

Eliminating Damage from Motor Shaft Currents Through Tachometers and Encoders

Brian W. Winter
Encoder Product Manager
Avtron Manufacturing Inc.
7900 E. Pleasant Valley Rd.
Independence, OH 44131
Phone : (216) 642-1230
FAX : (216) 642-6037
b_winter@avtron.com

Key words: Encoder, Tachometer, Reliability, Motor Currents,
Bearing Fluting, Bearing Currents, Shaft Currents, Shaft Grounding, Shaft Isolation

INTRODUCTION

Since the introduction of variable speed electronic controls for DC and AC motors, users have noted a troubling problem; voltage potential is sometimes induced on the shaft of the motor. The resulting current can discharge through gearbox bearings, through the motor bearings, or through the encoder or tachometer attached to the motor. This discharge causes the premature failure of motor bearings and/or encoder bearings. This paper discusses the phenomenon of encoder and motor damage due to motor shaft currents through encoders, and proposes several remedies.

PROBLEM

Both AC and DC motors controlled by electronic speed controls can experience “shaft currents”, where voltage is induced on the motor shaft, and the resulting current attempts to discharge to ground, or circulate through the motor through any conductive, contacting surface. Several excellent papers have been published on the topic, including Rockwell’s 3/11/02 “Inverter-Driven Induction Motors Shaft and Bearing Current Solutions”⁽¹⁾, and “Don’t Lose Your Bearings”⁽²⁾ by A. Muetze and A. Binder, IEEE 1077-2618/06. These shaft currents can discharge through arcing contact between the bearings and bearing races, causing the characteristic fluting damage to the races. This paper does not examine the causes of shaft currents, only the resulting impact on motor/encoder combinations.

In short, the discharge of motor shaft currents can damage encoder bearings, and improper encoder installation and design can cause shaft current discharges that damage motor bearings. Solving these problems is essential to avoiding premature motor bearing failure and/or encoder bearing failure.

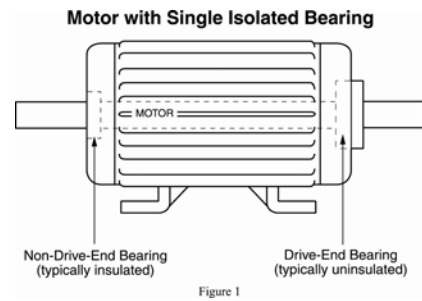
PROPOSED SOLUTION

Avtron Manufacturing, Inc. has created a set of encoder products that are electrically isolated from the motor shaft. These products prevent the discharge of shaft current through the encoder, either to ground or the motor frame; this prevents encoder and motor bearing damage that result

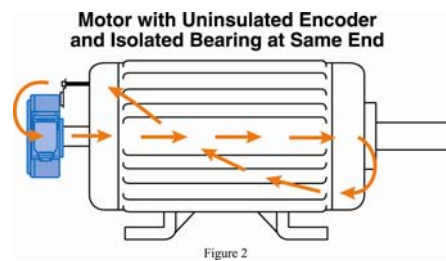
from the shaft current discharge. The products work without special installation or modifications to the motor that have been required by other encoder isolation solutions.

BACKGROUND

As detailed in the shaft grounding papers listed ^(1,2), any current path to ground, or return path between the shaft and motor frame can be highly undesirable. This is especially true when the current path is combined with the typical vector duty motor configurations shipped today, with a non-isolated bearing on the drive end and one insulated/isolated bearing on the non-drive end. (Figure 1) If the encoder creates a path to ground and/or the motor frame, current may circulate through the non-isolated drive-end motor bearing, and it can discharge through the encoder bearings. (Figure 2)



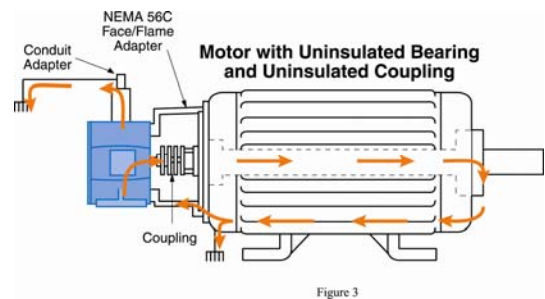
Industrial encoders were originally designed as stand-alone devices that were coupled to the motor or load (Solid Shaft/Coupled). As magnetic technology was introduced, and miniaturization and hardening of optical designs progressed, encoder manufacturers began to offer encoders for direct motor mount. These designs fell into two broad categories: Modular, and Hollow Shaft.



