

Application note: Reducing machine tool costs of ownership with FORTiS™ enclosed linear encoders

Considerations for machine tool specifications, use, and maintenance

Adoption of enclosed linear encoders, also known as 'sealed linear encoders' or 'linear scales', is widely accepted as a key consideration when specifying high accuracy machine tools. When error mitigation schemes, such as design refinements, temperature control, and error mapping, have been considered, the linear encoder can still deliver further improvements to machining accuracy, repeatability, and surface finish. Moreover, for some machine design specifications linear encoders may sufficiently mitigate the effects of temperature variation and ballscrew wear to eliminate the need for other independent compensation systems. Irrespective of the fundamental machine design and its integrated auxiliary systems, it's an inescapable fact that linear encoders for linear axes cannot make a bad machine good but will make a good machine perform better.

As demand for ever higher performance machines grows, so does interest in the benefits offered by closed loop positioning systems and the direct feedback delivered via linear encoders.

Why specify a FORTiS enclosed linear encoder?

For decades machine tool builders and industrial users have recognised the Renishaw brand for calibration, probing, tool setting, gauging and coordinate measurement.

Renishaw has also developed a large open encoder product range based on modern optical technologies. These industry-proven encoders are used for precision metrology and motion control applications across a broad range of applications and industries.

Renishaw's years of experience in machine tool applications, metrology, position measurement and motion control were applied to the development of a new, innovative enclosed linear encoder that offers distinct advantages over present conventional enclosed optical encoders.

Enclosed linear encoders for use in harsh environments have been available for many years and follow a common set of design features, such as mounting hole arrangements, enclosure sizes, and internal mechanisms to provide guidance for the readhead over the scale. The FORTiS™ encoder series uses conventional form factors and bolt hole arrangements but benefits from an innovative non-contact mechanical design.



FORTiS-N readhead



FORTiS-S readhead



How is the FORTiS encoder different?

Minimising the time and effort required to install an encoder in a machine is essential. FORTiS encoders are form and fit compatible with other conventional designs of enclosed optical encoder. Measuring lengths are also matched to existing machine designs, with the FORTiS-S™ (standard) model ranging from 140 mm to 4,240 mm and the space-saving FORTiS-N™ (narrow) model from 70 mm to 2,040 mm. These encoders are available with most popular controller communication protocols and with resolution options from 50 nm to 0.5 nm. Multi-readhead systems and Functional Safety variants are also available.

However, the internal structure of the FORTiS encoder system includes a range of innovative new features that are distinctly different to conventional enclosed encoder designs.

Instead of glass, the scale is made of tough stainless steel, which is more robust and has a coefficient of thermal expansion (CTE) of $10.1 \pm 0.2 \mu\text{m}/\text{m}/^\circ\text{C}$, similar to the CTE of base materials used in most machines. The matching of CTE values helps reduce errors due to thermal effects whilst increasing measurement certainty.

Low positional noise (jitter) of below 10 nm RMS and low Sub-Divisional Error (SDE, the error within a scale period) of just ± 40 nm enables encoder feedback of superior fidelity, to ensure smoother velocity control and rock-solid positional stability.

The single track, fine pitch ($30 \mu\text{m}$) optical scale is read by a miniature ultra-high speed digital camera, housed in a sealed readhead to offer greater contamination resistance, as shown in Figure 1. The readhead moves over the scale without any contact, offering significant advantages over conventional encoder designs having contact guidance mechanisms with delicate roller bearings and springs.

Removal of internal moving or sliding parts eliminates wear, minimises risk of scale breakage, and improves reliability, ensuring a longer system lifespan.

Furthermore, hysteresis and backlash errors associated with mechanical contact designs are reduced (as shown in Figure 2), improving workpiece surface finish and form.

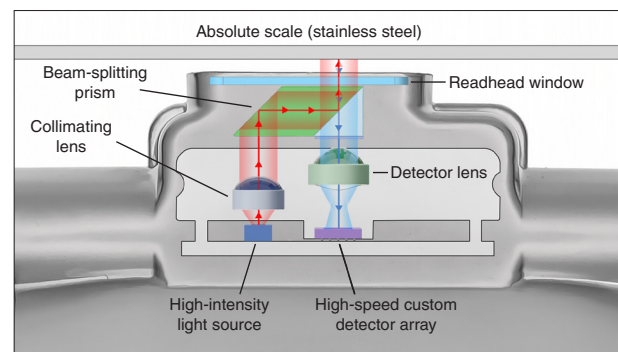


Figure 1. FORTiS encoder readhead optics scheme.

