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# The Effect of Material Factors on Bearing Life

Sukit Deeyiengyang [1], Koji Ueda[2], and Nobuaki Mitamura[2,*]

[1] NSK Asia Pacific Technology Centre (Thailand) Co.Ltd., 700/430 Amata Nakorn I.E., Chonburi, 20000, Thailand
[2] *1-5-50, Kugenuma-shinmei, Fujisawa, Kanagawa 251-8501, JAPAN*
[*] Corresponding Author: deeyiengyang@nsk.com, +66-38-454-631 to 3, +66-38-454-634

***Abstract***

Generally, flaking in rolling bearings can be classified into several types based on the failure mechanisms. There are mainly subsurface originated, surface originated and white structure flaking. Subsurface originated flaking can occur under clean lubrication condition, and surface originated flaking occurs under contaminated lubrication condition. White Structure flaking is observed in specific applications. In order to extend bearing life, it is essential to clarify flaking mechanisms that correspond to failure patterns. Therefore, we have investigated material factor that are affected by each failure mechanisms of bearings, and proposed technologies for each failure mechanism that can be used to extend bearing life.

***Keywords:*** Rolling contact fatigue, Subsurface originated flaking, Surface originated flaking, White structure flaking

## 1. Introduction

It is well known that bearing fatigue life can be calculated by load condition. However, the fatigue life is greatly influenced by other operating conditions, such as lubrication condition. We have investigated the fatigue mode. Generally, flaking in rolling bearings can be classified into three types based on the failure mechanisms, subsurface originated, surface originated and white structure flaking.

Subsurface originated flaking is occurred by stress concentration around non-metallic inclusions exist in the bearing steel under ideal lubrication condition. Surface originated flaking is a result of stress concentrations at dent edges formed by debris under contaminated lubrication [1]. White Structure flaking is observed in specific applications. White Structure flaking is caused by hydrogen. It suggested that types of lubricant, slip between rolling elements and rings, and static electricity affect hydrogen generation and diffusion into bearing steels. It is clear that bearing life becomes shorter and white structure is formed due to hydrogen as mentioned above [2,3] .

This paper will discuss how bearing material affects the three types of failure mechanisms, and examine specific factors that play a role in determining the primary failure mechanisms for each type of flaking.

## 2. EXPERIMENTAL

The specimens were made of JIS-SUJ2 bearing steel, equivalent to SAE 52100. The specimens were hardened by austenizing at 1113K, followed by quenching in oil at 333 K. After hardening, the specimens were tempered at 443 K to produce a final hardness of 740 HV.

Three type of bearing life tests were conducted in order to reproduce each type of flaking.

### 2.1 Subsurface originated flaking test

Subsurface originated flaking test was conducted using a 6206 deep groove ball bearing under the following conditions; P/C: 0.71, the rotating speed: 3900 $min^{-1}$, lubricant: VG68. The test rig used is shown in Figure 1.

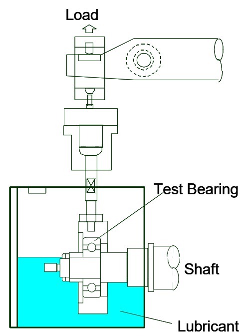


Fig. 1 Schematic of bearing fatigue life test rig.

### 2.2 Surface originated flaking test

Surface originated flaking test was conducted using a 51305 thrust bearing ring as the upper race and a flat washer as type specimen as the lower race (Figure 2), under the following conditions; Pmax: 4.9GPa, rotatingspeed:1000$min^{-1}$, lubricant:VG68; Contaminant particles: hardness HV740; diameter: 74 μm to 147 μm at 300 ppm.

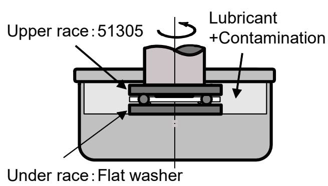

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Fig. 2 Schematic of 51305 thrust type life test rig.

