R. CELIN, D.KMETIČ

ISSN 0543-5846
METABK 47(1) 69-72 (2008)
UDC - UDK 621.822.8:620.1=111

CRACKS IN A ROLLER-BEARING

Received – Prispjelo: 2006-12-19
Accepted – Prihvaćeno: 2007-04-10
Professional paper – Strukovni rad

Bearings are among the most important components of electromotors, pumps, compressors and other processing equipment. After 30 years of work some non-destructive and metallographic examinations were carried out on a single-row cylindrical roller-bearing. A non-destructive liquid-penetrant testing revealed crack indications on an inner ring groove. When a sample of the roller-bearing outer ring was cut out for metallographic examination, new cracks were discovered that were not detected by the non-destructive testing. However, with the examination of the non-failed bearing it is possible to obtain useful information that can help us to decide how much of the remaining population of bearings with the same geometry and loading should be examined.

Key words: roller-bearing, crack, non-destructive testing

Pukotine na valjkastom ležaju. Ležajevi su veoma značajne komponente elektromotora, crpki, kompresora i ostale procesne opreme. Na jednorednom valjkastom cilindričnom ležaju, koji je bio u pogonu 30 godina bile su izvedene kontrole bez razaranja i metalografska kontrola. Sa metodom tekućih pentranata su se otkrile indikacije pukotina u žlijebu unutrašnjeg prstena. Kada je bio iz vanjskog prstena uzet uzorak za metalografsko ispitivanje otkrivene su bile nove pukotine, koje nisu bile detektirane kontrolom bez razaranja. Sa ispitivanjem ležaja koji nije otkazao tako je moguće dobiti korisne informacije, koje nam mogu pomoći o odluci koliki će biti broj ispitanih ležajeva između ostale populacije s jednakom geometrijom i opterećenjem.

Ključne riječi: valjkasti ležaj, pukotina, kontrola bez razaranja

INTRODUCTION

Roller-bearings are important components in the vast majority of machines, and are used in simple appliances, such as a wheel chair, to complex machines, such as automatic precision-grinding equipment, where accuracy has to be in the range of a micron. Practically all roller-bearings consist of four basic parts: inner ring, outer ring, retainer (cage) and rolling elements (cylinder, ball, needle, barrel, cone) [1].

Bearings are usually manufactured from high-strength steels with a high wear resistance, toughness, dimensional stability, excellent fatigue resistance and no internal defects. To achieve good mechanical properties the rings and the rolling elements are usually made from trough hardened steel.

The repeated high stressing on the contacts between the rolling element and the raceway eventually causes fatigue damage. In addition to this, the main reason for bearing failures is an improper handling-and-mounting procedure, corrosion, wear and manufacturing defects [2]. It is sometimes difficult to determine the real cause of bearing failure because of the effects of several inter-related factors [3, 4]. With a careful examination of the bearing it is possible to determine the failure mode, and with proper maintenance it is possible to prevent the recurrence of similar problems for the remaining population of bearings.

R. Celin, D. Kmetič, Institute of metals and Technology, Ljubljana, Slovenia

EXAMINATION

The object of the examination was a single-row cylinder roller-bearing with a retractable inner ring having the main dimensions:

- inner diameter, d = 80 mm,
- outside diameter, D = 240 mm,
- width , B = 80 mm,
- diameter of the rolling element, d_r = 30 mm.

The roller-bearing was in service for 30 years, with regular periodic inspections. For the dismounting and mounting onto the shaft the inner ring was heated to approximately 150 °C. No data about the actual loads and the bearing's operating time were available.

