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The prevalent motor bearing premature failures due to the high frequency electric current passage

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ABSTRACT

Bearing premature failures are prevalent in VFD (Variable Frequency Drives) motors. The three common symptoms of the modern bearing current appeared on the bearings of a group of pump motors. The bearing failure mechanisms have been studied from the tribological point of view. The natures of the three common symptoms have been uncovered. A hypothesis of the skin effect has been proposed to explain the three common symptoms. The discovery of the serial microcraters reveals the discharge with Fourier series features. The nature of the fluting patterns excluded the theories of both EDM (Electrical Discharge Machining) and discharge corrugation. VA (Vibration Analysis) detected the harmonics of the BPOR (Ball Pass Outer Ring) frequency which associated with the fluting on the outer raceway. This discovery may be applied to detect fluting in condition monitoring.

1. Introduction

Statistical data shows that over 60% of motor failures were bearing failures [1]. Since the application of Variable Frequency Drives (VFD) in contemporary motors, motor bearing premature failures have been prevalent due to the electrical current passage [2].

The bearing failures due to the electric current passage have been recognised for almost a century. The fluting phenomena in motor bearings were first discovered in the 1920s [3]. Subsequently, the bearing current issues in AC motors have been studied [4–7]. The various bearing symptoms have been listed in the bearing manufacturer's documents [8–11].

The practical solutions to bearing current, such as shaft grounding to bypass the current [2], ceramic-coated bearings [12] and hybrid bearings [13] for electric insulation, appeared to be effective. However, with the application of the fast switching PWM inverter in contemporary motors, the traditional solutions seems to be no longer effective for the high frequency bearing current [14].

In order to differentiate these two different kinds of bearing current, for the convenient discussion in this paper, the sinusoidal AC bearing current is referred to as the classic bearing current, and the high frequency non-sinusoidal current as the modern bearing current.

The research of modern bearing current had once been an active topic. Most of the studies focused on the bearing current sources from the electronic perspective [15–17], such as common mode voltage. However, fundamental research in modern bearing current issues from the tribological perspective has been very scarce. The difficulty lays in the complex failure mechanisms. In laboratory simulation tests, it is extremely difficult to separate a single mechanism from the complex

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Nomenclature

f	frequency of the current (Hz)
t	time (s)
A	half amplitude of the current intensity (ampere) – $I/2$
L	1/2 the period ($2L = 1/f$)
δ	skin depth (m)
μ	relative permeability of the medium
ρ	resistivity of the medium (Ω m)

mechanisms. Disregarding the simulation tests, on the other hand, scenarios and examples encountered in industry can be another path to understanding the fundamental failure mechanisms.

This paper presents some research on the motor bearing failure mechanisms due to modern bearing current passage from an industrial case study. The bearing premature failures occurred in a group of pump motors in the steamfields of a geothermal power plant in New Zealand. The motors were 250 kW with pulse width modulated (PWM) inverter VFD. The bearing numbers were 6318 (NDE) and 6320 (DE). Most of the bearings failed in approximately two years of service.

Visual inspection found that the bearing grease had been hardened or partially solidified. The bearing surfaces had been deposited with a brown film. From the symptoms of the brown deposit and the grease hardening, bearing failures due to the high frequency electric current passage was certain. Hence, the failed bearings can be applied in researching the fundamental failure mechanism.

2. Experimental methods

There were in total 20 of such motors. Vibration analysis in the condition monitoring programmes detected bearing deterioration. Before the motors break down, the problematic bearings had been replaced.

After the bearing grease had been ultrasonically cleaned, bearing coupons were cut from both the inner and outer rings. Fig. 1 shows a typical bearing coupon. Various analyses have been conducted on the failed bearing coupons.

2.1. LOM

LOM (Light Optical Microscopes), both stereomicroscopic and metallographic microscope, had been applied to examine the bearing coupons.

2.2. ESEM/EDS

The bearing coupons had also been examined under ESEM (Environmental Scanning Electronic Microscope); the model was an FEI Quanta 200 F with field emission gun. The EDS (Energy Dispersive Spectroscope) detector was EDAX brand SiLi (Lithium drifted) with a Super Ultra Thin Window.

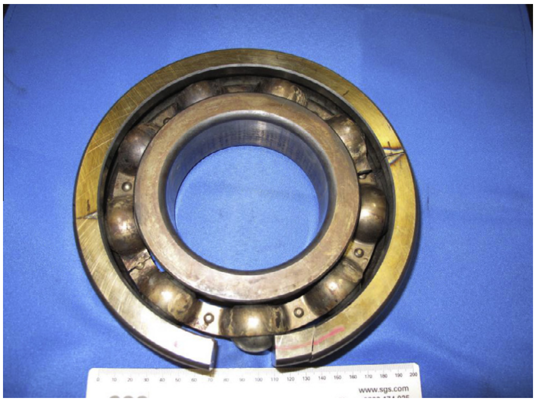

Fig. 1. The failed DE bearing covering with the brown deposit.