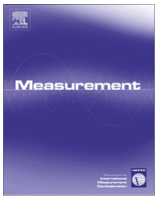
Measurement 74 (2015) 31–42

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement



Humidity and temperature effects on torque transducers, bridge calibration unit and amplifiers

K.M. Khaled [a,*], D. Röske [b], A.E. Abuelezz [a], M.G. Elsherbiny [c]

[a] National Institute for Standards (NIS), Giza, Egypt
[b] Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany
[c] Faculty of Engineering, Cairo University, Giza, Egypt

ARTICLE INFO

Article history:
Received 3 December 2014
Received in revised form 11 June 2015
Accepted 1 July 2015
Available online 15 July 2015

Keywords:
Torque
Relative humidity
Temperature
Bridge calibration unit
Amplifier

ABSTRACT

This paper presents a study of the effect of relative humidity and temperature on the DMP40 measuring amplifier and the BN100A bridge calibration unit. Furthermore, the effect of relative humidity on the zero signal of torque transducers is studied here. The results show that the DMP40 has a linear trend line with increasing relative humidity/temperature and also with an increase in the input voltage ratio. The developed equation is presented to predict the effect of relative humidity/temperature change on the DMP40 at any input voltage ratio by testing the DMP40 at both upper and lower relative humidity/temperatures for three input voltage ratios only. The stability of BN100A under relative humidity/temperature change is verified. The results show the symmetry of humidification and dehumidification effects on the zero signal of the torque transducer and there is good agreement between the developed characteristic equation using two exponential terms and the experimental results.

1. Introduction

Knowing the influence of relative humidity/temperature on electric/electronic measuring instruments, such as the DMP40 measuring amplifier and the BN100A bridge calibration unit, is of great importance in different metrological fields such as torque, force, pressure and mass metrology. This importance comes from the fact that the DMP40 is the most precise amplifier used in these fields for regular calibrations and tests and also during interlaboratory comparisons. The BN100A is considered to be the most stable bridge calibration unit. Therefore, knowing the behaviour of both instruments under relative humidity and/or temperature change is useful for uncertainty calculations and also for measurements corrections. Röske in [1] and Chunqian et al. in [2] test the uniformity of measured values in interlaboratory comparisons using DMP40 and BN100A. In this paper, a study of the influence of relative humidity/temperature on the DMP40 measuring amplifier at different input voltage ratios and at different relative humidity/temperature levels was carried out to determine the relative humidity and temperature coefficients and the linking relations. The stability of the BN100A bridge calibration unit under relative humidity/temperature change was also examined.

Studying the effect of relative humidity on the zero signal of torque transducers is to observe the time-response of the torque transducer to find out the time needed to reach stability for comparison or calibration measurements carried out under laboratory conditions or for on-site measurements in industrial applications. The authors suspect that humidity and temperature are mainly responsible for so-called drift and partially responsible for the zero signal changes in transducers. Stability of the zero signal is considered purposive as well for long-term measurements.

---

[*] Corresponding author.
E-mail address: khaled_fmmd_nis@yahoo.com (K.M. Khaled).

http://dx.doi.org/10.1016/j.measurement.2015.07.007

Brüge in [3] introduces simplified methods to measure the relative humidity coefficient of torque transducers in calibration laboratories and found that the relative humidity effect on transducers is $-5 \cdot 10^{-6}$/%. Even in an air-conditioned and temperature-controlled laboratory the relative humidity of the ambient air can vary by a few percent during a measurement. Therefore, laboratory work or comparisons made under different relative humidity conditions are affected and comparability of torque measurements may differ at a relative level of 10^{-5}–10^{-4} in which the influence on the electronic instruments is not taken into account yet. The study of the influence of relative humidity is even more important in the industrial field when torque transducers are used in industrial applications at relative humidity conditions highly differing from the calibration conditions or when measurements are done under uncontrolled relative humidity conditions. Torque calibration standards [4–6] did not require an environmental test, only [7] provides a temperature test for the calibrated torque transducer. Thus the classification of the torque transducer did not include a humidity parameter like other standards which work in the field of weighing instruments [8,9] which provide a specific test for humidity.