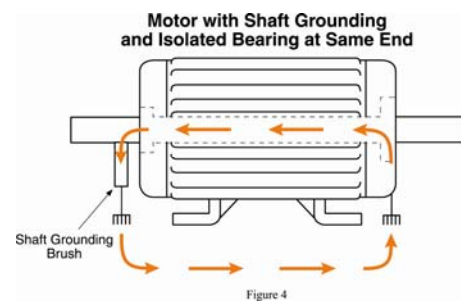
Modular encoder bodies today are typically mounted to a machined C-face on the motor, and the rotor is mounted to the shaft. Hollow Shaft encoders are mounted to, and supported by, the motor shaft, and secured by an antirotation arm.

Solid Shaft Encoders:

Standard solid shaft encoders (also called coupled) are not electrically isolated: The metal encoder shaft is linked to the motor shaft with a conductive coupling; current is carried through the encoder bearings to the frame, and the encoder is solidly bolted to a surface that is typically connected to the motor frame, such as a flange or foot. Electrical outputs are often connected via metallic grounded conduit, and some encoder designs do not isolate circuit ground from the encoder housing. This means shaft currents can quickly end the life of motor (or encoder) bearings. (Figure 3)



Because the encoder can mount in the typical grounding brush mounting location on an older motor, some solid shaft encoders offer shaft grounding kit options. Because they are mounted on the non-drive end of the motor shaft, they have the potential to create a circulating current path through ground (Figure 4), which can damage the uninsulated motor bearing as previously outlined.



Modular Encoders:

Modular encoders (also called pancake or C-face mount) by their design are isolated electrically and do prevent shaft current discharge. Although the encoder stator/housing is grounded to the motor frame, the rotor is electrically isolated from the sensor mounted in the stator by the air gap between the sensor and the rotor. Usually this gap is at least 0.010" [0.25mm], sufficient to electrically isolate the motor shaft's relatively low voltage potential from the housing.

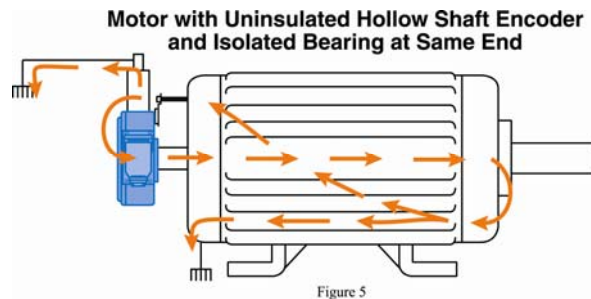
However, modular encoders may offer shaft grounding brush options, which create a path to ground, potentially endangering the uninsulated drive motor bearing in a motor with a single isolated bearing on the non-drive end.



Modular Encoders: Rotor (left) and stators (right) are electrically isolated, preventing shaft current flow

Hollow Shaft Encoders:

Hollow shaft encoders (also called tethered) are not inherently electrically isolated; the typical metal hollow shaft directly grips the motor shaft; current can be carried through the encoder bearings to the frame, and the antirotation arm forms the return path to the motor housing. As in solid shaft designs, some manufacturers connected or capacitor-coupled circuit ground to the housing. Moreover, some industrial encoder connectors feature metallic conduit adapters, offering a third path to ground through the encoder bearings.



Encoder manufacturers recognized the problem of antirotation arms early on, and added insulating washers to the antirotation arm mounting kit. However, many installers were (and still are) unclear on the purpose of these insulators and arm, and hoping for a more a sturdy mounting, they directly bolted the antirotation arm to the encoder, and shaft currents were free to flow once more. Encoder manufacturers responded with insulating nylon sleeves or coatings in their shaft assemblies to eliminate the need to isolate the arm with plastic washers. Users then discovered that the shaft sleeve plastics flow easily under clamping pressure, and do not have the same coefficient of expansion as the steel motor shaft. With the temperature cycling characteristics of vector duty motors, hollow shaft encoders with nylon sleeve designs have been slipping off motor shafts in ever-increasing numbers.

