Hermetically Sealed Torque Transfer Standard with Extremely Low Parasitic Sensitivity

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Abstract

A new design of strain-gauge torque transducer has been developed which is hermetically sealed and especially suitable for low nominal torque capacities. Apart from high basic repeatability, the major design aim was a high degree of insensitivity to parasitic forces and moments. In order to fulfil both requirements, a sensing element shaped as an elastic hinge was chosen. Theoretical considerations and measuring results confirm the characteristics which were aimed to be achieved. The particular design and the metrological performance make the new sensor ideally suited for applications as reference transducer and torque transfer standard.

1. Introduction

The output signals of torque transfer standards are expected to be independent of disturbing influences to a high degree of precision. In order to examine and verify the characteristics of a torque calibration machine it is necessary to quantify the measured quantity (torque) isolated from other forces and moments which are potentially present as well. Such disturbing influences should be analysed as separately measured signals.Torque calibration machines due to their design and construction are likely to suffer from small alignment errors, both radial and angular axis displacements are possible.

Such alignment errors cause additional loads (forces and moments) to the transducer mounted to the machine. The rated torque output of transfer standards must be independent of such parasitic loads. Nevertheless, these parasitic influences should be measured and analysed, for which additional instrumentation is required. The same type of torque transducer as used for transfer standards is also used as a reference in torque calibration machines which are based on a comparison principle, in order to achieve the highest possible accuracy.

Usually in one size of machine several measuring ranges are arranged, which means that the reference transducers have to be exchanged frequently. Changing the reference transducers should only have negligible effects, especially with respect to disturbing forces. In order to achieve this, good axial alignment and the use of couplings as recommended in DIN 51309 are required.

Another requirement for transfer transducers is stability over time. In the past, this was difficult to achieve over medium and long periods, as most sensor designs did not allow hermetically sealing, e. g. by welding. The result was that changes in temperature, humidity and air pressure caused the characteristics of such transducers to shift, particularly during transportation. Ideally, torque transfer standards should be sealed and protected against the environment in the same way as force transfer standards are, i. e. by welding, brazing or potting. This would allow achieving uncertainties in torque comparisons similar to those usual in force measurement

2. Design

The use of strain gauge technology for the transfer standards and reference transducers prohibits the realisation of

arbitrarily small capacities with cylinder-shaped sensor elements. A new design of the sensor body allows small torque capacities with the highest possible accuracy based on the principle of an elastic hinge. The sensitivity to disturbing influences such as bending moments, lateral and axial forces are minimal.
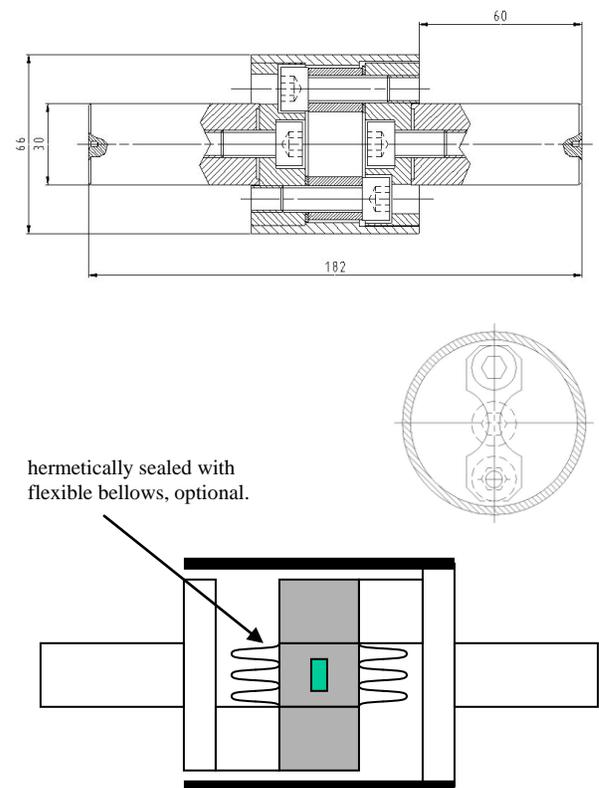

hermetically sealed with flexible bellows, optional.

Figure 1. Main dimensions, cross section schematic section of sealed version

In order to mount the torque transfer standards, shaft ends according to DIN 51309 are provided; see Fig. 1 for design and dimensions.