Brüge [3] presumed that the influence of humidity is due to the hygroscopic behaviour of the strain gauges and the adhesive layer which change their mechanical properties, while Sanponpute et al. [10] presumed that the humidity stability does not mainly come from moisture absorption of the stain gauge directly, but rather comes mainly from electrical properties of the bridge strain gauge circuit, especially the impedance. To appreciate the complexity of the humidity effect, it is useful to consider the torque measuring instrument as a system of elements. The strain gauge torque transducer consists of an elastic element, an adhesive layer, a strain gauge, lead wires, a protection adhesive layer, precision resistors, connection ends to transmit the applied torque, and in some transducers there are temperature, bending load an axial load compensation circuits and/or a hermetic seal. Absolute and relative humidity as well as temperature usually vary due to the weather conditions. Depending on these conditions, the ambient air may be dry or wet, warm or cold. Even if the absolute humidity is constant, its relative value can change as a result of temperature changes, and some torque transducer components be subjected to change in their mechanical and/or electrical properties. Thus, the temperature and humidity effects on torque transducers involve a complex combination of several interrelated time-dependent processes. This situation suggests that a direct empirical study of the response of the torque transducer as a whole under stable weather conditions using special climatic chambers needs to be carried out.

2. Effect of relative humidity and temperature on DMP40 amplifier

2.1. Design of the experiments

In these experiments the following equipment was used:

- A very stable climatic chamber with inner dimensions of $(0.7 \times 0.8 \times 0.8)\,\mathrm{m}^3$, temperature range of (283.15–363.15) K and relative humidity range of (15–95)%.
- Three DMP40 measuring amplifiers coded $P1$, $N1$ and $N2$. The settings of the amplifiers 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.
- A very stable bridge calibration unit BN100A. The range of experiments is from 0 mV/V to +2 mV/V with a step +0.2 mV/V and from 0 mV/V to −2 mV/V with a step −0.2 mV/V. A shielded cable is used to connect the DMP40s with the BN100A.
- Two sets of temperature and relative humidity sensors (Manufacturer: ALMEMO, Type: FHAD3Rx, Uncertainty: ±0.1 K for temperature and ±1% for relative humidity): one set inside the chamber and the other set outside.

Each DMP40 was placed inside the chamber individually and the BN100A was placed outside the chamber and connected through a hole in the chamber’s wall. Furthermore, the DMP 40 is connected to a PC through an RS 232 serial cable with developed interface software for automatic continuous recording. For each BN100A step, 20 measurements, one every second, are recorded and the average is presented in the figures. The warming up time for the DMP40 and the BN100A is observed, also the time needed for DMP40’s low pass filter to work.

For the relative humidity investigation the climatic chamber was set to 35% and constant temperature and the BN100A was set to 0 mV/V for about 4 h. Next the BN100A set point was changed as previously mentioned and the corresponding DMP40 values were recorded. Then the relative humidity was increased by 5% and the sequence was repeated up to 80%. The effect of relative humidity under different temperatures is also tested by repeating the experiments for DMP40 codes $P1$ and $N1$ at 15 °C, 22 °C, 31 °C and 40 °C. For the DMP40 code $N2$, experiments were conducted at 22 °C for 35%, 40% and 80% only. All measurements started at 35% relative humidity except the measurements carried out at 15 °C which started at 40% relative humidity due to equipment limitations. Also all measurement ended at 80% relative humidity except the measurements carried out at 40 °C which ended at 50% relative humidity due to DMP40’s environmental limitations.

For the temperature investigation the climatic chamber was set to 22 °C and 35% and the BN100A was set to 0 mV/V for about 4 h. Next the BN100A set point was changed as previously mentioned and the corresponding DMP40 values were recorded. This sequence was repeated at 23 °C, 31 °C and 40 °C. The effect of temperature at different relative humidity levels was also tested by repeating the experiments for the DMP40 codes $P1$ at 35%, 50% and 80%. All measurements started at 15 °C except the measurements carried out at 35% relative humidity which started at 22 °C due to equipment limitations. Also all measurements ended at 40 °C except the measurements carried out at 80% relative humidity which ended at 31 °C due to DMP40’s environmental limitations.