### 2.3 White structure flaking test

Both the thrust bearing test and the deep groove ball bearing test were conducted regarding White structure flaking. Thrust bearing test machines were used for rolling contact fatigue testing under clean lubrication conditions. The upper race was a 51305 thrust bearing ring and the lower race was flat washer type specimen under the following conditions: The Pmax: 3.8GPa and the rotating speed was 1000min$^{-1}$, lubricant: VG68.

Also the deep groove ball bearing test was conducted using a 6206 bearing under the following conditions: P/C: 0.46, speed: 3000min$^{-1}$; lubricant: special lubrication oil

As shown figure 3, before rolling contact fatigue testing, the specimens were charged with hydrogen by immersing them in $NH_4SCN$ aqueous solution at 323 K for 24 h. Furthermore, to investigate what material factors have an effect on this type of fatigue failure, tests using bearings made in steel with various alloying additions, as shown in Table 1, were conducted. In particular, bearings made in steel with varying amounts of chromium were tested.

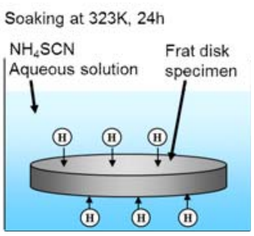



Fig.3 The method of hydrogen-charge

Table 1 chemical composition of steels using white structure flaking test.

| Steel symbol | Chemical composition wt% | | | | |
|---|---|---|---|---|---|
| | C | Si | Mn | Cr | N |
| Steel1(SAE52100) | 1.00 | 0.3 | 0.3 | 1.5 | - |
| Steel 2 | 0.89 | 1.0 | 0.3 | 3.0 | - |
| Steel 3 | 0.55 | 0.3 | 0.3 | 5.0 | - |
| Steel 4 | 0.45 | 0.3 | 0.3 | 13.0 | 0 14 |

## 3. RESULT AND DISCUSSION

### 3.1 Material factors affecting subsurface originated flaking life

The subsurface originated flaking was caused by stress concentrations at non-metallic inclusions. The factor that has a decisive influence on bearing life is the oxide inclusions in the steels. The best way to increase the resistance to subsurface originated flaking is the reduction of oxide inclusion.

So, we have studied the size distribution of oxide inclusion in the bearing steels. Figure 4 shows the result of oxide distribution and bearing life test under ideal lubrication condition. Form the results, the number and size of oxide inclusions in steel B is much smaller than A and this corresponds to fatigue life of B is longer than A. Using steel cleanliness evaluation method, we have developed long life bearing steel for subsurface originated flaking.

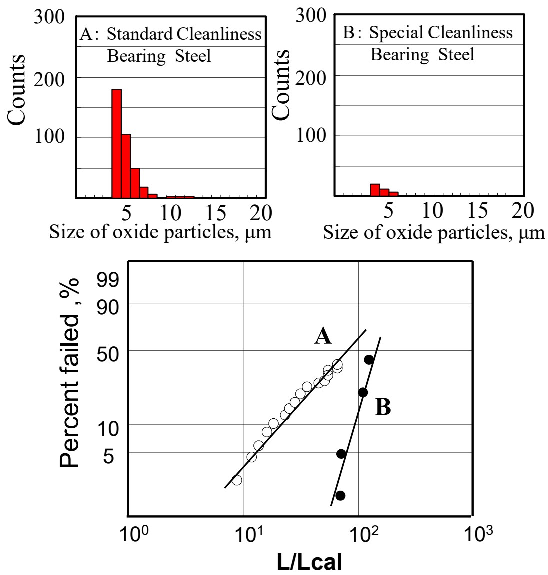



Fig.4 Rolling contact fatigue life of bearing standard cleanliness steel and high special cleanliness steel

### 3.2 Material factors affecting surface originated flaking life

When the bearings are used under contaminated lubrication condition, the debris makes dent on the raceway. Stress concentration occurs at the edge of dent, and results in crack initiation.

In the case of surface originated flaking, the stress concentration is very high and fatigue life becomes very short.

