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Review on Analysis of Failures Modes in the Electric Vehicles due to Electric Bearings

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Abstract - *Nowadays in electric instruments, particularly in electric vehicles, inverter control systems will cause complex shaft voltages and bearing currents. In an electric motor, several components have electrical failure issues, and among that bearings are the foremost sensitive and vulnerable element. In recent years, electrical failures in bearing have been regularly reported in electric vehicles, and therefore the electrical failure of bearings has become a key issue that restricts the life span of all-electric motor-based power systems during a broader sense. This review is to provide a basic understanding about the early bearing failures caused in electric vehicles. The electrical environments during which bearing works with various elements and therefore the origins of the shaft voltages and bearing currents, similarly because the typical modes of electrical bearing failure together with numerous topographical damages and lubrication failures, are mentioned.*

Key Words: **Bearings, electric vehicles, premature bearing failure, bearing damages, shaft voltages & electric currents, bearing failure modes, electrical environment**

1. INTRODUCTION

The bearings are the most important component in the electric vehicles. When bearings are made their load carrying capacity, rotating accuracy, sound levels, friction and frictional heat carrying capacity, long life and reliability are been checked. Therefore, it is quite natural that bearings should have come to play such a well-known part and that over the years they have been the subject of extensive research and continuous improvements.

Premature bearing failures are occurred due to variety of reasons. Each failure leaves its own special mark on the bearing. Consequently, by studying a failed or damaged bearing, it is possible in the majority of cases to establish the root cause and define corrective actions to prevent a recurrence. This review is intended to provide a basic understanding of bearing failures and various failure modes. With the knowledge presented in this review, it is possible to assess simple failure situations and start the right analysis.

Every year an estimated 10 billion bearings are manufactured around the world. Only a small portion of all bearings in use actually fail. Most of them (some 90%) survive the equipment in which they are installed. A number of bearings (9.5%) are replaced for security (preventive) reasons. Around 0.5% of bearings are replaced because they are damaged or fail. This means that some 50,000,000 bearings are replaced every year due to damage and failure so it is very important to research on this topic and find out possible solutions for the future of electric vehicles. This paper provides a detailed review of the key research progresses on the electrical bearing failures. This review explains that how electrical bearing failures are produced, various damages produced to bearing and the solutions to suppressing or avoiding electrical bearing failures.

2. BEARING FAILURE MODES

Bearing failure can occur due to various reasons like morphological damage due to shaft voltages and bearing currents (frosting, fluting, pitting, spark tracks, pitting and welding), Lubrication failures and Traditional bearing failure like fatigue spalling, fretting, smearing, skidding, abrasive wear, corrosion, cracks etc..

2.1 ELECTRIC SHAFT VOLTAGE

Shaft voltages are generated due to three reasons: magnetic flux asymmetry, electrostatic effects, and inverter-induced voltage effects. These forms of shaft voltages raised will cause damages to the bearing.

2.2 BEARING CURRENTS

Bearing currents are of two types: Circulating current, Non circulating current.

2.1 CIRCULATING CURRENT

A kind of "circulating" current mostly occurs owing to magnetic flux asymmetry, and the frequency corresponds to the shaft speed. When the induced shaft voltage is strong enough to break through the oil film/grease in a bearing, the bearing current would circulate in a conductive loop

2.2 NON CIRCULATING CURRENT

It is termed "non-circulating" because these currents pass through the bearings unidirectional from the rotor to the stator. The conductive currents mainly occur when the motor is running at a low speed. Since an efficient insulating film cannot be maintained at low rotations, the inner contact area of the bearing is metallic. Thus, when the current flows

through the stator winding will appears to be conductive in the bearing. At normal rotational speeds, the insulating lubricate oil/grease film electrically works as a capacitor. When switching continues to occur in the IGBT, as long as the switched voltage does not cause a breakdown, the capacitor of the bearing is charged or discharged.

2.3 LUBRICATION FAILURES

Lubrication plays a important role in the performance and life of a bearing. Without lubrication, premature bearing failure will occur and possibly cause other equipment to fail. Improper lubrication will increase friction and wear, loose stability, resulting in a sharp reduction of bearing lifetime. Lubricants are generally chemically inert; shaft voltage and bearing current provide the energy required for chemical reactions, accelerating the degradation.

Liquid contaminants will reduce the lubricant viscosity, which can lead to metal to metal contact. In addition, it can cause corrosion on the bearing contact surfaces. These conditions lead to increased temperature, wear, and sound levels.

3. BEARING DAMAGES

Morphological damage due to shaft voltages and bearing currents can be classified into five types: frosting, fluting, pitting, spark tracks, pitting and welding etc…

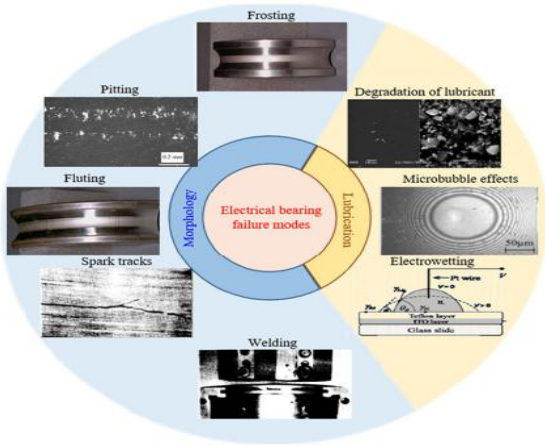

Fig -1: Bearing Damages

3.1 FATIGUE SPALLING

Spalling occurs due to the repeated stress change. When repeated stress continuously undergoes on bearing micro cracks propagate on the bearing and bearing failure occurs.

3.2 SMEARING

Smearing is surface damage which occurs from a collection of small seizures between bearing elements caused by oil film rupture and sliding.

