AVTRON ENCODERS

Ending Encoder-Related Downtime in Oil & Gas Drilling Applications
Part 1 of a Series: Top Drive Encoders

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This series of white papers describe how to dramatically reduce encoder failures and encoder-related downtime in a range of applications for encoders in oil drilling and rework applications, from the top drive to coil tubing rigs. Encoders are an essential part of the control system yet cause serious downtime issues—these papers explore problems and practical solutions.

Top Drive History

Since its invention in the late 1970s, the top drive has revolutionized drilling technology with huge time savings and flexible drilling programs that simply weren't possible with "Kelly" drilling and rotary tables. However, since its inception and especially since AC motor technology supplanted DC motors in the early 1990s, feedback systems are both essential and an Achilles heel of the top drive. Encoders provide feedback to the drive system to allow the drive to start the motor from zero speed with the drilling workload, and keep the velocity and torque under control during highly variable drilling conditions such as bit-bounce and slip-stick. Put simply, modern electric top drives won't work without encoder feedback.

Often a huge locomotive-grade electric motor meshed with a 750 ton capable gearbox is dependent on an encoder's glass disk, fragile electronics and one tiny 40lb single-row bearing!

This horrific mismatch between the incredible mechanical durability of the top drive itself and the fragile nature of many encoders has led to an endless search for both OEMs and drilling users alike: How can the encoder be made far more reliable in top-drive applications?

Fundamental Challenges

Vibration: The top drive (encoder) experiences nearly continuous vibration during operation, and drillstring dynamic motions such as bit-bounce, stick-slip, bending and BHA whirl create even greater dynamic forces on the encoder. Site-to-site transportation of mobile rigs often causes 200G+ shock loads.

Temperature Cycling: The top drive forces huge temperature swings at the encoder as the rig is warmed up from potentially -50°C conditions and the motor heats the encoder to nearly 100°C. This hot and cold cycling is frequent. Brake drag can push encoder temperatures quickly over 150°C! These temperature cycles cause direct electronic failures but even more commonly cause seal failures in standard encoders.

Environment: The drilling site can be 100% condensing humid, with salt water, ice, dirt, hydrocarbons and acids all present.

Safety Certifications: Approving insurers and drilling operators vary significantly in their safety certification requirements. Some top-drive encoders may require ATEX, IECEX, UL Class/Div (US NEC 500) or UL Class/Zone (US NEC 505) certification.

Failure Modes

Electrical failure: Encoders onsite are frequently exposed to voltage surges and short circuits caused by site wiring issues. Standard encoders can't withstand either condition.

Optical electronic failure: Typical encoder construction uses optical sensors with a glass disk. Lines on the disk interrupt a light beam to a photo eye. But this system can easily be disrupted by dirt and water that interrupt or distort the beam, and the glass disk is very prone to cracking or shattering. **(Fig 1)**

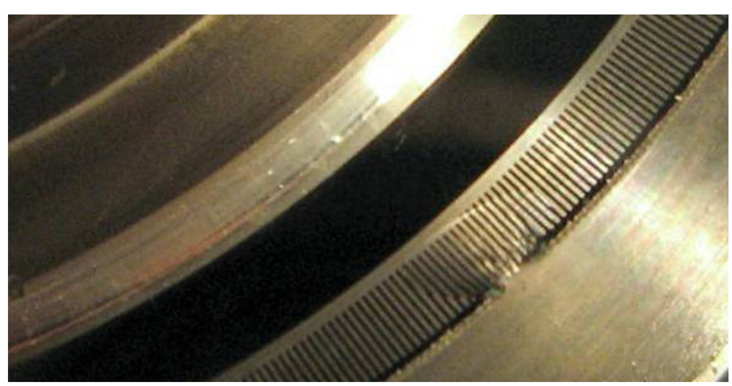


Fig 1

Bearing failure: Typical encoders use a tiny ball bearing to support either a solid or hollow shaft construction. These bearings frequently fail when subjected to vibration and loads caused by tethering hollow shaft models, spline coupling systems or belt-driving shafted models.

Seal failure: The repeated temperature cycling causes pressure on the encoder seals which then give way. More temperature cycles draw dirt, dust, water and oil into the optics and bearings, causing optical system or bearing failure.

<u>**Practical Solutions**</u>

First, the encoder must protect its electronics. Insist on units with automotive or better grade input voltage regulators to protect against surges of at least 50v. Moreover, the outputs should be fully protected against all types of short circuits—line-to-line, line-to-ground, and line to V+ or higher. Wiring errors, such as wiring power to an incorrect pin, should not cause encoder failure.

