YORK BY JOHNSON CONTROLS	FLUTING ON MOTOR BEARINGS COMPANY CONFIDENTIAL	
TECHNICAL DATA	New Release	Form 160.00-TD7 (710)

INTRODUCTION

Some customers have expressed concern regarding motor-bearing failures on low-voltage, variable-speed centrifugal chillers. However, fluting failures are seen on only 1-2% of all YORK variable-speed chillers. This document describes fluting, why it occurs, and how to mitigate the risk of it occurring. This document is intended to be an internal resource on how to communicate this topic with our customers.

DEFINITION & BACKGROUND

Bearing fluting is a term to describe early deterioration of motor bearings due to an electrical current passing across the grease film in the normal wear-path of the bearing. Tiny pits created during each electrical discharge form a washboard-like pattern, or "picket fence", of parallel oval marks around the wear-path. In the early 1900s, this condition was typically caused by magnetism, shaft eddy currents, or asymmetrical currents in a motor. Today this same deterioration can be caused by variable-speed drives (VSDs).

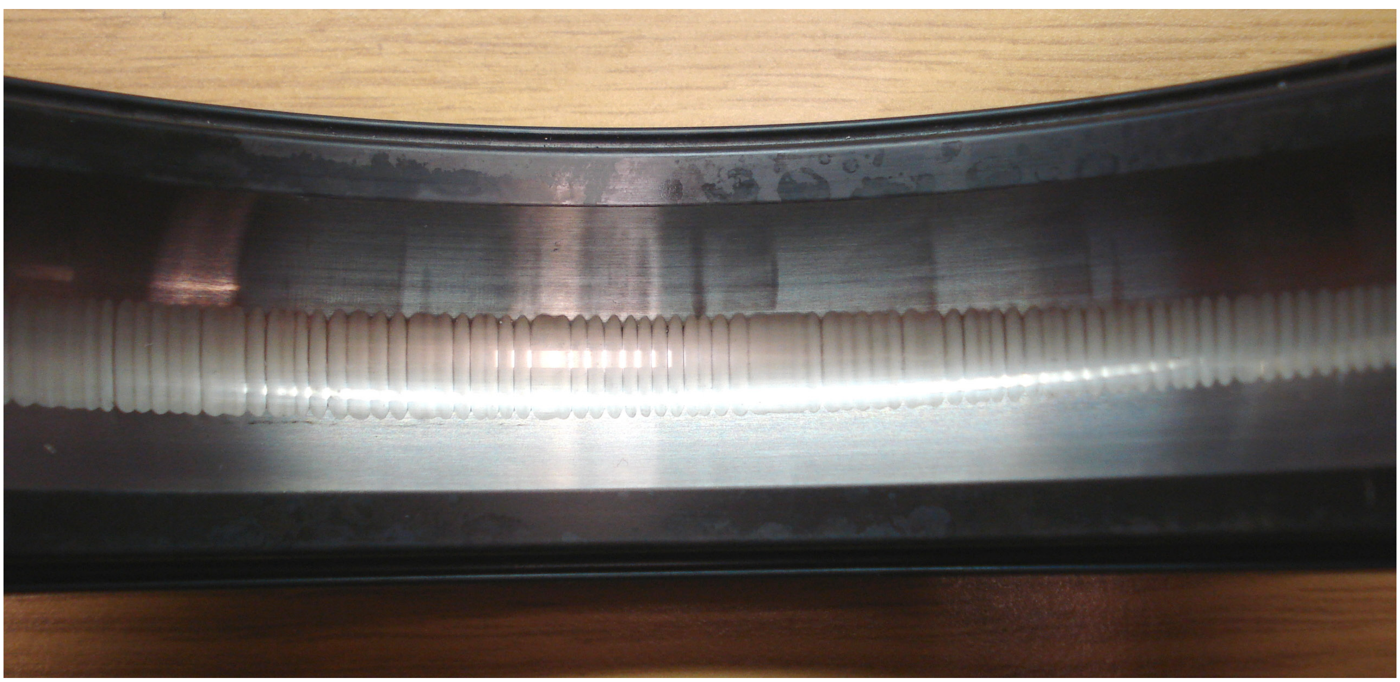

FIG. 1 – FLUTED BEARING

Johnson Controls designs its OptiSpeed™ VSD to minimize the adverse effects of bearing fluting, and the vast majority of centrifugal chillers shipped over the past three decades have never experienced this issue. However, in recent years, we have discovered some locations where bearing fluting has occurred. The odds of having bearing fluting occur on YORK® centrifugal chillers is about 1%-2%, based on well over 10,000 VSD-equipped centrifugal chillers sold since 1995.

