“TN” torque transfer standard with improved usability for inter-laboratory comparisons

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Abstract. Torque reference transducers, serving as transfer standards for the mechanical quantity torque, are usually based on strain-gauge technology. To be able to benefit from the advantages offered by a complete monolithic design in NMI applications, one has to choose a shaft-type torque transducer, which requires an “open” design, meaning that the strain gauge cannot be hermetically sealed. The strain gauge is therefore dependent on environmental conditions. As torque transfer standards are meant for inter-laboratory comparisons, its usability under changing conditions is of major importance and therefore critical to duration and success of the procedure. Therefore a detailed analysis of the application conditions of “travel standards” during inter-laboratory comparisons resulted in ideas that have been implemented in the new “TN” torque transfer standard and to the high precision electronics.

1. Introduction
Driven mostly by automotive industry, an increasing number of national metrology institutes (NMIs) has made the experience that it is not enough to trace back the quantity torque based on force and length, but a dedicated laboratory and dedicated research for torque has to be established. To master the challenges in industry it is becoming increasingly important to ensure that the quantity torque is realized and disseminated according to the stated and gradually further reduced uncertainties. Thus, measurement chains, consisting of transducers and precision instruments provided for torque key comparison used in these torque laboratories have to fulfil tight requirements.

Torque reference transducers, serving as transfer standards for the quantity torque, are usually based on strain-gauge (S.G.) technology. Such transfer standards are important for the comparison of standard machines. First of all precision measurement chain, consisting of a reference transducer and a high precision amplifier, must be portable to allow for use as a stable “travel standard” for inter-laboratory comparisons. Depending on these varying conditions on the journey from laboratory to laboratory there is a time needed to adapt to the climate in the laboratory, necessary to start measurement.

By the principle used in the transducer, beside of temperature, nowadays also humidity needs to be carefully considered as a significant source of uncertainty. Humidity deserves special attention, as “open” strain-gauge transducer designs are known to be influenced by humidity due to the hygroscopic behavior of carrier of the foil-type S.G. Hygroscopic substances accumulate in water. In case the carrier of the strain gauge absorbs the water. You may imagine it like a sponge, what sucks the water from the environment. The resulting change of the mechanical properties of the strain gauges in the Wheatstone bridge, as well as external, additional resistances, can affect the strain-gauge bridges’ behavior. When such a S.G. based and “open-design” torque transducer is exposed to
varying humidity levels, it displays a response in both sensitivity and zero signal. The effect on the zero signal is often much higher than the change in sensitivity, however, most of it can be compensated by taring. Only the relatively small deviation of the zero signal taking place during the – relatively short – loading time cannot be compensated for by taring but it should be neglected here. The impact on the sensitivity of the measurement, however, is essential for the uncertainty budget and the outcome of the inter-laboratory comparisons. It is thus essential for usability in inter-laboratory comparisons. For this reason, questions related to environmental stability foil-type S.G. have been asked by several NMIs. Usually, glass fiber reinforced phenolic resin has been used as a carrier material of the strain gauges used in the reference transducers [2]; [3]; [4].

2. A new torque transfer standard
The “TN” series has been HBM’s top-of-the-line torque transfer transducer series for already some decades. According to its purpose, it is a non-rotating, shaft-type reference torque transducer, specifically for the use as a transfer standard in calibration laboratories in compliance with DIN 51309. As mentioned before, it is part of the equipment used in NMIs for the quantity torque, as well as in secondary laboratories of accredited bodies such as DakkS, JCSS or others.

![New TN torque reference transducer](image1)

![New carrying case with sealing lip](image2)

Due to its importance in the traceability chain, the set up but also the scope of supply of this transducer now has been revised. As a result, the formerly often requested bending moment option is now offered in the standard scope of supply. That means that the new TN torque transfer standard device is, beside of the torque channel, equipped with two bending moment channels in the X & Y directions, allowing the examination of possible misalignments.

In addition, the sensor now also comes with a new carrying case in the standard scope of delivery. This carrying case is equipped with a special sealing lip that provides good mechanical protection as well as good separation of the contents from the outside air.

With the provided wider standard scope of supply, only one ordering number and type per measuring range will be necessary in the future, making it easier to provide customers with a single version per range in a more time-defined way. The transducer is offered for nominal torques of 100, 200, 500 N•m and 1, 2, 5, 10 and 20 kN•m.

Because of the special application requirements, however, some frame conditions had to be considered. Two main design choices for a reference torque transducer are shown in Fig. 3 & 4.

![Different types of flange type torque transducers](image3)

![Shaft type torque transducer](image4)
Fig. 3 shows different versions of flange type torque transducers. This design choice is best for high stiffness and restricted space conditions e.g. in test stands. NMIs often require shaft type torque transducers for their mounting configuration and for offering a monolithic shaft as a measuring body. However for this design choice it is difficult to hermetically encapsulate the S.G. Thus the signal of the S.G. could be influenced by the humidity of the ambient air.