Chui et al clarified that the failure mechanism of surface originated flaking is caused by stress concentrations at the dent edge (Figure 5). The value of stress concentration is estimated by this equation as a function of r/c. Here r means curvature of the edge of indentation and c means size of indentation. So we have investigated what kind of material factor has effect on r/c value.

Figure 6 shows relationship between r/c value and amount of retained austenite. The volume fraction of retained austenite has good relationship to the r/c value. With increasing volume fraction of retained austenite, r/c value increases and stress concentration decreases.

Based on this result, we have conducted the surface originated flaking test as described above. Figure 7 illustrates the relation between retained austenite and result of bearing life under contaminated lubrication condition. It is clear that increasing volume frac[...] is an effective means of ext[...]d flaking life.

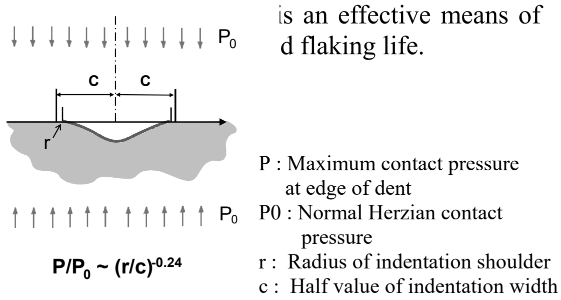



Fig.5 Contact pressure at edge of dent

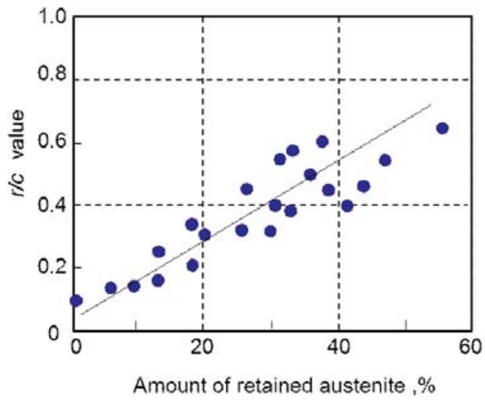



Fig.6 Relationship between r/c value and amount of retained austenite.

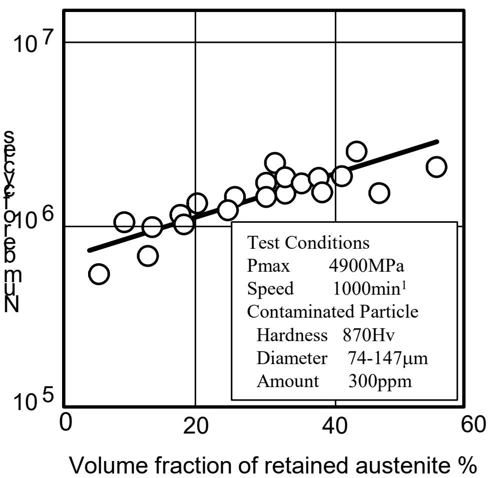



Fig.7 Relation between rolling contact fatigue life and amount of retained austenite under debris contaminated lubrication condition.

### 3.3 Material factor affecting white structure flaking life

Figure 8 shows the results of the rolling contact fatigue tests under the clean lubrication conditions. Flaking did not occur in the uncharged specimens. On the other hand, flaking occurred in most of the hydrogen charged specimens. It was noticeable that the fatigue life of the specimens that had been hydrogen-charged using the 20 mass % $NH_4SCN$ aqueous solution was much shorter. This can be attributed to the hydrogen content in these specimens that was higher than in the other specimens .

Figure 9 shows the microstructure adjacent to the area of flaking in a specimen that was hydrogen-charged. White structure and many fatigue cracks were observed. It is supposed that hydrogen localizes the plasticity in the rolling contact fatigue process. That localization of plasticity accelerates crack formation and propagation as well as microstructural change, which result in a reduction in the rolling contact fatigue life.

