Why Optical Encoders Fail in Metals Industry Applications

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This paper will introduce various metals industry encoder applications and discuss typical challenges. These challenges can be grouped into Environmental Challenges and Mechanical Duty Challenges.
The reasons why optical encoders fail to overcome the challenges found in metals applications will be discussed.

Optical encoders, which have been used in metals applications for many years, never met the demanding reliability requirements of the metals industry. Quite simply, optical encoders are vulnerable to myriad kinds of damage:

- The optical disk may shatter during vibration or impact
- The bearings fail due to stresses
- Oil, dirt, or water gets inside the encoder due to seal failure

Most styles of optical encoders come sealed from the factory. Over time temperature cycling causes pressure changes and seals fail, which creates a path to the inside of the encoder. Often, the cause of the problem is simply moist air which enters the encoder and then condenses, rains, or freezes inside the encoder.

Optical Encoder Environmental Considerations
Dirt + Water = A Potent Combination for Problems

Optical encoders use an internal, stationary light source, usually an L.E.D., to shine light through a rotating disc (rotor) containing machined slots or etchings. A mask of light sensors detects the resulting shadow and light bars and creates the pulses as shown in the figure below.

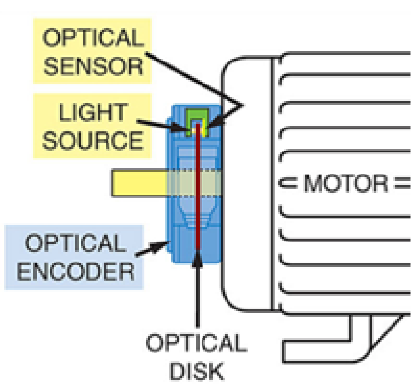

Figure 1- Optical Encoder Components

The main problem with this sensing type in metals applications is dirt and water penetration over time interfering with the machined slots or etchings in the rotor. The optical encoder works well when it is brand new because the machined slots or etchings are precise and free of contaminants.

But over time, dirt and water inevitably penetrate the encoder causing the rotor slots or etchings to lose their precision:

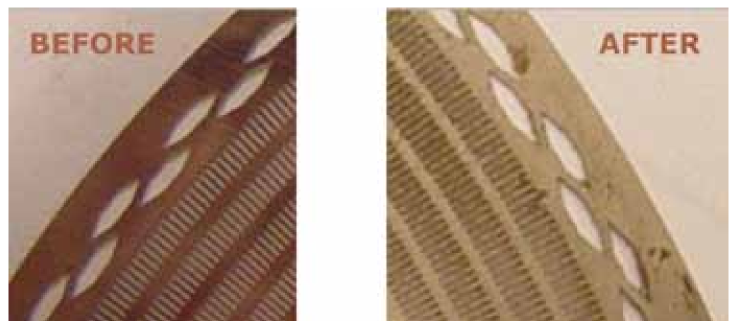

Figure 2- Optical Encoder Disks-Before and After Metals Industry Use

The result? The speed of the metals process using the encoder starts drifting or swinging resulting in strip breaks, surface scratches, strip steering problems and a host of other undesirable production issues. So the encoder designer attempts to seal the encoder tighter and tighter so outside contaminants can't enter the encoder and cause problems.

Sealed "Tighter than a Drum" is Good……Right?

Environmental protection ratings are then used to classify the encoder against the ingress of foreign contaminants. The two-digit IP (International Protection) Rating classifies the degrees of protection provided against the intrusion of solid objects like dust and water in electrical enclosures.

The first digit indicates the level of protection that the enclosure provides against the ingress of solid foreign objects. The most common indicators used for encoders:

5	Dust Protected	Ingress of dust is not entirely prevented, but it must not enter in sufficient quantity to interfere with the satisfactory operation of the equipment; complete protection against contact.
6	Dust Tight	No ingress of dust; complete protection against contact.
The second digit indicates the level of protection that the enclosure provides against the ingress of water. The most common indicators used for encoders:		
3	Spraying water	Water falling as a spray at any angle up to 60° from the vertical shall have no harmful effect.
4	Splashing water	Water splashing against the enclosure from any direction shall have no harmful effect.
5	Water jets	Water projected by a nozzle (6.3mm) against enclosure from any direction shall have no harmful effects.
6	Powerful water jets	Water projected in powerful jets (12.5mm nozzle) against the enclosure from any direction shall have no harmful effects.
7	Immersion up to 1m	Ingress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time (up to 1 m of submersion).
8	Immersion beyond 1m	The equipment is suitable for continuous immersion in water under conditions which shall be specified by the manufacturer. Normally, this will mean that the equipment is hermetically sealed. However, with certain types of equipment, it can mean that water can enter but only in such a manner that it produces no harmful effects.

In fact, optical encoder manufacturers routinely seal the encoder so tight that outlandish I.P. ratings are now common. I.P. ratings of 66 or 67 are now common place for optical encoders.

Temperature Effects Quickly Deteriorate Reliability

But when temperature and, especially, temperature cycling, enter the equation, tightly sealed encoders and the IP rating methodology are quickly proved invalid.

