3.3 to −9 nV/V per % relative humidity.

In this investigation, the influence of temperature and relative humidity is shown on the sensitivity and characteristics such as residual zero torque, reversibility and creep of torque transducers. Furthermore, the influence of changing rates of temperature and relative humidity on the sensitivity and characteristics of torque transducers are investigated.

2. Effect of temperature and humidity on the sensitivity of torque transducers

2.1. Design of the experiments

In these experiments the following equipment was used:

- 20 N·m deadweight torque standard machine.

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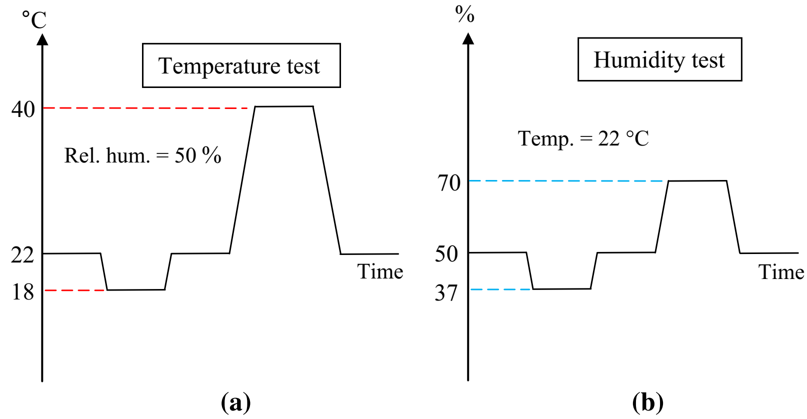

Fig. 1. Environmental test sequence for (a) temperature (left) and (b) relative humidity (right).

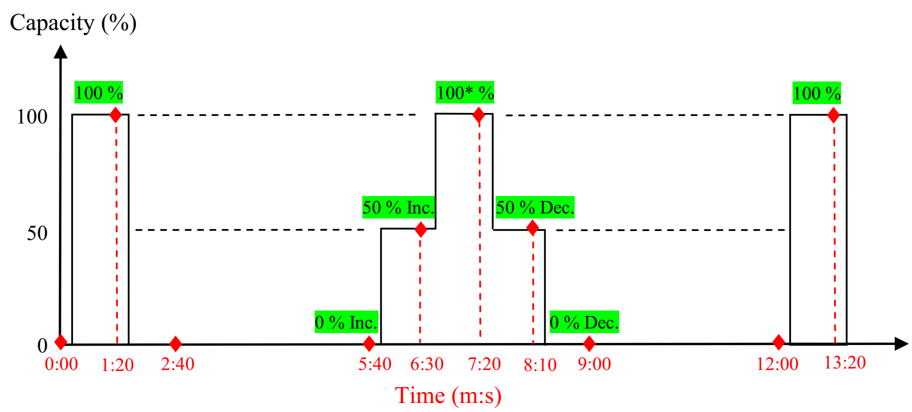

Fig. 2. Torque loading regime.

- Specially designed climatic cabinet with a temperature range of (15–40) °C ± 1 K (°C) and relative humidity range of (30–80)% ± 1%.
- Seven torque transducers (three different types) from 2 different manufacturers.
- DMP40 measuring amplifier. The settings of the amplifier are: filter of 0.22 Hz Bessel, signal reading is "absolute", measuring range is 2.5 mV/V, and the excitation voltage is 5 V.
- Temperature and relative humidity sensor (Manufacturer: Rotronic, type: HygroPalm-HP21, uncertainty: ±0.2 K (°C) 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. Fig. 1 shows the environmental sequence of the climatic cabinet while Fig. 2 shows the transducer's loading regime, which was applied consistently along the environmental sequence line. The machine experimental setup is shown in Fig. 3.

In order to estimate the waiting time needed to reach signal stability for each torque transducer, the values of the effect of temperature and humidity on the zero signal of each torque transducer were used. 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 (°C) and (45 ± 5)% humidity.

2.2. Results and discussion

2.2.1. Effect on the torque transducer's sensitivity

Figs. 4–10 show the effect of temperature change, followed by relative humidity change, on the sensitivity of the 7 torque transducers. In all the figures, the x-axis is the time in days, the left y-axis is the difference between the DMP40 values and the first DMP40 value, and the right y-axis is the temperature and relative humidity.

Figs. 6–10 show that the sensitivity of torque transducers is inversely proportional to temperature or relative humidity which means if the temperature or relative humidity increases, the sensitivity will decrease, whereas for the first two torque transducers type TT1 cage-shaped design from Raute (Figs. 4 and 5) the relation is directly proportional.

The torque transducers (type TT1 from the same manufacturer) used in Figs. 6, 7 and 9 were solid shaft design while the torque transducers used in Figs. 4 and 5 were cage-shaped design and they show different response to temperature or relative humidity, therefore it seems that the design has an effect on the behaviour, but the physical reason for the different behaviour was not further investigated.

All tests showed that the effects of increasing temperature and increasing relative humidity on sensitivity are both in the same side, and vice versa.

Torque transducers in Figs. 6, 7, 9 and 10 show high influence (transient overshoot) during temperature change which reaches about 3 times the steady state effect. Therefore the effect of