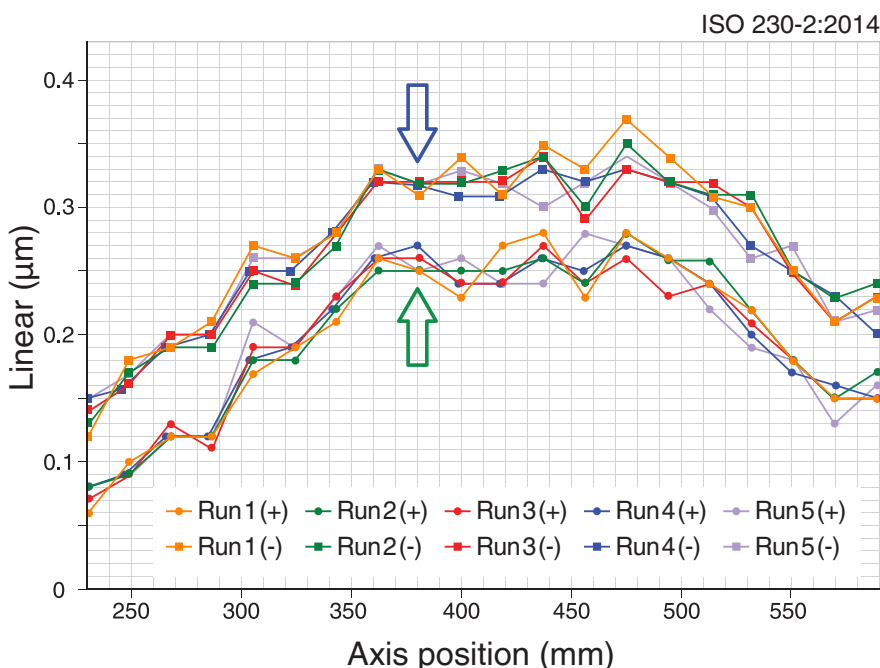


Figure 2. FORTiS encoder hysteresis errors in the positive (forward) and negative (backward) directions after five experimental runs.

A breakthrough in readhead design

A key focus for Renishaw's engineers has been the effect of vibration on a linear enclosed encoder. Conventional contact encoders are known to be vulnerable to vibration effects under certain conditions such as the machining of particularly tough materials, intermittent cutting, and gradual machine wear. The non-contact readheads of both the FORTIS-S and FORTIS-N models benefit from the application of tuned mass damping technology, enabling class leading vibration resistance. Tested beyond 30 g for extended time periods, even at the encoder's resonant frequency, both FORTIS encoder models achieve the same robust measurement performance and can endure the same harsh conditions. The sealed readhead bodies, shown in Figure 3, also protect the encoder from immersion in the rare event of a flooded encoder housing, enabling in-field cleaning for a faster recovery from 'machine down' situations.

Convenient form and fit

Both FORTIS models are bolt-hole compatible with alternative brands of enclosed linear encoders, simplifying design change.

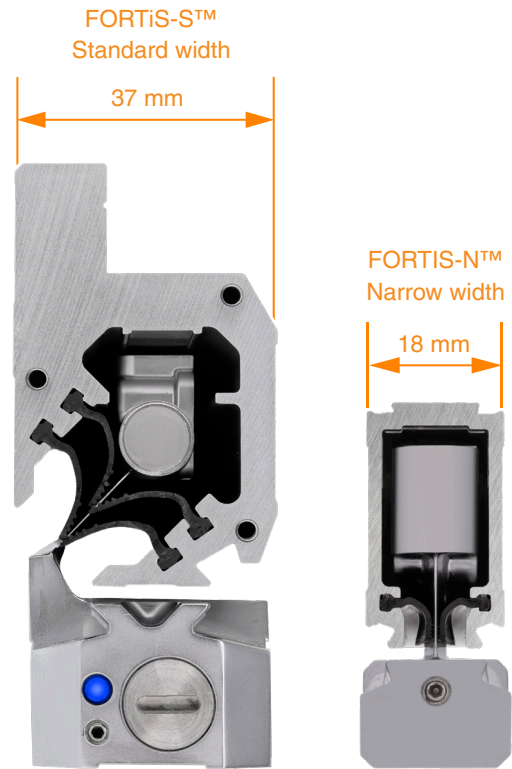


Figure 3. Vertical sections through FORTIS-S and FORTIS-N enclosures showing non-contact readhead orientations



Figure 4a. Side view of FORTIS-N encoder.



Figure 4b. Side view of FORTIS-S encoder.

Easier, faster installation

Minimising the time and effort required to install an encoder in a machine is essential. Unlike traditional enclosed encoders, the installation process of the FORTiS encoder is not reliant upon dial gauges and peripheral diagnostic equipment. Renishaw's patented set-up LED and carefully designed installation accessories provide an intuitive procedure that ensures a right-first-time installation, up to 90% faster than other typical contact encoder systems, even in space constrained locations. A major advantage of the FORTiS design is that the set-up LED indicates signal strength, so a blue LED showing maximum signal strength also confirms correct alignment of the encoder's body and readhead whilst an axis is traversed.