The optical system is a huge liability—the simplest solution is a magnetic encoder. Magnetic encoders don't require fragile glass disks or dust-free operation. Magnetism reaches through moisture, oil and dirt unaffected, enabling the magnetic sensor to correctly and accurately detect rotation under all conditions. **(Fig 2)**

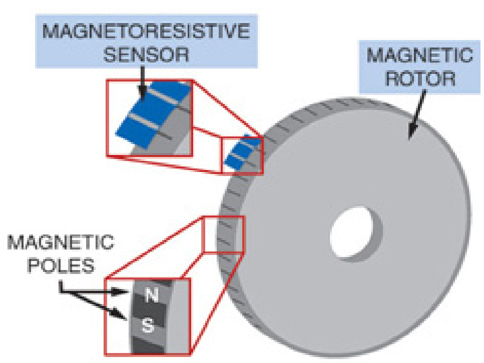


Fig 2

Vendors offer magnetic encoders in a broad variety of form factors including shafted models, hollow shaft, and modular styles **(Fig. 3)**.

Shafted Model Hollow Shaft Modular Encoder

Fig 3

Magnetic systems enable the encoder vendor to mechanically protect the electronics with plastic potting compounds. This ensures the electronic sensors are impervious to liquids and increases shock, impact, and vibration resistance. **(Fig 4)**

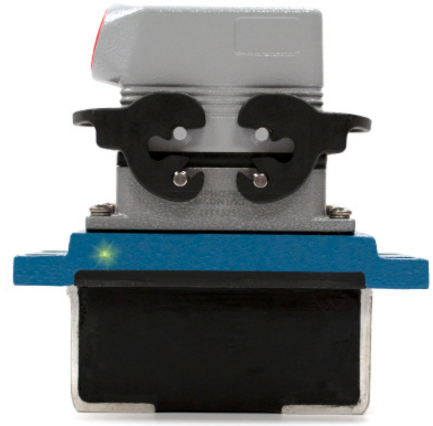


Fig 4

Next, reduce the gear train load on the encoder. Shafted encoders driven by belts should be supplanted with hollow shaft or modular (two-piece) bearings that mount directly on the motor. If hollow shaft encoders are used, ensure the tethering system follows the vendor's instructions; good tethers are very rigid against encoder body rotation, but flexible in the axial direction to allow for shaft movement and runout. Fully rigid tethers will quickly destroy hollow shaft encoders!

Select severe duty models with improved sealing. **(Fig 5)**

Fig 5

Labyrinth and combination seals are used instead of simple rubber washers. This greatly decreases ingress of water and dirt. While water and dirt don't directly cause potted magnetic sensors to fail, they can cause any bearing to fail over time.
Finally, solve the bearing failure issues. Two options are available:

Great choice: select severe duty encoders with much larger bearings. Two encoders are shown for comparison. The industry standard HS35 style shown below features 2 bearings rated at approximately 50kg each. The severe duty unit, which mounts on the same shaft size, offers 2 bearings rated at 2200kg each. **(Fig 6)**

Fig 6

Even when the encoder is not exposed to high forces, the huge bearings greatly increase life because they withstand minor contamination better and offer much longer life under minor loads.

Best choice: eliminate bearings altogether with modular two-piece, no bearing encoders. These encoders have virtually no moving or wearing parts (or seals!). The magnetic ring or rotor is mounted onto the motor shaft or stub shaft. The magnetic ring rotates in front of a magnetic sensor which provides the measurement of position and speed, just as it does in a conventional magnetic encoder with bearings. The difference is that the system utilizes the motor's own heavy-duty mechanical construction. **(Fig 7)**

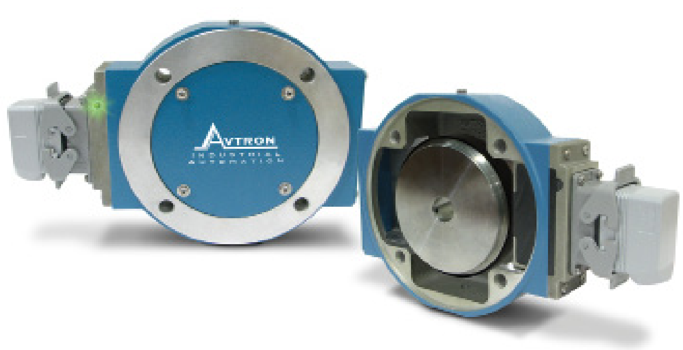


Fig 7

As long as the motor parameters (axial movement, radial positioning accuracy) are within the mounting and operating limits of the encoder, a modular no-bearing magnetic encoder provides the longest service life and highest durability of any top-drive encoder solution available.

A Few Words About Preventative/Predictive Diagnostics

Get predictive diagnostics. Period.

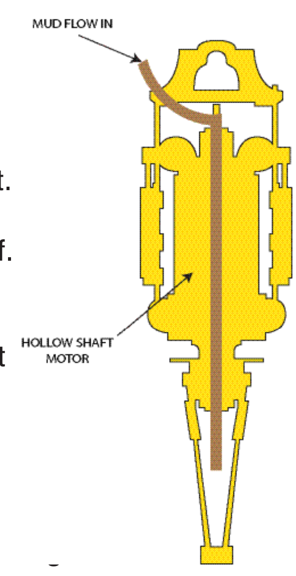
Older encoders had virtually no external diagnostics and required an oscilloscope to troubleshoot, or required the connection of a computer, both of which are completely impractical in real-world top-drive operation.