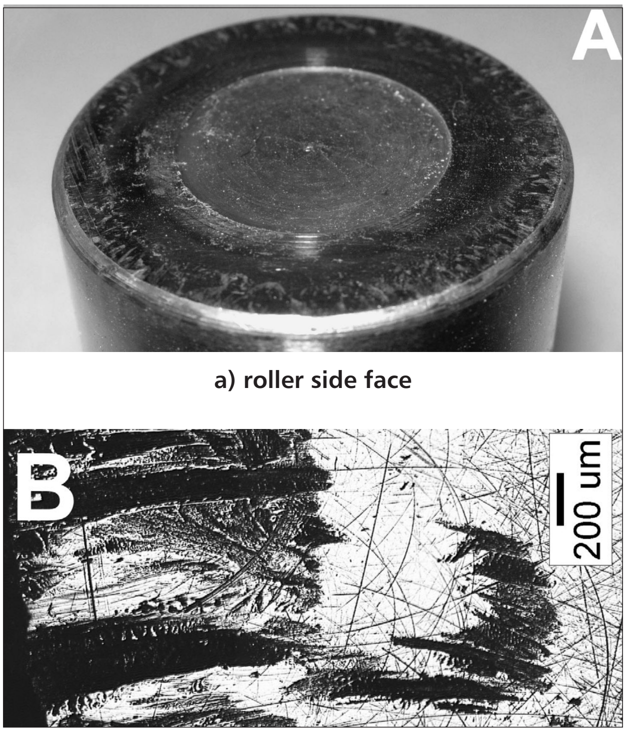
The bearing was submitted to a careful visual examination, liquid-penetrant testing, and a chemical analysis, hardness measurements, and metallographic examination of the steel were carried out. The metallographic examination was later completed with an electron energy-dispersion analysis on an electron microscope.

EXAMINATION RESULTS

Visual examination

On the outer and inner rings there were no hammering-impact damage marks due to incorrect handling procedures. The raceways on both rings and the cylindrical roller elements were without any marks of spalling, brinelling or track markings. The brass casting retainer was without any visible deformation marks or cracks.

On each of the side faces of the rollers traces of spalling were found. Figure 1a shows the side face of one roller, and Figure 1b shows the same surface at a magnification of 50×.



a) roller side face

b) spalling and scuffing magnified 50

Figure 1. Roller side face surface

Both rings were without any traces of scuffing or spalling.

Liquid-penetrant examination

All the surfaces of the inner and outer rings were examined with a red-dye liquid penetrant. On the outer ring no indications of defects were found. Three linear indications of cracks were found in the groove between the side rib and the raceway (location C in Figure 6). Figure 2 shows indication no. 1 with lenght of 22 mm. The lengths of indications no. 2 and no. 3 were of 25 mm and 60 mm, respectively.

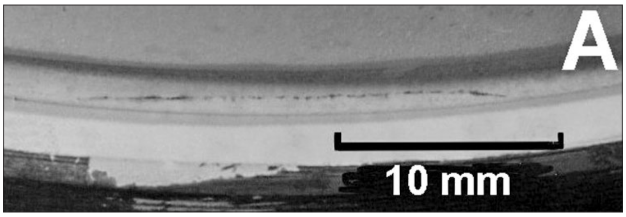


Figure 2. Indications of an inner-ring crack no.1

Metallographic examination

On the inner ring cross-section samples were cut out on the crack indications no. 1 and no. 2. Figure 3 shows cross-section of the crack indicated in Figure 2.

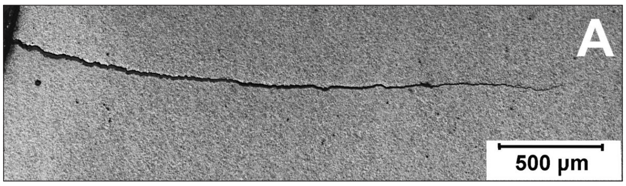


Figure 3. Crack no. 1

The depth of crack no. 1 is approximately 3 mm. Also, a sample cross-section was cut out at random from the outer ring. Rather unexpectedly, crack no. 4 (spot A in Figure 6) was discovered. The crack opening in Figure 4 is so narrow that the applied liquid-penetrant technique was not sufficiently sensitive to detect the crack.

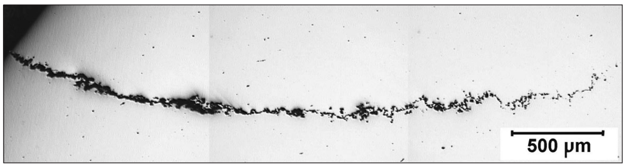


Figure 4. Crack no. 4

Due to the discovery of crack no. 4 another sample was cut out from the roller-bearing's outer ring. Another crack, no. 5, shown in Figure 5, was discovered (spot B in Figure 6).

