Air Gap Enlargements in Encoders Improve Reliability

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Introduction

Industrial encoders and tachometers face severe environmental challenges, yet must provide precise, accurate output of speed and position. Customers demand the decreasing cost curve of electronic devices to apply to encoders, yet still rely on encoder uptime to maintain high cost, high value processes, and machinery.

Problem

As industrial encoder size and cost has decreased, the challenges of maintaining high reliability and high precision have increased. In optical encoders, shock and vibration can produce deflections in, or failure of, the optical disk. With traditional optical disks riding approximately 0.003” from the sensor, a tiny deflection in the disk can produce an error in counts. A slightly larger disk deflection results in a sensor head crash where the disk contacts and damages the sensor assembly, and/or shatters the optical disk.

Solution

Utilizing improvements in optical encoder Wide-Gap technology, Nidec-Avtron is able to provide small, low cost optical encoders that are highly reliable. These products maintain a much larger space between disk/ rotor and sensor. This greatly increases reliability and the ability to withstand shock, vibration, misalignment, and high temperatures which stress optical encoders.

Background

Industrial applications: the bane of delicate instruments. Often temperatures swing 50 degrees C or more within minutes, to near 100°C, then plunge downward, sometimes due to a frigid spray of washdown liquid or air jets. The extreme heat of loaded vector duty motors conducts quickly to the encoder. Humidity is often at 100% and condensing, despite warranty disclaimers for operation in these conditions.

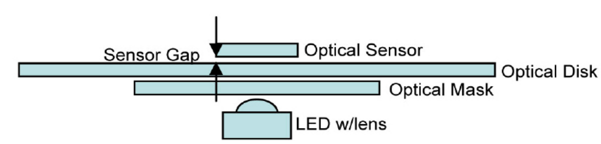
Once limited to speed feedback tachometer applications, industrial encoders are now used for both speed and position feedback. Encoders have long been considered the weak link in industrial closed loop motion system designs. Failure rates are so high that most engineers and technicians routinely replace the encoder before they try any other method of repair to the system.

Over 50% of all returns to industrial encoder manufacturers are reported to be “No detectable fault” by the manufacturer handling the return! Clearly, there is a crisis of confidence in encoder reliability in industrial applications, well grounded in actual failures.

Design Basics

In an optical encoder, a light source (typically an infrared light emitting diode) shines through a rotating disk with radial lines drawn or etched on it. On the opposite side of the disk, a light-sensitive sensor is mounted. As the disk rotates, the sensor sees an interruption in the light beam from the lines, and generates pulses as a result.

Standard Optical Encoder Construction



Project Scope

Nidec-Avtron set out to solve the small hollow shaft encoder failure problem by starting with a clean design. Since prior models from Nidec-Avtron were large heavy duty industrial products, there was a strong expectation that the new product would have to meet customers’ expectations of high durability, even under heavy service conditions.

The preliminary investigations focused in on the key failure modes for optical encoders: bearings were upsized from industry standards and seals were added to keep contamination out, along with superior line drivers to withstand mis-wiring. However, primary failure modes of existing competitive models reported by many customers pointed to “LED burnout”, “head crashes” and disks shattering, terms familiar to most early computer owners.

In an encoder head crash, just like a hard drive, the sensor contacts the disk spinning at full shaft speeds

(5000 RPM in many encoders). This contact will abrade the sensor within milliseconds into a useless shard of silicon. The disk may shatter if the sensor head contacts it, or the disk may be shattered by shock or impact (dropping the encoder during installation, for instance.) The LED used to provide the light to the sensor detection circuit has no backup; LED burn out means the encoder fails.

The problems are intertwined: because the light must pass through the disk to the sensor, the sensor is close to the disk. Therefore, the disk must be extremely flat and rigid; only glass was suitable. A great deal of light from the LED is needed to activate the sensor. Also, if the disk changes shape, the electronics must correct for the deformation of the disk to avoid creating position errors.

The project was outlined to create a new optical encoder design that would eliminate the existing failure modes of products in this market space.

Key Design Goals
Nidec-Avtron determined that glass disks were unacceptable to industrial customers.

Extremely high encoder reliability was required.

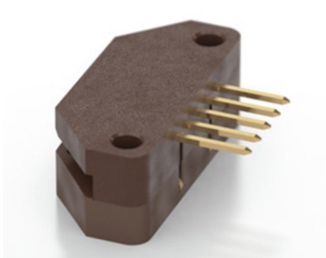
Shock and vibration resistance must be as high as possible, as both are extremely common in both installation and operating conditions.

Accuracy and signal quality must exceed industry standards.

Overall size of the encoder package must be compatible with the industry standard.

Sensor System Design Results
The HS25A and HS35A encoders were designed to utilize only shatterproof optical disks.

The sensor gap was increased from 0.003” [0.076mm] to over 0.025” [0.635mm].
New fully integrated sensor and signal conditioning technology was utilized to detect the far less powerful light beams at this greater distance and produce the highest quality signal output.

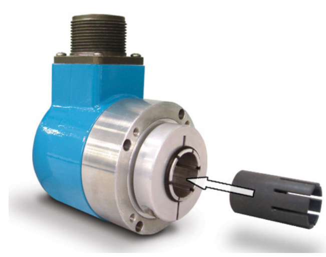


Wide-Gap Optical Sensor for Nidec-Avtron HS25A and HS35A

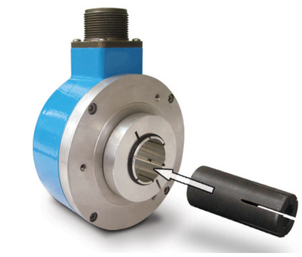
As a by-product, the LED light source current in this design is reduced to less than 25% of maximum permitted current at 20°C. This is extremely important, as LED current tolerance drops greatly at high temperatures. The HS25A and HS35A sensor design gives much longer LED life than competitive designs. This increase in life is greatest at high ambient temperatures, because the LED is running at low current. This permits the encoder to provide long service life even at 100°C ambient.

Both HS25A and HS35A products are fully rated to 5000 RPM at 100°C ambient. Typical competitive models must be temperature de-rated above 1800 RPM.

Shock survival exceeds 50G, exceptionally tough for optical encoders. Vibration survival exceeds 20G, 5-2000Hz, beyond the market standards.



Nidec-Avtron Optical HS25A Encoder with Wide-Gap Technology



Nidec-Avtron Optical HS35A Encoder with Wide-Gap Technology

Customer Results
The Nidec-Avtron HS25A and HS35A Wide-Gap optical encoders were introduced to the market in 2006 and experienced unprecedented sales growth.

The HS25A and HS35A Encoders have experienced a failure rate below 0.5%, a phenomenally low failure rate for optical encoders applied in industrial applications.

Summary
Wide-Gap optical technology greatly increases reliability of optical encoders by eliminating head crashes, disk failures/shattering, and LED burnout.

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

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