BEARING FLUTING MITIGATION

We have found the factors which determine whether fluting occurs at one site versus another site are largely due to the power-source impedance, the degree of harmonic distortion present on the distribution, the integrity of the building grounding system, and the size of the VSD.

Early efforts to correct this problem using a grounding brush, or grounding ring, on the motor shaft did not work. In fact, we also tried applying these grounding rings on both ends of the motor rotor without success. Later, we tried special bearings with a non-conductive coating on the outer ring of the bearing. This just created another capacitor in the electrical path, and did not solve the problem either.

Research in 2008 found that when fluting occurs, currents circulate from the VSD to the motor, across the bearings to ground, and back through the building electrical system to the VSD. It was also determined that these currents can be eliminated by placing an impedance in series with this circuit path. This could be accomplished by adding three-phase line inductors in front of the VSD, or after the VSD, or by placing inductors on both sides of the VSD's DC bus.

Our 790HP and 1100HP OptiSpeed drives did not have inductors on both sides of the DC bus, and only 790HP and 1100HP VSDs had been found to experience occasional fluting. Johnson Controls now creates kits to retrofit existing DC bus inductors, placing ½ of the inductance on the positive side of the bus and the other ½ on the negative side. This has proven to eliminate bearing fluting in most cases, and has now become standard in all new 790HP and 1100HP VSDs shipped since December of 2009.

