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White Structure Flaking in Rolling Bearings for Wind Turbine Gearboxes

By H. Uyama and H. Yamada,
NSK Ltd.

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Hideyuki Uyama and Hiroki Yamada, NSK Ltd.

[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Bearing failures in wind turbine gearboxes were investigated and rolling contact fatigue tests to reproduce them using a hydrogen-charge method were conducted. Two main failure modes in wind turbine gearbox bearings were white structure flaking and axial cracking, which were involving a microstructural change. Both failure modes can be reproduced by using specimens charged with hydrogen. Operating conditions, which can induce hydrogen generation from lubricant and penetration of the bearing steel were discussed. Effects of bearing material on white structure flaking life were suggested as one of the countermeasures.

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American Gear Manufacturers Association
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Hideyuki Uyama and Hiroki Yamada, NSK Ltd.

Introduction

Premature failures of rolling bearings occasionally occur in wind turbine gearboxes [1]. One of the main failure modes is flaking involving a microstructural change. This type of flaking is called white structure flaking (WSF) or white etching crack (WEC) because the area of the microstructural change observed in the flaking cross sections looks white after etching. Therefore, understanding the mechanism of white structure flaking is important for wind turbine gearbox reliability.

Flaking in rolling bearings occurs due to rolling contact fatigue and it is a similar phenomenon as spalling in gears. Flaking is generally classified to subsurface originated flaking, which is initiated at nonmetallic inclusions in materials and surface originated flaking, which occurs under contaminated or poor lubrication conditions [2]. However, recently white structure flaking can be seen in several applications, which is a different type of flaking from the subsurface and surface originated flaking mentioned above. For example, it is known that white structure flaking sometimes occurs in bearings for automotive electrical accessories as shown in Figure 1 [3]. There are many studies about the failure mechanism and the countermeasure for white structure flaking in automotive bearings. Some of them suggested that this type of flaking is induced by hydrogen generated by decomposition of the lubricating oil, grease, or water in the lubricant and that this phenomenon is concerned with hydrogen embrittlement [4] [5] [6] [7] [8] [9] [10] [11].

Axial cracks are also observed in failed bearings for wind turbine gear boxes [12]. This failure mode is very unique and it is seldom found in other applications. The same microstructural change as seen in white structure flaking is often observed in the cross sections around the axial cracks.

However, it is unclear whether the mechanisms of white structure flaking and axial cracking are the same or not. In this study, rolling contact fatigue tests were performed in order to reproduce white structure flaking and axial cracking by using specimens charged with hydrogen. From the view of hydrogen theory, influencing factors in operating conditions were discussed and effects of materials on bearing life were suggested as the countermeasure.

Observation results of failed bearings for wind turbine gearboxes

Failed bearings used in wind turbine gearboxes have been observed and two types of failures were mainly observed, which are classified as white structure flaking and axial cracking.

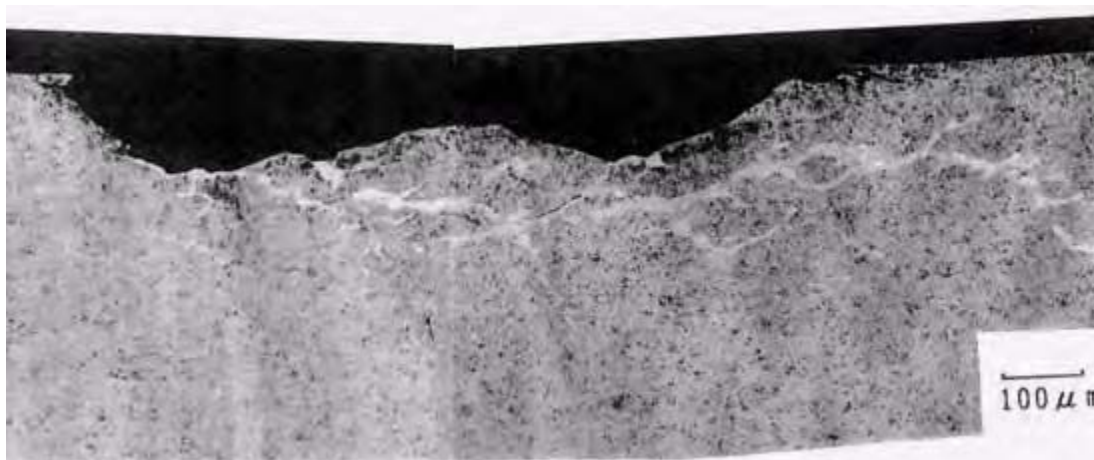


Figure 1. An example of the cross section of white structure flaking in an automotive electrical accessory bearing [3]

Figure 2 shows the observation results of a failed cylindrical roller bearing, which were used on the high speed shaft in wind turbine gearboxes. A small flaking was seen in the raceway surface as shown in Figure 2a. Figure 2b shows the cross section of the flaking area at the dotted line in Figure 2a. A microstructural change called white structure was observed at the flaking. Flaking morphology of failed bearings in wind turbine gearbox and automotive electrical accessories seem to be very similar as shown in Figure 1 and Figure 2b although bearing types and size are quite different. Namely, small size ball bearings are used for automotive electrical accessory and large size roller bearings are used for wind turbine gearboxes. Figure 2c shows the cross section of an area without flaking in the same bearing as shown in Figures 2a and 2b. White structure was observed even in this area, which is most likely to be the prior stage to flaking. Therefore it is presumed that this type of flaking in wind turbine gearboxes is initiated at the white structure.