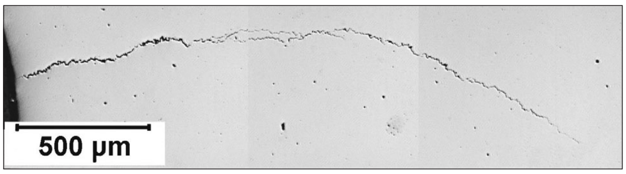


Figure 5. Crack no. 5

The positions of the detected cracks on the inner and outer rings are shown in Figure 6.

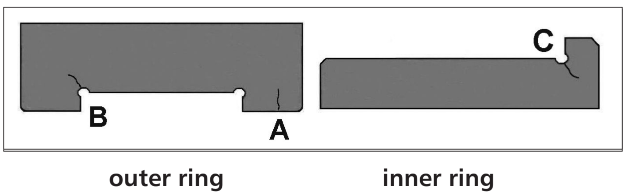


Figure 6. Ring cross-sections with discovered cracks

The microstructure of the outer ring is shown in Figure 7. The microstructure consists of tempered martensite with an even distribution of small globular carbide particles.

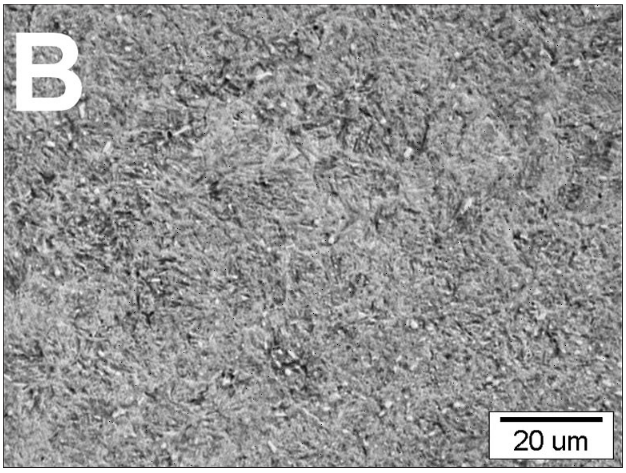


Figure 7. Microstructure of outer ring

An EDS analysis on crack no. 4 was carried out, and the presence of zirconium oxide (ZrO_2) was detected. Figure 8 shows a picture of the crack with the distribution of ZrO_2.

Hardness

The HRC hardness was measured on the outer and inner rings, on the cross-section of the roller and on the end face of the roller. The results are presented in Table 1.

The measured values correspond to heat-treated steel grade 100 Cr 6.

Table 1. **HRC measurements results**

no.	Inner ring	Outer ring	Roller cross section	Roller side face
1.	62	59,1	62,5	62,7
2.	62	59,7	62	62,8
3.	62	60,1	62,9	62

The chemical analysis

The chemical composition of the inner ring sample was: 0,95% C, 0,37% Si, 0,39% Mn, 0,022% S, 0,019% P, 1,45% Cr, 0,03% Mo and 0,021% Al. According to standard EN 10 027-1 this is a steel grade 100 Cr 6.

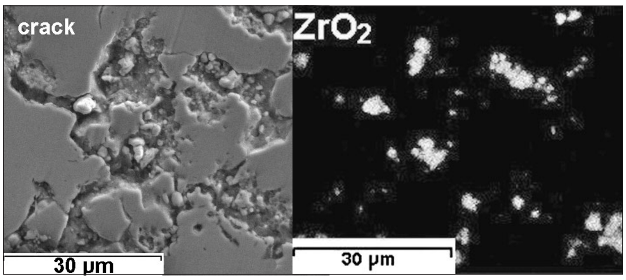


Figure 8. Crack no. 4 with the distribution of the ZrO_2

DISCUSSION

The roller-bearing surfaces were without visible imperfections. The raceways on the inner and the outer rings as well as the rollers were without indications of spalling, brineling or track markings. It is thus possible to conclude:

- the roller-bearing was not overloaded for a considerable time in service, since no visible damage was found on the raceways
- the raceways are clean and smooth

On the side faces of all the cylindrical rollers traces of spalling were detected. This is due to a lack of lubricant between the side face of the roller and the ribs of the inner and outer rings or retainer. The spalling shown in Figure 1b is minimal and in its initial stage. The contrast of the indications in Figure 2 is very poor because:

- of the very narrow crack opening, which is on the very limit of detection for the liquid-penetrant system applied,
- the lubricant penetrated into the crack during roller-bearing operation and was impossible to remove it with the applied cleaning and degreasing procedure.

