Measuring shaft torque in challenging environments

Measuring torque on rotating shafts on a test rig is one thing, but real world applications can present challenges for torque transducers. Mark Ingham of **Sensor Technology** looks at different torque measurement principles explaining the advantages of surface acoustic wave technology

In heavy duty applications in marine, agricultural, renewable energy, offshore and materials handling industries, as well as more specialist or exotic sectors such as aerospace or Formula 1, the torque sensor may well have to deal with dust, dirt, condensation, extremes of temperature, vibration, and more. In addition, we always have to consider the effects of electrical noise and electromagnetic interference in the environment.

Let's consider, then, torque measurement instruments built on the most widely used principles – strain gauges, phase measurement, magnetism and surface acoustic waves – and see how they compare in these challenging environments.

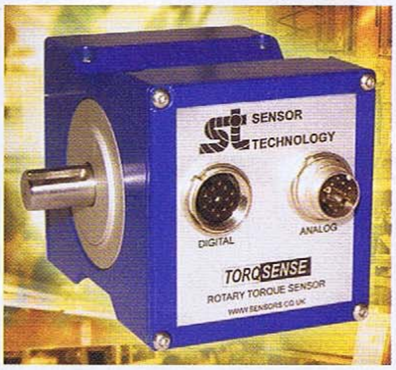
A quick recap first on the different torque measurement principles. The strain gauge is a torque sensor that is bonded directly to the shaft, with connection to the signal conditioning unit using either slip rings inductive coupling. Where slip rings are used, contact is made via brushes. Where inductive coupling is used, either a rotary transformer or radio telemetry can be employed. In a rotary transformer arrangement, either the primary or secondary coils rotate with the shaft. In a radio telemetry system, a stationary antenna induces power in the loop antenna of the rotating shaft, powering the strain gauge transmitter. The strain gauge information is encoded as a frequency modulated signal. A stationary coil placed nearby picks up the signal and feeds a decoder.

Phase measurement techniques can be built around various different sensor technologies, including optical, proximity and displacement. The principle is similar for each: if sectioned or toothed discs are mounted at either end of the shaft, offset from one another, then the relative movement of the two discs is proportional to torque and can be detected.

Torque measurement systems built around optical sensors can also provide a useful solution. If sectioned discs are mounted at either end of the shaft, offset from one another, then the relative movement of the two discs changes the effective aperture in a way that is proportional to torque. With no susceptibility to electromagnetic interference and noise, the optical technique can provide a useful method of torque measurement. Capacitive sensors can also be used, in a device that measures the change in capacitance as the twisting shaft changes the gap between two charged plates.

Magnetic measurement techniques are built on the principle of changes in magnetic field of a material as it twists. The resulting changes in magnetic field are proportional to the applied torque, and can be measured by magnetic field sensors, enabling the torque value derived.

Surface acoustic wave technology (SAW), measures the resonant frequency change of surface acoustic wave devices in a non-contact manner when strain is applied to a shaft to which SAWs are fixed. The applied torque causes a deformation of the quartz substrate of the SAW device, which in turn causes a change in its resonant frequency. In Sensor Technology's TorqSense range of products, two SAWs made of ceramic piezoelectric materials containing frequency resonating combs are glued onto the shaft at 90 degrees to one another. As the torque increases, the combs expand or contract proportionally to the torque being applied. An adjacent RF pickup emits radio waves towards the SAWs, which are then reflected back. The change in frequency of the reflected waves identifies the torque. So how do these different technologies stand up in demanding environments?



Sensor Technology has pioneered a range of surface acoustic wave (SAW) devices which can accurately and reliably measure torque in challenging environments

Vibration

Strain gauges: Where slip rings and brushes are used, excessive vibration can quickly cause wear, which will quickly impact on the reliability of the output and lead to premature failure. In radio telemetry products, maintaining the correct antenna gap is critical, and excessive vibration can impact on this.

Phase measurement: Reliable operation depends on accurate alignment of the discs and sensors. If vibration causes any shift in position of the sensing elements within the transducer, the reliability of the output is compromised.

Magnetic: Relatively immune to the problem of vibration.

Surface acoustic wave: Excellent resistance to mechanical vibration.

Temperature

Strain gauges: Relatively immune to changes in temperature, although large swings can cause condensation which can impact on the electrical connections of slip rings and bushes, as well as promoting corrosion.

Phase measurement: Critical disc tooth or aperture dimensions can change with temperature, impacting on the reliability of the torque reading.

Magnetic: Permeability can vary with temperature.

Surface acoustic wave: Inherently insusceptible to changes in temperature, although for absolute reliability sensors are integrated to monitor shaft temperature for better compensation and accuracy.

Dust and dirt

Strain gauges: Brushes can be compromised by dirt, impacting on overall reliability.

Phase measurement: The operation of optical sensors will eventually be compromised by a build up of dirt, whilst dirt or debris collecting on the discs can cause a false reading.

Magnetic: Relatively Insusceptible to dirt and dust

Surface acoustic wave: Inherently able to withstand dirt and dust.

Noise/electromagnetic

Strain gauges: Slip ring/bush connections can generate high levels of electrical noise, and are susceptible to electrical noise. Transformer and RF coupled strain gauges can compromised by electromagnetic interference.

Phase measurement: No susceptibility.

Magnetic: Permeability can vary.

Surface acoustic wave: Not susceptible.

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