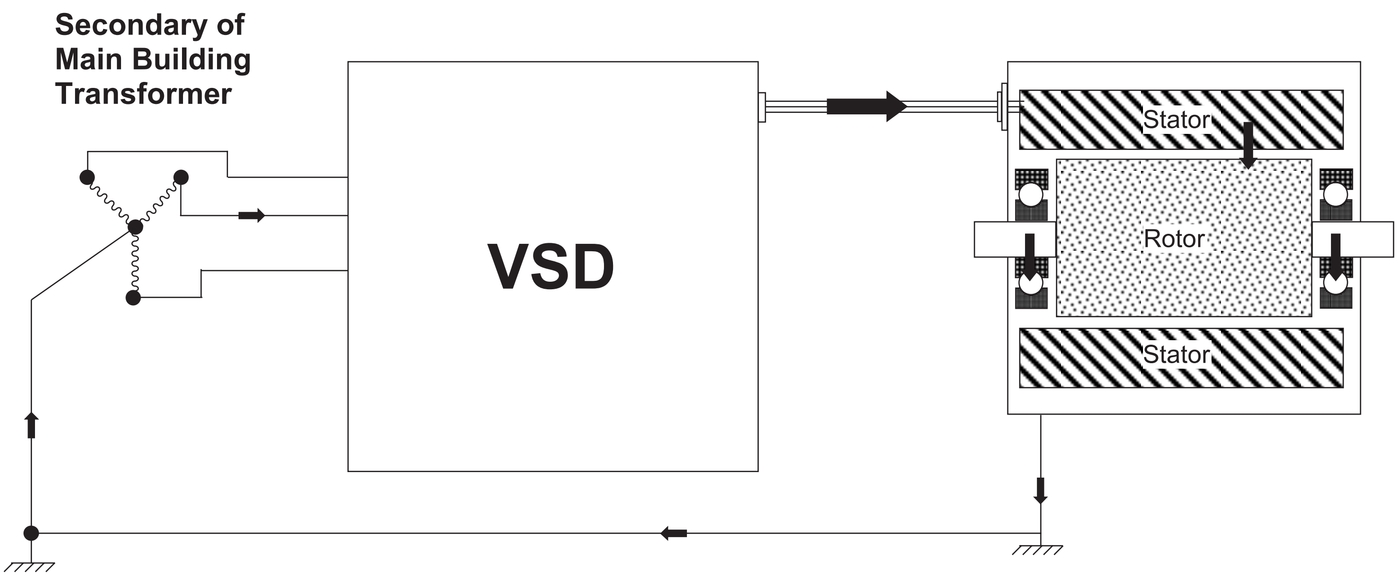

FIG. 2 – CURRENT CIRCULATING FROM VSD TO MOTOR, TO GROUND, AND BACK TO THE VSD

Although our inductor modification has corrected the bearing fluting in most of the isolated cases that developed, some of those locations were later found to be so severe that a mild frosting of the bearing surface continued to occur.

FIG. 3 – FROSTED BEARING

Further research in 2009 found this frosting to be caused by additional currents which circulate from the motor-rotor, across one bearing, to the frame, and back across the other bearing to the rotor. This circulating current occurs entirely within the motor, and is the same current path that exists when parts of the motor become magnetized. The only means of stopping this current is to break the circuit path by replacing one of the bearings with a non-conductive bearing. Special bearings are now being made with non-conductive balls made of silicon nitride material, which is harder and higher-rated, than standard steel. These special bearings are now available through the Johnson Controls Parts Distribution Center.

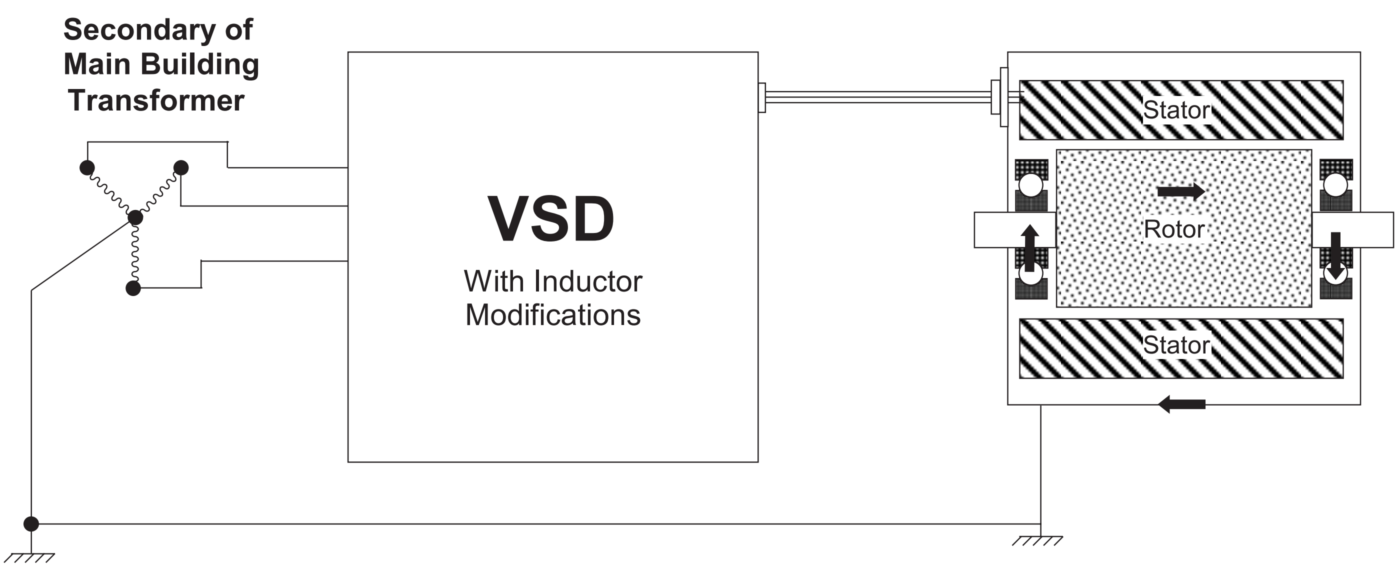

FIG. 4 – CURRENT CIRCULATING WITHIN THE MOTOR

Additional testing of motors using this non-conductive bearing has proven that it eliminates the circulating currents which cause frosting in the wear-path. Although these currents no longer exist, we have discovered that the voltage on the shaft, with respect to ground, actually increases. So, to prevent the higher shaft voltage from creating any potential issues, we have elected to apply a shaft-grounding ring to any motor that has been modified with a non-conductive bearing. This keeps the shaft voltage at design levels.

