Electrical Fluting

What is Electrical Fluting?

Electrical fluting occurs when a current is passed through the motor bearing instead of a grounded source. PWM (Pulse Width Modulated) drive switching frequencies result in undesirable motor shaft currents, a side effect that causes bearing damage within the motor through pitting and fluting. The audible noise generated by the damaged bearings is unacceptable and motor failure soon follows.

NEMA Motor Standards

To help deal with the effects of fast switching IGBT's on motors, NEMA has defined a standard for motor insulation system capacity. NEMA standard MG1 Part 31.40.4.2 attempts to define dv/dt or change in voltage over time as well as maximum peak voltage. It is described as a 0.1 micro second rise from 10% to 90% of steady state voltage with a 1600 volt maximum peak.

The standard is a start toward helping motor manufacturers to define motor insulation integrity. It also has an indirect relationship to the motor shaft bearing current problem. Electro-magnetic Interference (EMI) generates undesired effects that include current in to parts of the motor and surrounding areas where they may be disruptive. EMI includes motor shaft currents and reflected waves.

Motor Shaft Currents

AC drives with fast switching insulated gate bipolar transistors (IGBTs) create new application issues to consider. Variable speed drives produce many switching pulses that result in common mode noise (see figure 2). Common mode noise is a result of faster rise times (dv/dt) and higher carrier frequencies - the rate at which pulses are generated from the drive to the motor. These frequencies usually range from 3,000 Hz to 15,000 Hz.

Common mode noise produced by variable speed drives often results in undesirable motor shaft currents, a side effect that causes bearing damage through pitting and fluting of the bearing race as seen in figure 1.

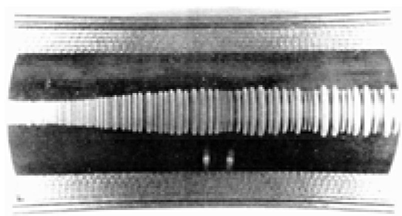

Figure 1
Surface roughness of a bearing race due to electrical fluting

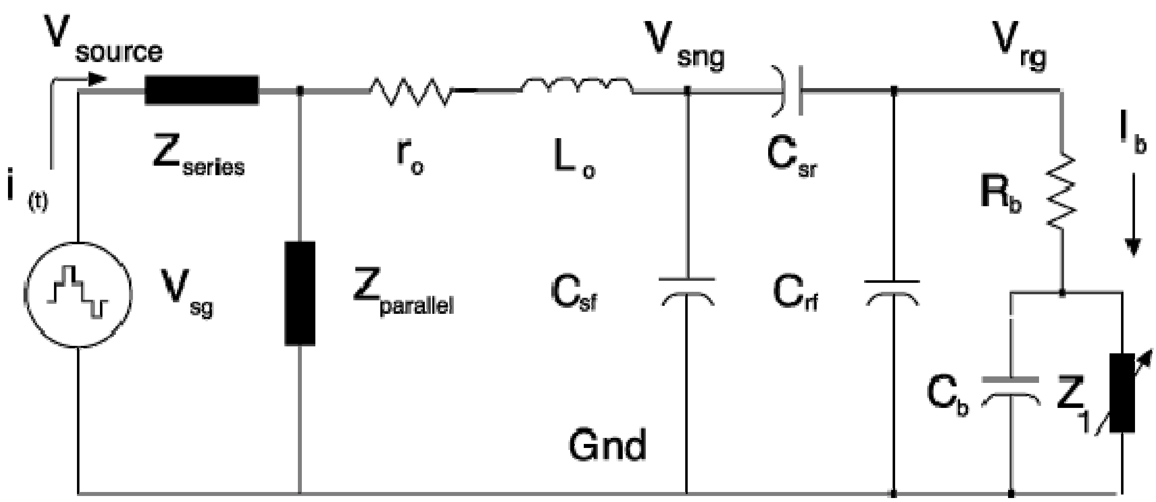

Figure 2
Common mode equivalent model

When the motor shaft is turning, the bearing grease insulates the bearing balls and the bearing race. The motor bearings and the race act as two capacitors. The stator and the rotor generate charge accumulation through capacitive coupling that is electrostatically induced in to the motor shaft. This current then passes through the motor shaft to the bearings and discharges from the balls with enough energy to pit the bearing race (see figure 3)

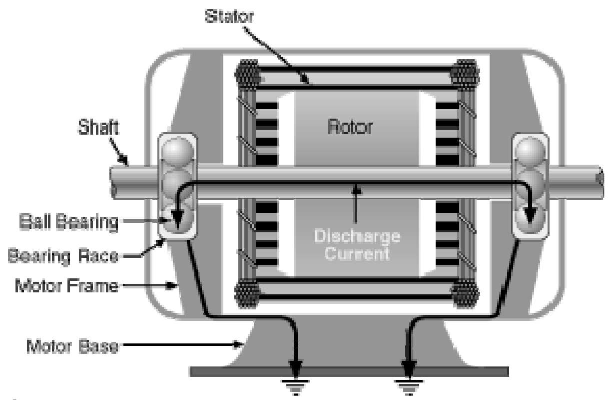

Figure 3
Motor shaft currents pass through to the bearing and discharge enough energy to pit the ball bearing and the race.

Current solutions to bearing pitting and fluting

1. Shaft Grounding Kit - With this method of diverting motor shaft currents away from the bearings, a shaft grounding kit is installed with a conductive grounding brush that is in contact with the shaft. The brush conducts shaft currents to the motors ground. Eventual oxide buildup on the shaft reduces the brushes effectiveness. If the shaft gets covered with dirt or grease, the brush may fail to pick up the currents and sparking occurs across the brush or the bearing race. Regular maintenance is required to help ensure that this method is effective. In addition, there is no easy way to tell if the brush is working.

2. Conductive Grease - This method entails using special conductive grease that conducts the motor shaft currents through the grease to a motors ground. But there are concerns that the process makes that makes the grease conductive interferes with the performance of the grease as a lubricant. Also the conductive agents in the grease eventually separate and the grease loses its performance capability as a shaft protector as well as a lubricant.

3. Insulated Bearings - By isolating the bearings with insulation, it is possible to prevent motor shaft currents from entering the bearing race and damaging the bearing balls. Some motor manufacturers cover the bearing seats with glass impregnated tape, others coat the entire bearing housing with ceramic material, some even coat the bearings themselves. Currents generated by the inverter will eventually find a weakness in the insulation. When motor shaft currents exceed the voltage threshold of the insulation it begins to breakdown and the current flows through the material.

4. Faraday Shield - By applying a conductive strip of foil across the stator slot that is grounded to the motor frame it is possible to defeat the coupling capacitance from stator to rotor. The Faraday shield means that the electrical charge sits on its outer surface. In this case, the shield is placed between stator windings and the rotor forming a conductive tube in the motor, leading the current to ground.

5. Filtering - A dv/dt filter or sine wave filter will mitigate the common mode currents from the drive but not completely eliminate them. As with all electronic components they have a MTBF (Mean Time Between Failure) of around 150,000 hours. The only way to tell if the filter is not working is to put a scope on it. The filter usually is installed between the drive and the motor.