STRAY VOLTAGE OR STRAY CURRENTS

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Listening to all of the news stories about the stray voltage problems in Toronto this past winter reminded me of a similar, but different problem that occurs in pumps. It is commonly referred to as stray currents. While this problem does not cause any harm to pets or humans, it does cause tremendous problems with pumps, motorsand, specifically, bearings.

The water and wastewater treatment industries are addicted to variable frequency drives, (VFDs). Everything from raw lift pumps, RAS and WAS pumps, and high and low lift pumps are now operating with variable speed drives. While VFDs solve many operational problems, they can also create some major maintenance headaches.

What are stray currents?

Stray currents build up on the shafts of AC motors when controlled by variable frequency drives. The extremely high on/off switching speeds of the pulse width modulation, generated by the insulated gate bipolar transistors, are induced onto the motor shaft as a result of the parasitic capacitive coupling between the stator and rotor. This common mode voltage builds up on the shaft until it finds a discharge path to the motor frame, usually through the motor bearings.

These damaging currents cause fusion craters in the bearing through a process known as electrical discharge machining and, ultimately, result in severe frosting, fluting, bearing noise, and premature motor failure. Without protection, this phenomenon occurs continuously during operation of the motor/drive system until premature motor failure occurs.

If this sounds a little technical, the important thing to remember is that these currents build up in the motor and must find a way out to ground. How does this apply to pumps?

Often, motors are mounted on a metal base that is then mounted on a concrete pad, where the path to ground is not that easy. If the motor is connected to a line shaft, which is connected to a sewage pump in a dry pit, which is connected to a piping system that is most likely well grounded, then the path to ground can be through the pump. More importantly, the path to ground is through the pump bearings.

Alternatively, in the case of submersible pumps, the pump bearings are the motor bearings and are thus the only path to ground.

What kind of damage can occur?

Several years ago, I was involved in a problem, occurring at the City of Peterborough WPCP, where a particular problem, occurring had experienced several failures over its short life. The pump was removed from site, brought back to our service centre, dismantled and inspected. The cause of failure was obviously the bearing, as shown in Figure 1.

The damage in Figure 1 appeared to be a typical bearing overload failure, which can be caused by lack of lubrication, overloading, or other typical mechanical problems. Everyone involved in the dismantle was confident this was the cause of failure. Due to the catastrophic nature of these types of failures, the root cause is often difficult to identify.

When it came time to write the report, I had all of the bearings cleaned for inspection and photographed. I quickly noticed there was more to this failure. I looked at the other bearing that did not fail and noticed some rather familiar and distinctive markings. There was evidence of both etching and fluting in almost a classic form.

Etching and fluting are classic results of stray currents arcing across the very small gap in the bearing.

The etching in Figure 2 is quite visible, however, when you run your finger along the bearing, it feels as smooth as the original ground metal.

In Figure 3, the horizontal scratches, which were caused by metal-to-metal contact during the ultimate bearing failure, almost hide the underlying vertical flutes. The flutes were caused by the stray currents and the root cause of the failure.

To be absolutely certain of the diagnosis, I consulted a long-time colleague of mine from the Timken Bearing Company, who quickly confirmed my diagnosis. In fact, he commented that these parts could be the poster child for stray current damage patterns.

How common is this and what do we do to prevent it?

I suspect many failed bearings such as the one in Figure 1 are simply discarded and replaced. The pump or motor is put back into service with no knowledge of the root cause. If the pump fails every year, or two or three, it could easily be missed as a systemic problem. Without some form of failure analysis, the root cause of the problem may never be known.

Once the problem is identified, there are two basic solutions. The fundamental method of solving these problems is to prevent the currents from passing through the bearings. Current will always find the easiest and quickest path to ground.

One way to do this is to provide a ceramic coating on the motor bearing journals. The ceramic acts as an insulator and prevents the current passing from the shaft through the bearings. This is a common repair method for motors and is relatively inexpensive when compared to the cost of continual failure.

However, you must follow the path to be sure of the solution. In the case of a vertical line shaft pump and motor combination, the ceramic coating will protect the motor bearings, but the currents can still go down the line shaft and into the pump bearings.

The solution to this is to ground out these currents before the pump bearings. A shaft-grounding ring or brush can be installed relatively easily. The grounding ring or brush works very much like a DC

Figure 1: *Damage caused by bearing failure*

Figure 2: *Showing etching*

Figure 3: *Showing vertical fluting*

motor brush, where the current takes the easy path to ground, which is through this brush, thus preventing the currents from arcing across the pump bearings.

This brings me to the topic of submersible pumps. Most new projects I see have both submersible pumps and variable frequency drives. I have little knowledge or history of this being a problem with submersible pumps. However, I suspect submersible pumps are not immune from this problem.

During a PWO training session in Kingston last year, I was showing these actual bearing parts and explaining stray currents and the failures. An operator from a surrounding community brought up a nagging bearing failure he was having with his newly-installed submersible pumps. He was frustrated that the OEM could not identify exactly what was causing his bearings to fail. In fact, he said they told him it was lack of lubrication. After some discussion, we both felt it was a good possibility stray currents may be the cause of his grief.

The stray voltage problem in Toronto started out as an isolated problem. However, as more and more pets were hurt and killed, the number of reported problems increased to the point where Toronto Hydro had to take action. I suspect this problem is more common in our industry than we think and I am very interested in your feedback.

To conclude, I have a few recommendations to consider:

- Be aware of what stray currents are and respect the damage they can do.
- Work with a repair partner that is capable of identifying root causes of all of your failures.
- Establish a strategy of ordering new equipment with ceramic coated bearing journals. The higher the horsepower, the more important this is.
- Insulate your line shaft bearings and consider shaft grounding rings or brushes for your dry pit line shaft pumps.
- Specify only top of the line, high quality variable frequency drives.

Click HERE to return to Table of contents