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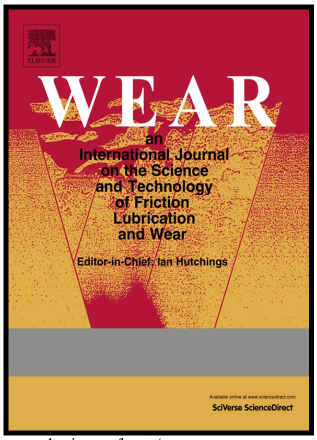

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Investigation on the Mechanisms of White etching crack (WEC) Formation in Rolling Contact Fatigue and Identification of a Root Cause for Bearing Premature Failure

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ABSTRACT

This paper reports on a study that has resulted in the identification of one of the root causes for bearing premature failure characterized by sub-surface 'white etching' cracks (WEC) and surface axial cracks leading to spalling on ring raceways. Failure analysis performed on some failed rolling bearings used in wind turbines revealed fretting corrosion bands on the inner ring bore having positions that coincide circumferentially with zones of sub-surface WECs and surface axial cracks on the raceways. Appearance of fretting corrosion bands on the bearing bore is an indication of bearing seat form deviation. It was demonstrated by FE simulation that bearing seat form deviation such as waviness can result in tensile stress near raceway, which, if exceeding a certain limit, can weaken the material and, in combination with Hertzian stress, result in early initiation and accelerated growth of cracks from the pre-existing material defects, leading to premature failure of the bearing. Rubbing between the crack faces during subsurface crack propagation causes microstructure alteration of the crack surfaces and the formation of WECs. The tensile stress drives the propagation of the subsurface cracks towards raceway, leading to occurrence of the surface-breaking cracks or the so-called "hair-line" axial cracks, and eventually spalling of the ring raceway. A specially designed bearing test has successfully reproduced the failure mode occurring in prematurely failed bearings in wind turbine gearbox. Such a test involves a wavy sleeve shaft that results in sufficiently high tensile stresses in the raceway region of a cylindrical roller bearing inner ring. All tested bearings failed prematurely under a relatively low load due to axial cracks on the raceway surface with associated clusters of sub-surface white etching cracks, i.e. the mode of failure that is commonly representative for wind turbine bearings.

Keywords: White etching crack, WEC, butterfly premature failure, root cause, rolling bearing, tensile stress.

1. INTRODUCTION

1.1. BACKGROUND

Bearings are critical machine components for carrying load and transmitting motion. The challenge of ever increasing power density from modern equipment manufacturing imposes higher demand for the load-carrying capacity on one hand and the reliability of bearings on the other hand.

Nowadays, bearing failure due to rolling contact fatigue is generally a rare occurrence and the final achieved life of rolling bearings is usually in excess of the calculated rating life. There are instances, however, where in specific applications the bearings fail prematurely at 5% - 10% of the calculated rating life. A characteristic feature of many premature failures is the extensive subsurface crack networks that have a 'white etching appearance', referred commonly to as white etching cracks (WEC). Such cracks propagate typically to the surface causing spalling of raceway which has commonly been observed on field returns from applications like wind turbine gearboxes [1], automotive driveline, alternators and peripheral auxiliaries [2, 3], paper mills [4] and marine propulsion system [5].