3. Theoretical Model

3.1. Torque Path in the Torque Transfer Standard

The strain-gauged (sensing) section of the sensor body is in a neutral position with regards to disturbing influences. Fig. 2 shows schematically the construction of such a torque transfer standard.
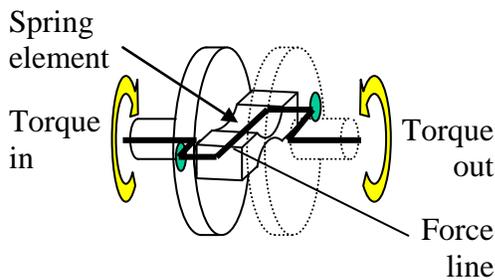

Figure 3. A cross section through the elastic hinge

Figure 2. Schematically constrution

The bending spring is arranged at 90°relative to the measuring axis. Flanges fixed to both sides (green dotted lines) transfer the acting torque from the shaft ends into the bending spring.

Fig. 3 shows a cross section through the elastic hinge (bending spring) and also indicates the deformation caused by the acting torque.
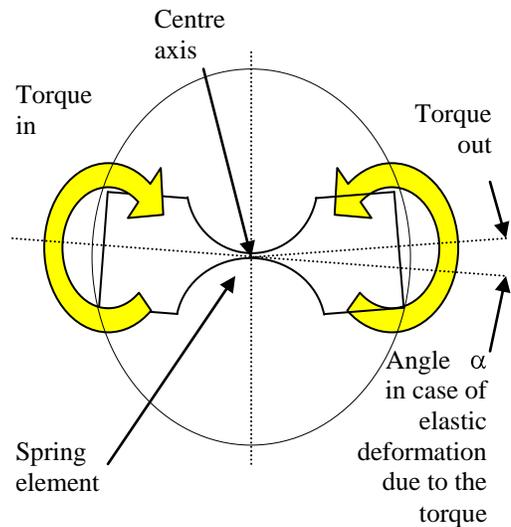
The main direction of deflection is designated by the angle α.

3.2. Low Parasitic Sensitivity

The weight force of the torque transducers mainly causes bending moments around the transverse axes of the transfer standard. In Fig. 4, the deformation caused by such a bending moment is shown, assuming it acts around the longitudinal axis of the bending spring, which suffers torsional deflection as depicted in the figure 4.
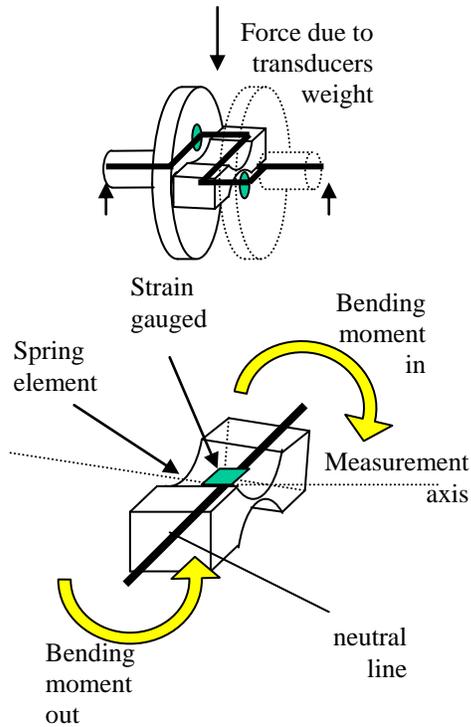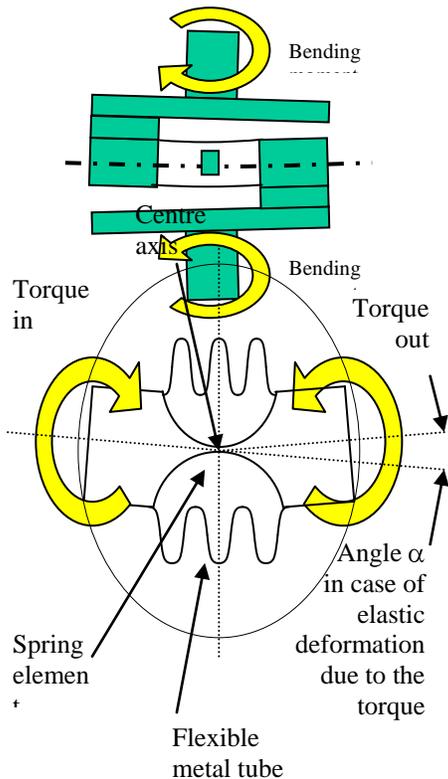
Figure 4. Deflection due to the bending moment