3.3 FRETTING

Fretting is the wear and corrosion damage that occurred on the contact surface. This damage is produced under load condition and in the presence of repeated relative motion, as induced for example by vibration.

3.4 FROSTING

The grey discolored line formed all or part of the bearing race and may be seen in the inner and outer race. The discolouration may be caused by wear or by EDM.

3.5 PITTING

Pitting is caused when the excessive voltage pass through the bearing. Pitting can be seen on both rolling elements and raceways.

3.6 FLUTING

Fluting is caused when a current is passed through the motor bearing instead of a grounded source. PWM (Pulse Width Modulated) drive switching frequencies produce an undesirable motor shaft current, a side effect that causes bearing damage within the motor through pitting and fluting.

3.7 SPARK TRACKS

This form of damage consists of long tracks which appear to be made up of numerous small pits, each of which has a rounded 'molten' appearance.

This is caused by a form of electrical discharge different from that described under electrical pitting. Usually, the cause of spark tracks is due to the machine shaft becoming magnetized, causing stray currents to be generated as it rotates.

3.8 WELDING

Welding is mainly seen in the housing spits, pads and seals of the bearing and it are attributed to the thermal effect when a large current flows through the bearing. Normal EDM process cannot generate such a large current flow, and hence welding is mainly caused by direct momentary contact between stator and the rotor.

4. RESULTS & DISCUSSIONS

Electrical bearing failure can be reduced by various methods such as: - Reasonable grounding and minimizing the electric field, Suppressing the electrical breakdown etc.. The purpose of studying electrical failure is to prolong the bearing service life and achieve long-term stability.

4.1 REASONABLE GROUNDING AND MINIMIZING THE ELECTRIC FIELD WELDING

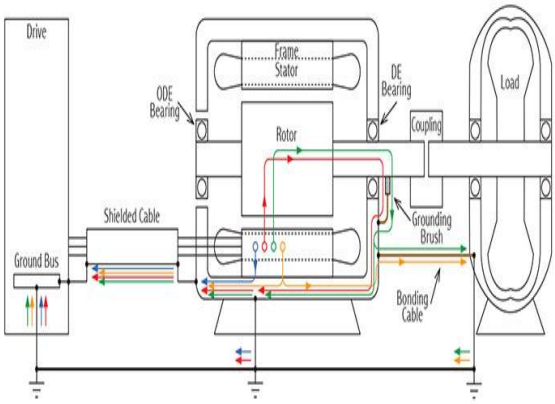

Fig -2 : Schematic diagram of an electric motor using a ground ring

Reasonable grounding and minimizing the electric field has decreased the large current flow through the bearing and lubricant film. Grounding is done by use of a ground ring composed of conductive microfibers, which is installed on the shaft outside the bearing. With the conductive brushes connected to the shaft, the ground ring act as a diverter, directing the shaft voltage to ground and diverting currents that would otherwise flow through the bearing. This technique works well for the EDM currents and the high frequency circulating currents.

4.2 SUPPRESS THE ELECTRIC BREAKDOWN

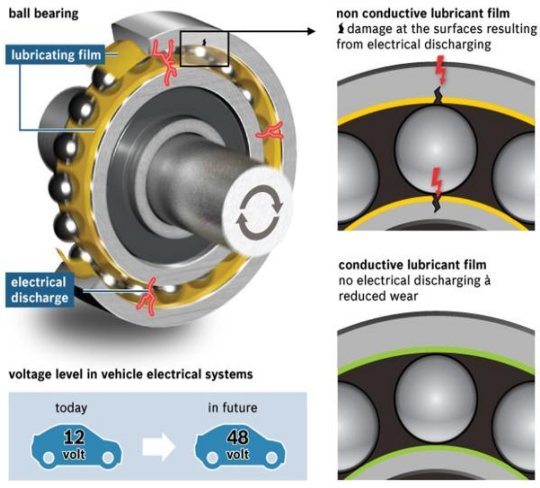

Fig -2 : Enhancing the conductivity of the lubricant film

A normal method to suppress the high-frequency bearing current is to build an insulation layer on the bearing. For example, hybrid/full ceramic bearings have been used in commercial electric vehicle. The purpose of this method is to increase the impedance between the bearings and the ground. Thereby, preventing electric discharge by insulating layer. Circulating currents can be suppressed by the ceramic or hybrid bearings, while the EDM currents are less affected. However an insulated bearing limits the dissipation of the heat flow from the rotor.

Suppress the electrical breakdown by improving the insulation performance of the bearing and enhancing the conductivity of the lubricated interface. High frequency insulating currents are suppressed by insulated layer like hybrid bearings it can prevent the EDM currents. Enhancing conductivity method is similar to the lubricant components, and simply adding metal particles to the grease could increase mechanical wear Thereby, a well designed electric contact lubricant will increase the lifetime and reliability of the system. When adding carbon black into calcium sulfonate complex grease and lithium, enhancing their conductivity, friction reduction and anti wear properties.

5. CONCLUSION

Through this study discussed about the various bearing failure problems and their solutions to overcome the bearing failure. Bearing failure caused by bearing currents, lubrication instability, fatigue spalling, fretting, smearing, skidding, abrasive wear, corrosion, cracks etc..and new electric-related failures like frosting, pitting, fluting, spark tracks have been discussed and various solutions were introduced. In this study, an overview on electrical bearing failure in electric vehicles has been discussed. Relevant topics such as common mode voltages, bearing currents, electric discharge machining and lubrication instability have been discussed. The generation and composition of shaft voltage and bearing current and the appearance of electrical bearing failure, and then to fundamental researches on lubrication behaviors under charged conditions, and finally feasible ways to solve the problem, are discussed.

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