Figure 3 shows the observation results of the other failed bearing, which is also a cylindrical roller bearing and used on the high speed shaft in wind turbine gearboxes. There were several large cracks longer than 10 mm and many small cracks around 1-3 mm in the axial direction on the raceway surface of the inner ring. Figure 3a shows two small cracks chosen of many axial cracks, which were observed on the raceway surface. The small cracks seem to be an early stage of crack propagation. A small axial crack was chosen for the cross section observation because small cracks are easier than large cracks to find the location of the crack initiation. Figure 3b shows the cross section including the small axial crack area. White structure was seen and it is seemed that a crack propagated along the white structure and reached the raceway surface. This crack is seen as the axial crack on the raceway surface.

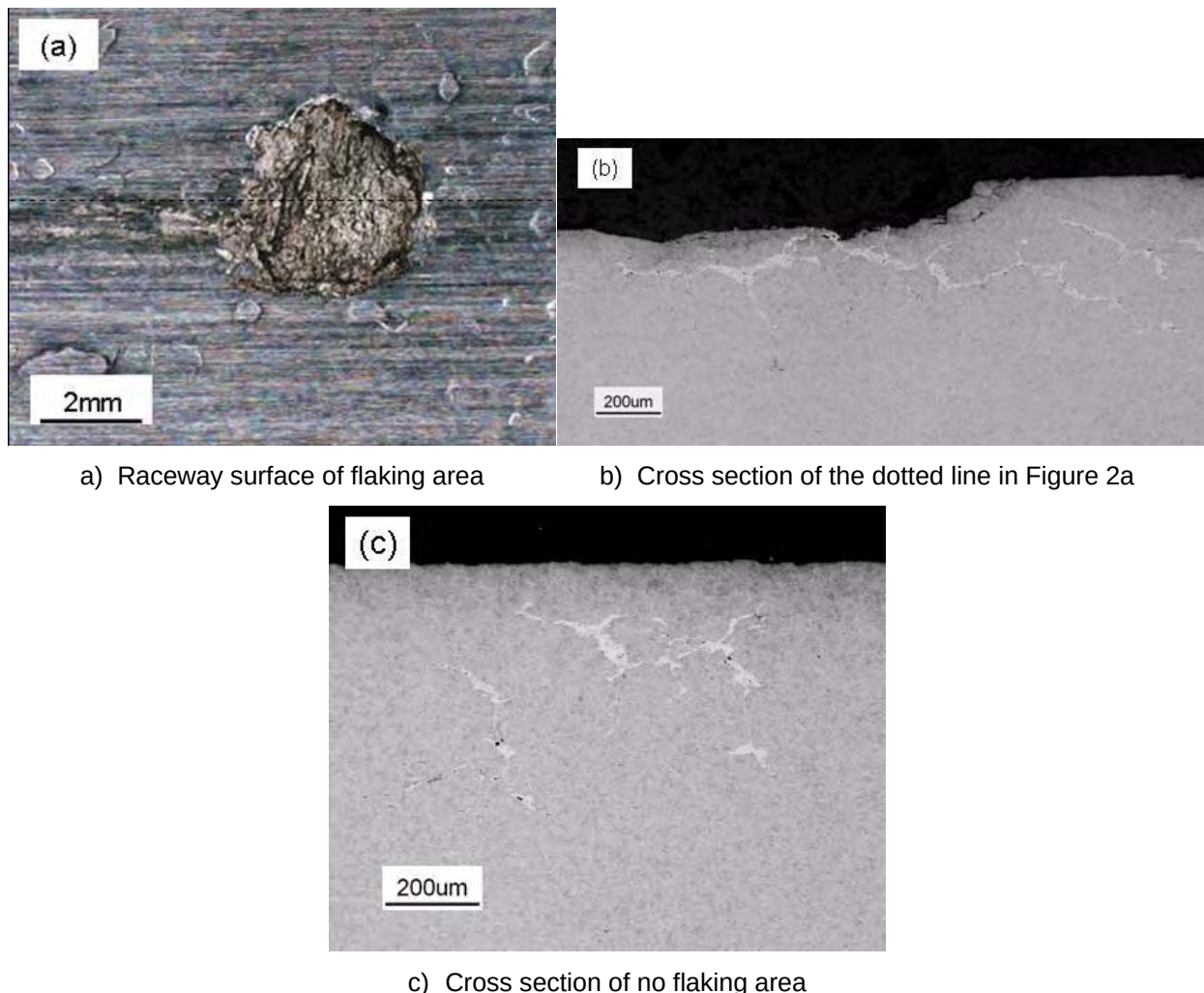


Figure 2. The raceway and the cross section of a failed bearing with white structure.