TECHNICAL WHITE PAPER

Shaft Encoders & Bearingless Encoders

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This short paper discusses shaft encoders and bearingless encoders; their relative merits and where design engineers might deploy each type.

A shaft encoder is probably what most design engineers imagine when they think of an encoder. Typically, they look like a small can with a shaft poking from one end – turn the shaft and the encoder outputs an electrical signal according to angle or change of angle. Inside most shaft encoders, there's an opto-sensor and a grating which is attached to the encoder's shaft. As the shaft rotates, the grating interrupts the sensor's light path and an electrical pulse is produced.

Pretty straightforward, eh? Well, actually, in many instances yes - if you're measuring to modest accuracies in benign conditions, the ubiquitous shaft encoder will work well. These devices are compact and widely available in standard sizes – most notably size 22 or 58mm diameter.

However, if you need to measure angle to $<1^{o}$ accuracy in a tough or outdoors environment, such encoders may not be a designer's best choice. There are various problems. Firstly, optical sensors aren't that robust and don't like temperature extremes (-20 to +70C is a typical operating temperature range); foreign matter (such as water, oil, dust or even fluff) or any rough treatment in terms of impact or shock (it can break the grating). Condensation affecting the opto-sensor is a classic failure mode for outdoor equipment.

One option is to use a shaft encoder that's based on a sensing technology other than optical. Options include capacitive, magnetic or inductive techniques. Unfortunately, capacitive sensors are just as unreliable in nasty environments as optical devices. Magnetic sensors can work well in tough conditions but have limited measurement performance and a susceptibility to DC fields. Inductive encoders – or incoders – are a more recent phenomenon but are increasingly being used as an alternative to traditional inductive devices such as resolvers or RVDTs (rotationally variable differential transformers). Resolvers and RVDTs have been the traditional choice in sectors such as heavy industry, aerospace, defence and medical where reliability is all important. Incoders use the same basic physics as resolvers and so offer similar levels of reliability and performance.

Inductive shaft encoders are more compact than their optical counterparts and, as well as being tougher, they also offer shorter axial length.

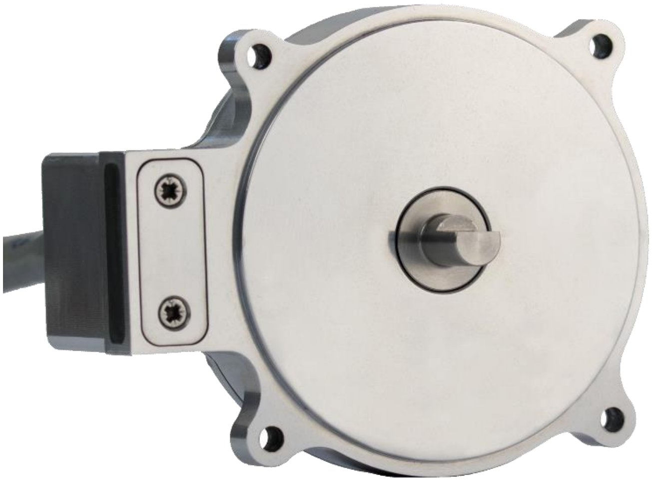

Figure 1 - A 58mm Shaft Incoder (Inductive Encoder)

Inside a shaft encoder, the shaft rotates in a bearing arrangement. The bearings are usually small and not designed for any significant load. This means that the shaft, to which the encoder connects, must be aligned along its axis so it doesn't fight against the encoder's own bearings. If there is misalignment, it's likely that the encoder's bearings won't last long.

If your installation tolerances are loose, one trick is to use a flexible shaft coupling to minimise the effect of misalignment. Flexible couplings work well but are typically not recommended if you're measuring angle to high accuracy. This is because angular displacement of the main shaft does not necessarily result in the same angular displacement of the encoder's shaft. This results in 'lost motion' or hysteresis and, in turn, measurement inaccuracy.

Bearingless Encoders

Another trick to avoid bearing alignment problems is to use a bearingless encoder. As their name implies, rather than the encoder using its own bearings, it relies on the host system's own bearings. Bearingless encoders typically come in two parts – a stator and a rotor. Typically, the stator that has an electrical connection (for power supply and data output) and so it's usually the stator that is fastened to the host system's main chassis, with the rotor fastened to the rotating element.

Figure 2 – A bearingless Incoder

As with shaft encoders, there are various sensing technologies and optical is the most common. Similarly, there can be problems with bearingless optical encoders – more usually referred to as ring encoders - if the operating environment is anything other than clean, stable and carefully installed. Typically, an optical ring encoder features a stationary read head and a rotating optical disc. If measurement accuracies are <1° then the installation tolerances of the optical disc relative to the read head need careful consideration. Notably, with high accuracy ring encoders, the tolerances required to achieve the headline measurement performance are only stated in data sheet's small print. Installation eccentricities of <0.025mm or <0.001" are not uncommon for some optical ring encoders.

Alternative approaches include inductive ring encoders, which still work reliably if they are in extreme temperatures (e.g. -60 to 105C) or covered in dirt. They are also much more tolerant to installation misalignment since their basic physics uses the planar faces of the stator and rotor, rather than the point measurement of a single, optical read head. Such inductive ring encoders are increasingly preferred over the more traditional 'pancake' or 'slab' resolvers which have become expensive and difficult to source in recent years.

The biggest reason, however, to use a bearingless encoder is size and shape. As stated previously, shaft encoders are compact and although they are available in through shaft (or hollow shaft) designs they are rare and expensive when the through bore needs to be bigger than couple of inches or 50mm. This is where bearingless encoders are particularly useful to a designer. Their inherent form factor means they are well suited to arrangements where low axial height and/or a large bore are needed. The large bore enables cables, piping or mechanical elements to readily pass through the middle of the encoder.

Conclusion

As with many aspects of equipment design, it is often the case that one technique is not necessarily 'better' than the other. Shaft encoders and bearingless encoders are each suited to different design approaches. Shaft encoders are compact and easy to deploy – bearingless encoders eradicate the need for bearing alignment and suit designs where low axial height and big a bore are required.

Further Information / Contact

For more information about Zettlex ring encoders, or to discuss your application with an angle sensor expert, please contact Zettlex directly or speak with your nearest local representative.

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