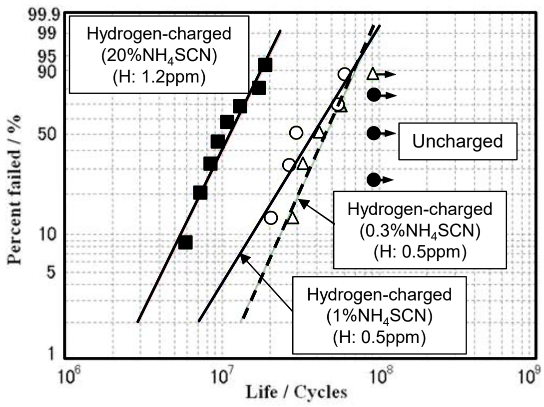



Fig.8 The result of rolling life test of specimen charged with hydrogen.

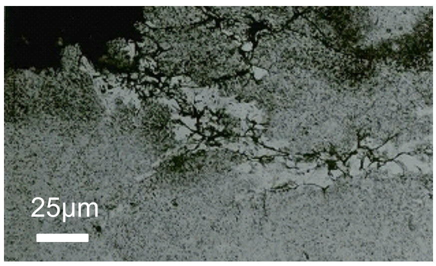
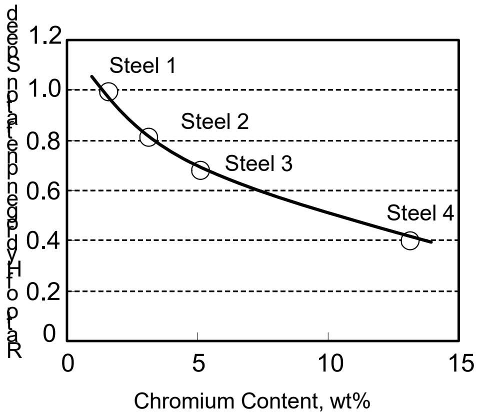



Fig.9 The microstructure adjacent to the White structure flaking

Figure 10 shows the relationship between the chromium content and the hydrogen penetration speed. The specimens used to determine the relationship were firstly immersed in 20% ammonium thiocyanate to saturate the steel with hydrogen. After saturation was achieved, the amount of hydrogen emitted from the samples was measured as a function of time.

The results showed that there was a strong relationship between the chromium content of the steel and the hydrogen penetration speed. As the chromium content increased, the hydrogen penetration speed reduced. The effective factor which affects flaking caused by hydrogen was examined.

Figure 11 illustrates the relation between added amounts of chromium and white structure flaking. As a result, increasing the amount of chromium in bearing




steel can be an effective means of extending bearing life.

Fig.10 Hydrogen penetration speed of various chromium content steel.

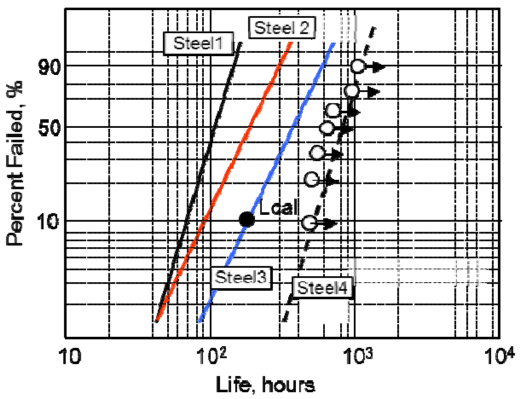



Fig.11 Relation between the additive amounts of chromium and the white structure flaking life.

## 4 CONCLUSION

- Steel cleanliness is effective against subsurface originated flaking under ideal lubrication condition. The best way to extend subsurface originated flaking life is reduction of oxide inclusion.
- A higher volume fraction of retained austenite is effective against surface originated flaking under contaminated lubrication.
- Increasing the chromium content of the steel can reduce the hydrogen penetration speed and consequently improve the resistance of the steel against white structure flaking.

## 5 REFERENCES

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