Hollow shaft encoder bearings may also be destroyed by motor shaft current discharge. Most encoder bearings are less than 1/10 the size of motor bearings. This makes encoder bearings much more vulnerable to damage from motor shaft currents. Fluting and the corresponding bearing destruction may occur within days or months. Many users have reported large-scale hollow shaft encoder failures when shaft currents were unchecked.

Adding to the woes created by hollow shaft encoders, users began to demand shaft grounding kits. In some cases, the users hoped that the grounding brush would eliminate both the motor

bearing damage and the hollow shaft encoder bearing failures they had experienced. While shaft grounding brushes on the non-drive end can, in some cases, protect the encoder bearings, they do create a path for destruction of an un-insulated motor drive-end bearing in a motor with a single non-drive end isolated bearing.

SUMMARY: APPLICATION GUIDANCE TO AVOID SHAFT CURRENT DAMAGE

The first guideline is a simple one: Apply shaft grounding wisely:

- Don't add shaft grounding brushes to the same end of a motor as the insulated or isolated bearing when the other motor bearing is un-insulated. The resulting circulating current can cause premature motor drive-end bearing failure.
- If the motor does not have any insulated or isolated bearings, or the motor has two insulated bearings, shaft grounding kits may be applied at the encoder or drive end with no ill effects.

Second, follow encoder manufacturers' guidelines for installation:

- If the hollow shaft encoder antirotation arm is provided with insulating washers, use them. For solid shaft encoders, select an insulated coupling that isolates the encoder shaft from the motor shaft.

Finally, select an encoder that by its construction methods prevents shaft current discharge through the encoder without special installation concerns:

- The encoder should prevent discharge to ground through encoder signal connections and conduit adapters, as well as prevent circulating currents through the encoder frame and bearings.
- Avtron Manufacturing, Inc. produces a full range of products that are inherently isolated, and therefore prevent motor and encoder damage from shaft currents through the encoder. A list of these products with their shaft current protection methods are listed in an attached appendix.

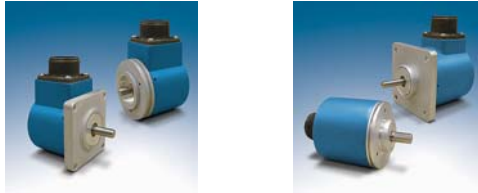
Appendix: Avtron Encoder Output Isolation:

All Avtron encoders feature fully isolated outputs; signal ground is never connected to, nor electrically coupled to chassis ground. This means that shaft current cannot discharge or circulate through Avtron encoder outputs.

Avtron Solid Shaft Encoders

Avtron Solid Shaft Encoders can be purchased with optional shaft isolation, and Avtron offers (third party) isolated shaft couplings.

AV20/AV25: These light mill duty encoders offer optional insulated/isolated bearing construction to prevent motor shaft current discharge.



Avtron Solid Shaft Encoders with isolation

Avtron Modular Encoders:

Avtron Modular Encoders are fully isolated from the shaft as a standard construction feature on all models.

AV850, AV1250, M56, M56S, M67, M85, M115, M193B, M285, M1250: All these heavy mill duty modular encoders are inherently isolated; the motor shaft and rotor are not electrically connected to the housing and motor body. Modular encoders do not have bearings, which eliminates encoder bearing failure issues.



Avtron Modular Encoders with isolation

Appendix: Avtron Encoder Output Isolation:

Avtron Hollow Shaft Encoders

Avtron Hollow Shaft Encoders feature isolated shaft systems, available as standard or optional features, depending on the model.

HS25A/HS35A: These light mill duty optical encoders feature a shaft electrical isolation insert that is matched to the temperature expansion coefficient of the motor's steel shaft and will not deform under clamping pressure.

HS35M: This mill duty magnetic encoder prevents shaft current discharge through the use of a non-conductive engineered resin housing.

M3/M4: These mill duty encoders offer optional insulated hollow shaft construction, and for the industrial connector options, optional non-metallic conduit adapters.

M685: This severe mill duty magnetic encoder features a fully insulated antirotation tether arm without the use of insulating washers. For the industrial connector options, optional non-metallic conduit adapters are offered.



Avtron Hollow Shaft Encoders with isolation

References

(1) “Inverter-Driven Induction Motors Shaft and Bearing Current Solutions”
Rockwell Automation Industry White Paper
3/11/02

(2) “Don’t Lose Your Bearings”
A. Muetze and A. Binder
IEEE 1077-2618/06