3. Sensitivity to humidity

Sensitivity to humidity is not only a topic for the transducer, but for the entire high-precision measurement chain. This fact seems to be not so important because most NMIs do not have climate-controlled laboratories. However, recent investigations have shown that, as error images of humidity can be so various, it is worthwhile to work toward climate-safe reference chain components, i.e., transducers and electronics. Regarding transducers based on S.G. the NMIs have been addressing the problem for some years already. It turned out that, for a shrinking measurement uncertainty budget, the influence of humidity cannot be neglected anymore [5].

3.1. Influence of humidity on “open” foil-type strain gauges

In this chapter the properties of PEEK as a relatively new carrier material and its use for foil-type S.G. should be described. PolyEtherEtherKetone (PEEK) is an organic thermoplastic polymer used in engineering applications such as automotive & aerospace, as well as in medical and pharmaceutical applications, due to its excellent mechanical and chemical resistance properties that are retained at high temperatures. PEEK is a semi-crystalline thermoplastic, i.e., not amorphous, but partly crystalline. PEEK offers a high melting point, reduced humidity absorption (compared to Kapton and to glass fiber reinforced phenolic-resin carrier material) and additionally, a quite good resistance against most chemicals. To sum it up, compared to glass fibre reinforced phenolic resin, PEEK carrier material shows significantly lower humidity absorption, at approx. a ratio of one to six.

In Figure 5, the signal change due to moisture absorption for the following three types of strain gauges are compared. They are PEEK, polyimide and glass fiber reinforced phenolic resin. The chart shows maximum values for utilization in a full-bridge design, while only one S.G. is exposed to humidity. Measurements have been taken at a temperature of 50 °C and 95 % relative humidity.

PEEK offers an excellent stability against moisture, which is the main reason why strain gauges used for the new TN transducer are now based on exactly this carrier material, which ensures excellent metrological properties – and makes them suitable for transducers with high accuracy requirements. Additionally, the carrier material is also quite easy to use during installation and allows small curvature radii, which is important for radially symmetric transducers with strongly curved surfaces.
The used special PEEK S.G. carrier also in terms of thickness is much thinner than glass fiber reinforced phenolic resin, and thus the hygroscopically relevant volume is much smaller. The carrier’s hygroscopic behavior can again be visualized using the image of a sponge: the smaller its volume, the less moisture will be absorbed.

3.2. Influence of humidity on high-precision instruments for S.G. based measurement

Electronics are also influenced by humidity and, in terms of precision electronics, stability plays an important role. This is why the so-called “climate safety of electronic assemblies” has been a research topic already [6]. It was found that, apart from incorrect measurement results, error images such as electrochemical migration, leakage currents, flashover, solder joint load, and corrosion may occur. In the stability of BN100A under humidity and/or temperature change has been verified, while DMP40, the now not any more produces predecessor of the present high precision device, still seemed to show a slight linear trend line with increasing humidity or temperature [7]. This is also the reason why one has to pay close attention to this point: in the selection of electronic components, but also in such factors as the instruments’ inner space and even in the housing design, such as our guideline use of metal housings [8]. It was also pointed out by another source [9], that due to necessity of the condensation of water at the inside wall the cabinet the use of metal housing is essential for building up precision amplifiers.

4. Meeting the requirements for inter-laboratory comparisons

As pointed out before, the practical problem during inter-laboratory comparisons is not only the use in the lab but also the transport route from one laboratory to another [10]. Problems with the use of transfer standards may occur on their “journey” for comparison measurements from country to country, for instance, during the transport in the cargo space of intercontinental flights, where the devices often are stored at about 5° C for many hours and, after the arrival, for example, in tropical countries immediately exposed to 30° C for hours of waiting on the runway/airfield of an airport.

Therefore, the usefulness of the new carrying case with a special sealing lip is not to be underestimated. It effectively preserves the “microclimate” around the transducer. To use this effect, it is recommended to directly pack the transducer in the laboratory environment and to close the carrying case tightly, so that one “takes along” the ambient air of the lab. When arriving at the “next” laboratory in the daisy chain of the “inter-laboratory comparison”, it is essential to wait for an appropriate time, until a new balance in terms of humidity and temperature is reached. Some NMIs have expressed that they need a better device coping with 40 ± 2 % relative humidity with a change of a few ppm only. Other institutes even demand similar stability for much bigger humidity changes. It can thus be assumed that the described measures are highly desired and they will improve the suitability for the application.

5. Conclusions

TN transducer is a top-of-the-line model for torque reference applications. It can be used as a transfer standard for comparison and for traceability in torque calibration systems, as well as a reference sensor in calibration laboratories using the reference principle [11]; [12]; [13]; [14]. Under the given design choices, the improvements for the sensor itself and in conjunction with a new carrying case providing good mechanical protection as well as good insulation from different environmental conditions. It is an important progress.

Generally, a reduction in moisture sensitivity due to the use of a less hygroscopic material also allows shortening the above-mentioned time of sufficient “balancing” before starting the measurement. The necessity has been repeatedly noted in scientific articles of the PTB and other NMIs [15]; [16]. More recent results of humidity investigations are published in [17] as well.

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6. References

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