This simple installation method means that for the machine tool builder, linear encoders can now be installed by an assembly operator, improving production flow through the factory, and freeing up highly skilled technicians for other tasks.

The same benefits are available to the service and repair technician whether replacing encoders as part of a structured maintenance programme or as an urgent repair in a 'machine down' situation. The end user also benefits from the significant reduction in downtime cost.

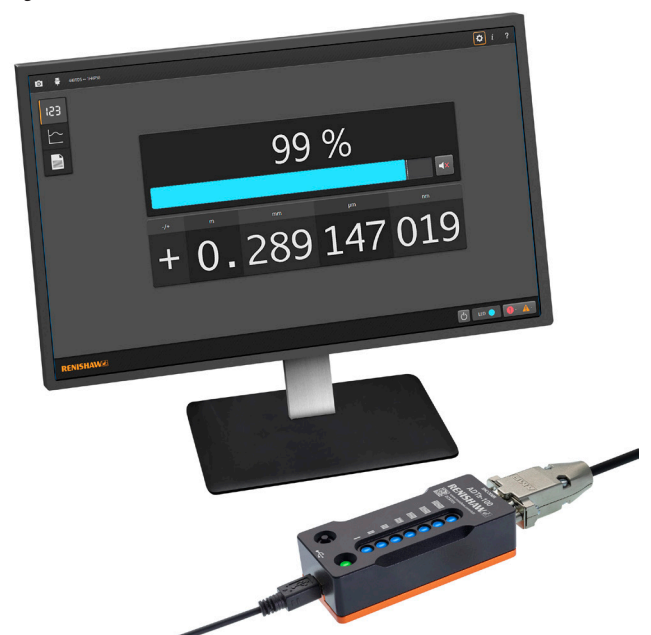
Furthermore, FORTiS linear encoders are form and fit compatible with other brands of encoders so they can be used as a drop-in replacement for maintenance and field repairs.

For enhanced functionality, installers can connect the Advanced Diagnostic Tool, ADTa-100, via a standard USB connector, to a PC running Renishaw's ADT View software. This provides a user-friendly graphical interface of advanced diagnostic information, including key encoder performance parameters such as signal strength along the axis length. A permanent record of installation data can be saved, providing confidence to machine tool builders, their end users and maintenance technicians alike.



Figure 5. Samples of installation accessories (FORTiS-S featured)

Figure 6. ADT View software interface



Reducing energy consumption and operating costs

Accelerated life testing simulating five years under the harshest conditions, has enabled Renishaw to develop and refine the advanced DuraSeal™ lip seals. These offer excellent resistance to wear and machine tool lubricants, providing superior sealing and ingress protection up to IP64 when combined with air purge. In addition to increasing machine uptime, this seal design reduces air leakage from the air purge system by up to 70 %, which results in lower operating costs, a reduced carbon footprint and longer life.

Lifetime wear tests on the DuraSeal lip seals were carried out with fine iron swarf and carbide grit deliberately added to their contact surfaces for maximum abrasion. Even after 14 million cycles, the lip seals showed only minor wear and were fully functional, proving the encoder's suitability for long-life use in applications such as grinding, where the encoder will be exposed to extremely aggressive abrasives.

Through these design innovations the FORTiS enclosed linear encoder range offers key technical and commercial benefits in performance and operation to machine tool builders, their customers, and the technicians that maintain their machines.

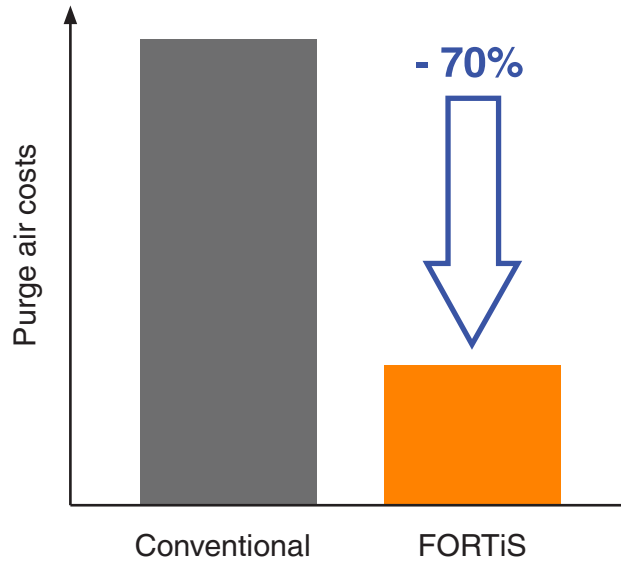


Figure 7. Comparison of purge air costs between the FORTiS encoder and a conventional enclosed encoder.



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