Crack no. 4 was probably formed at the outer ring forging due to the crashing of hard non-metallic inclusions [5]. It appears that the crack itself did not propagate during the operation of the roller-bearing. The zirconium oxide inclusion probably originates from the steel casting process as a fragment of the pouring ladle, for which ZrO_2 is often used. In the other cracks there were no deposits found (scale, sulphide, oxide); only in the area near the crack opening were the remains of a lubricant detected.

Cracks no. 1, 2, 3 and 5 are positioned on the low stress area of the roller-bearing. Taking into consideration the morphology of the cracks it is very difficult to estimate and evaluate their nature. Figure 9 shows the end of crack no. 2, with a splitting end and an intergranular path, which is characteristic of a quenching crack.

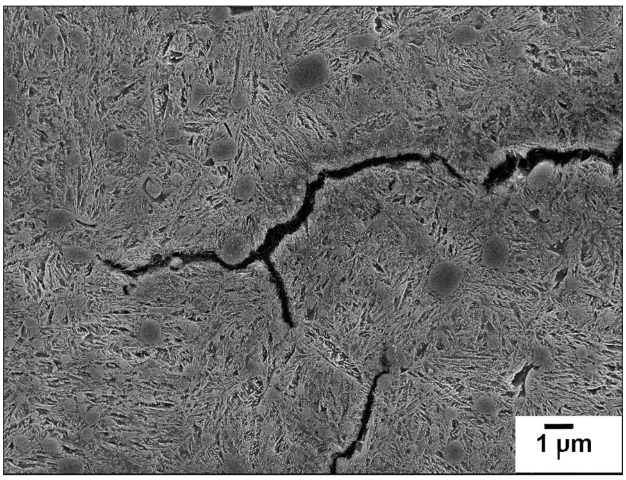


Figure 9. No. 2 crack end

The results in Table 1 show that the inner ring and the cylindrical roller have approximately the same hardness, with the outer ring being slightly lower.

The measured values in the case of the hardness are common for 100 Cr 6 heat-treated martensite microstructure with small carbides. The end face roller hardness shows that occasional friction contact without lubricant did not cause overheating of the surface.

CONCLUSION

The roller-bearing is an element with a very important role and dominates the performance of some machines and process equipment. If one of the bearings fails, the damage can be minimal. On the other hand, bearing failure on a transportation device can have severe consequences. Every bearing becomes unservicable after a certain operating time, even if it is installed correctly and operated properly. To prevent unnecessary bearing failure, a regular inspection must be carried out. The examined bearing, which was in operation for 30 years, did not show any damage on the raceways. The HRC hardness was in the usual range for a roller-bearing heat-treated steel grade.

A visual examination of the roller-bearing's surfaces did not reveal any signs of a damage. The cracks were detected with non-destructive and destructive examinations. The purpose of the inspection was to determine the overall condition of the roller-bearing. Because of the detected cracks, the frequency and the extent of the inspections on the roller-bearings with a similar geometry and loading were increased.

REFERENCES

[1] K. H. Decker, Decker, Elementi strojeva, Tehnička knjiga, Zagreb, 1987, pp. 220-239

[2] J. L. A. Ferreirra, J. C. Balthazar, A. P. N. Araujo, Enginering Failure Analysis 10 (2003), 745-758

[3] W. Ost, P. De Baets, Enginering Failure Analysis 12 (2004), 772-783

[4] P. J. L. Fernandez, Enginering Failure Analysis 4 (1997) 2, 155-160

[5] R. Kiessling, N. Lange, Non-metallic inclusions in steel (parts I-IV), The Metals Society, London, 1978, pp. H II: 87

Note: Linguistic Adviser/ English language Paul Mc Guiness, Ljubljana, Slovenia.