With the advent of digital signal processing, encoders can now self-diagnose and provide output indication if the encoder signal is less-than-perfect or degrading over time. This provides a huge reduction in downtime because encoders can now warn the operator long before they are in danger of failure. The encoder can be serviced or removed for service during a scheduled downtime, so no drilling time is ever lost to encoder failures.
These diagnostics also greatly decrease mean-time-to-repair—if the drive indicates an encoder-related fault, but the encoder remote diagnostics show "green" status, the technicians can look elsewhere for the problem rather than fruitlessly replacing the encoder, then discovering the problem is elsewhere.

Diagnostics should be both remote (via alarms to drives or control systems) and offer a local visual alarm red/green LED, etc. (for technicians working directly on the top drive motor).

<u>**The Additional Challenge of Direct-Drive Top Drives**</u>

The latest innovation in top drive technology is the elimination of the gearbox. A large-diameter motor is constructed with a hollow shaft. The drilling pipe and mud passes through the motor itself. **(Fig 8)**



This leaves no small stub shaft to mount or drive the encoder.

With low RPM and high torque requirements, the encoder is an even more critical part of direct drive top drives.

Many direct-drive top drive manufacturers have experimented with encoder drive trains, including gears and timing belts to drive small off-axis encoders. The fundamental problems with the small fragile encoders in conventional top drives are only made worse: the gears or timing belts produce large forces on the encoders' tiny bearings and belts may break. Worst of all the dynamic nature of the gears or timing belt system often interferes with accurate encoder feedback. **(Fig 9)**

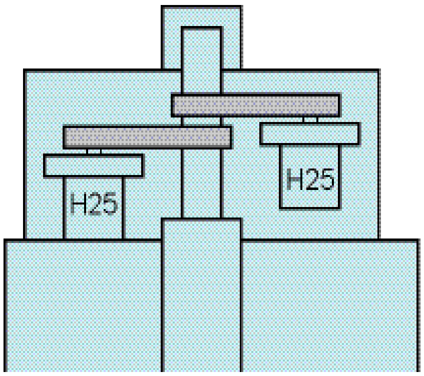


Fig 9

Fortunately, some of the same modular magnetic encoder innovations that dramatically improve conventional top drive reliability can be used in direct-drive top drives. The encoder vendor provides a magnetic ring or rotor which is large enough to pass over the motor shaft itself, then a magnetic sensor is placed in position to sense the rotation of the ring. **(Fig 10)**

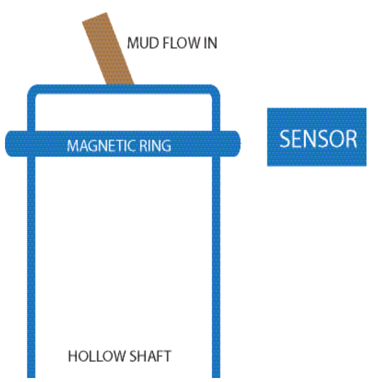


Fig 10

Some key ingredients are required for success: first, the rotor-to-sensor air gap must be large (>1mm ~0.040"), and axial movement tolerance must also be >+/-1mm to permit reasonable motor construction and mounting tolerances. Second, the electronics in the sensor must be protected from the environment and rough handling with metal housings and potting materials. Third, the electronics must be self-protected against surges, short circuits and more, so that the sensor can be installed deep into the motor assembly without the need for frequent replacement.

Models that meet all these requirements are available and some models include self-diagnostics, allowing remote sensing of proper encoder operation and providing predictive maintenance warnings to allow the operator to service the encoder before any downtime is caused.

Summary

OEMs can dramatically reduce encoder failures in top drives by selecting and properly installing severe duty magnetic encoders. End-users can enjoy the same benefits on existing top drives by retrofitting existing encoders with the severe duty models. Either hollow shaft or modular encoder styles can be added or retrofitted to existing top drives. Add diagnostics to the encoder model to ensure there are no unscheduled downtime incidents. In short, downtime-causing encoder failures don't have to be a fact of life on top drives any longer!

The appendix shows various Nidec-Avtron encoder models that have been proven to dramatically increase reliability of top-drive applications. Ultra-high durability models with safety certifications (ATEX, IECEX, UL, CE) are also shown.

Appendix: Nidec-Avtron Encoder Models Suited for Top Drives in Oil and Gas Drilling:

AV5, AV12, XR5, XR12

Modular magnetic encoder sensors for direct mount
Allows up to 200mm (7 7/8") shaft
No bearings
Potted electronics
Predictive diagnostics
ATEX Zone 1,2, IECEX; UL Pending: XR5, XR12

AV56, AV115, XR56, XR115

Modular magnetic encoders for flange mount
Allows up to 85mm (3 3/8") shaft
No bearings
Potted electronics
Predictive diagnostics
ATEX Zone 1,2, IECEX; UL Pending: XR56, XR115

XT45, XR47

Hollow shaft magnetic encoders
Allows up to 30mm (1 1/8") shaft
Huge bearings
Labyrinth seals
Potted electronics
Predictive diagnostics
300G shock rating
ATEX Zone 1, 2, IECEX; UL Pending: XR47

For more information about this article or encoders & tachometers in general, contact:

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