If a bending moment around the other transverse axis is present, i. e. around an axis that lies at right angles to both the

transducer's and the elastic hinge's longitudinal axes, pure bending of the sensor element is the result, see Fig. 5. As the strain gauge application is symmetric to the neutral axis of the element, there are no influences on the output signal. The insensitivity to axial forces is explained in Fig. 6.
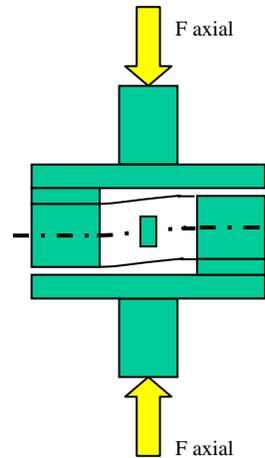
The deformation is S-shaped, causing shear

Figure 6. Deflection in case of axial force

strains to the sensing section. Assuming good alignment of the individual gauges, the net effect of such stresses at 45° to the sensor axis remains zero.

336

4. Measuring Results

The first test results confirm the advantages of the described design. Fig. 7 shows the readings taken from a 20 Nm D-TN transducer for both clockwise and anticlockwise direction in one diagram. The test was in accordance with DIN 51309, using three rotational positions for each direction. The deviations are relative to the full scale output, in order to be able to include the zero return value. The reproducibility in changed mounting positions according to DIN 51309 is less than 3×10^{-5}.
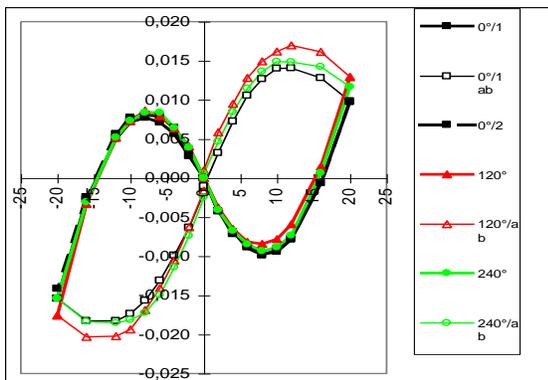

Figure 7. First results of calibration in acc. to DIN 51309

5. Future Optimisation

As stated above, the sensor element was designed such that welding can hermetically seal it. The design relies on a stainless steel bellows surrounding the instrumentation, and laser-welded to both ends of the bending

spring. From Fig. 8 it will become clear that the deformation of the spring causes no volume change to the bellows, as one side is compressed as much as the other is expanded.

Since the bellows are very thin and flexible, their contribution to the output signal (torque shunt) is small. Welding causes a permanent, hysteresis-free connection between the bellows and the sensor, making relative movement impossible. This means that – as usual in load cell (force measurement) practise – the environmental protection becomes part of the sensor, and is calibrated with it. From load cell experience it is known that once the complete sensor has been calibrated, its characteristics will not change measurably even over long periods of time, as long as mechanical and thermal overloading is avoided.

This should allow to achieve another significant improvement of reliability and measuring uncertainty. Trials to this extent are currently being carried out.
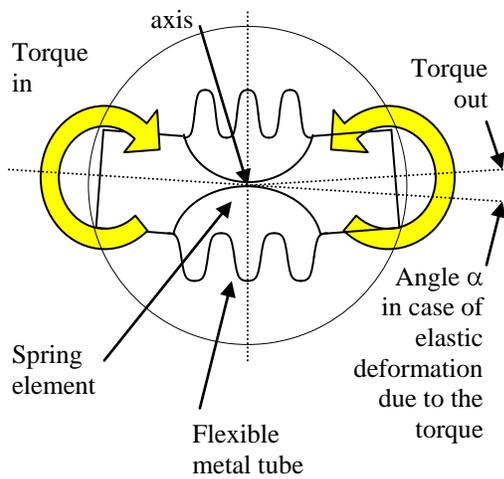
Figure 8. Covered version in cross section

7. References

[1]. Gassmann H., *GTM Gassmann Theiss Messtechnik,* Germany D 64404 Bickenbach

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