Typical metals processes using encoders tend to heat the encoders when they are running. But they also require periodic downtime for maintenance. During a maintenance outage, the encoder cools to near ambient temperature and it is this temperature cycling (in combination with the tightly sealed encoder housing) that spells doom for the optical encoder. This is because the encoder ***creates its own water in the housing through condensation*** as the encoder cools. This is readily apparent in the pictures below of the inside of a failed optical encoder (note the water marks clearly visible):

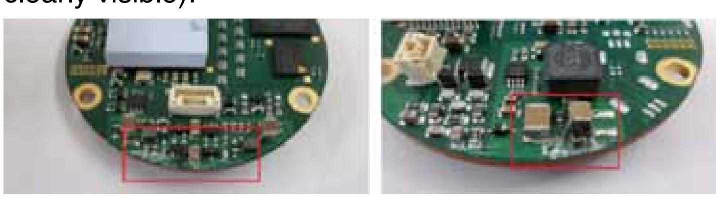

Figure 3- Water Penetration Damage in an Optical Encoder

So the challenge for the encoder designer is to design an encoder that can withstand the adverse effects of dirt and water penetration while at the same time breathing so that condensation caused by temperature cycling is eliminated.

Optical Encoder Mechanical Considerations

Shock + Vibration = A Potent Combination for Problems

Most metals processes using encoders have high degrees of shock loading and vibration present. This is especially true for Hot and Cold Rolling applications.

Optical encoders inherently require very precise alignment and positioning of the light source, the rotor and the optical light sensing mask in order to attain the required pulse performance. Optical encoders need to see tiny lines on a disk accurately; they make optical errors when there is any type of misalignment or out-of-position components.

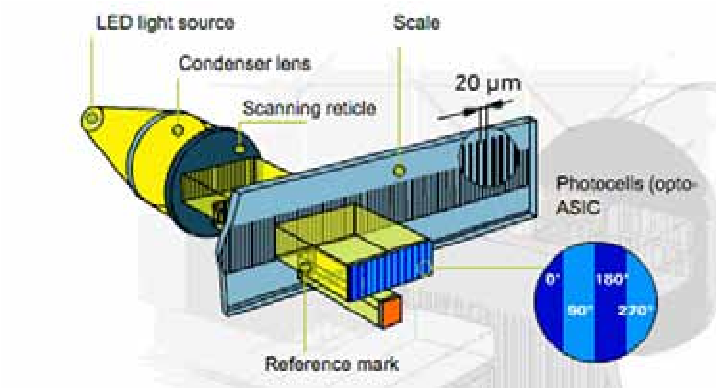

Figure 4- An Optical Encoder's Sensitive Internal Alignment

The internal positioning and alignment will have a direct effect on the shape of a single pulse and the pulse-pulse relationship of the encoder output. This will result in deterioration of the ideal pulse characteristics shown in the diagram below:

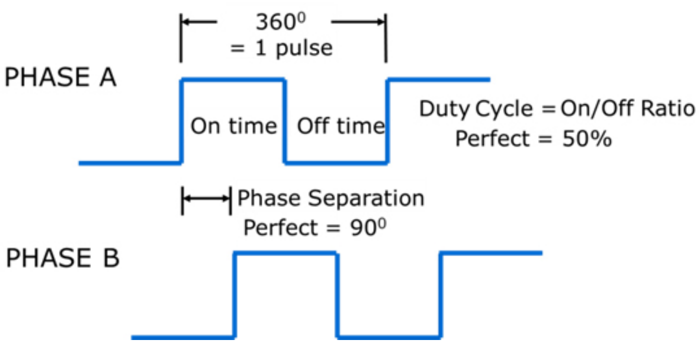

Figure 5- Ideal Encoder Pulse Wave-Shape

When the pulse duty-cycle or the pulse-pulse phase separation becomes erratic, the speed of the metals process with the encoder also becomes erratic. Shock and vibration will wreak havoc on the internal positioning and alignment of sensitive optical components and can easily cause problems with the metals process being controlled.

In the extreme, shock and vibration can also cause serious problems with the optical disks inside the encoder. With enough externally applied forces, the disks can crack or shatter. More common are isolated areas on the disks being damaged from shock and vibration. The leading cause is the disk impacting the sensor.

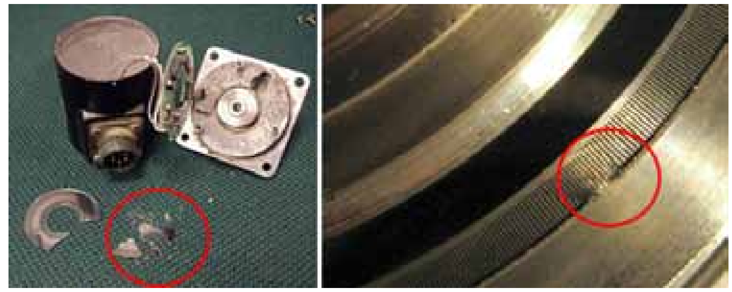

Figure 6- Shock and Vibration Related Damage Examples in Optical Encoders

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