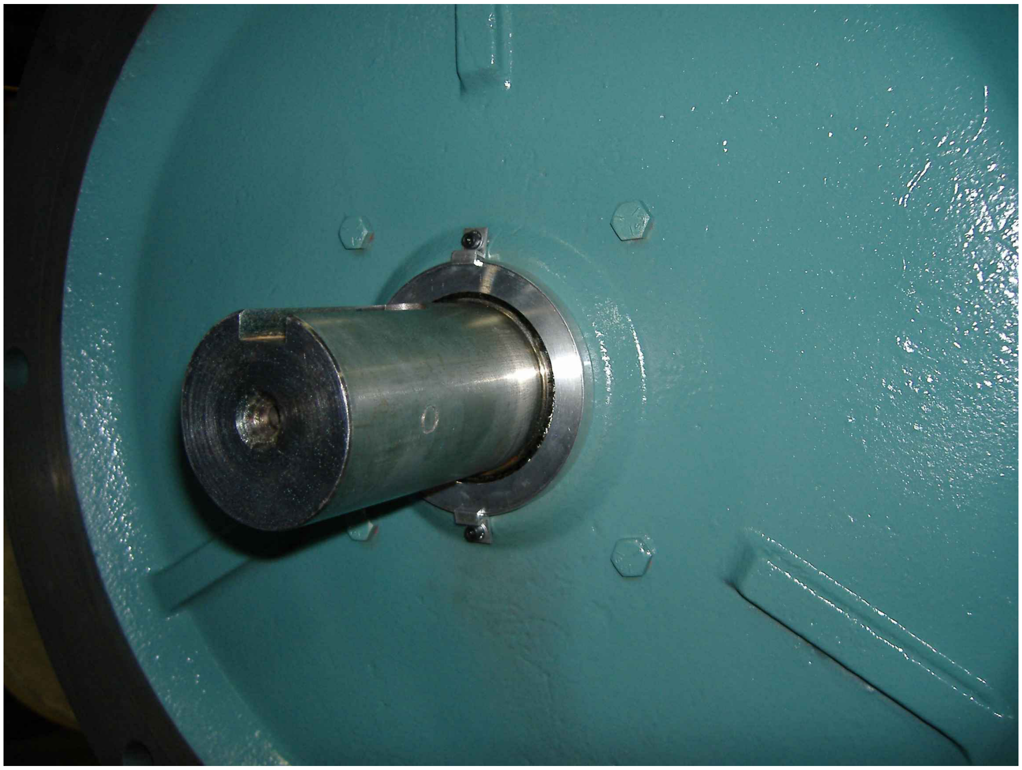

FIG. 5 – SHAFT-GROUNDING RING

Although continued application of shaft-grounding rings in combination with non-conductive bearings is expected, keep in mind that testing has proven that grounding rings alone do not eliminate fluting. Even if grounding rings are applied along with the modification of the VSD inductor, bearing frosting is not eliminated. Grounding rings are applied solely to maintain a lower shaft voltage after the addition of non-conductive bearings.

SUMMARY & CONCLUSIONS

Less than 2% of all YORK variable-speed centrifugal chillers have ever experienced bearing fluting. Only a small percentage of 790HP and 1100HP units have been affected, and most of these have been corrected by the addition of a DC-bus-inductor modification within the OptiSpeed drive. In some extreme cases, we have seen a frosting condition continue to occur, and we have proven this can be addressed by changing the motor non-drive end bearing to a non-conductive bearing, along with the addition of a shaft-grounding ring. Furthermore, the inductor modifications have now been incorporated into production of standard units, and are now present on all YORK OptiSpeed drives shipped after December, 2009.

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