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A Study on the Failure Mode of the Rolling Bearing with Defective Balls

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In this paper, the endurance life of the rolling bearings with defective balls and their failure (flaking) phenomena are presented. It was found that the lives of ball bearings with defective balls were shorter than that of calculated L10 life as well as that of normal bearings in spite of the using standard bearing components. Although the bearings were assembled with defective balls, whereas the other parts were qualified new ones, the main failures were occurred on the inner ring raceways. Moreover, the failures were on the center of the groove curvature and the severity of failure is similar to the order of initial defect depth of the balls. These shows that the defects on the bearings can affect the life of tribologically contacted mating parts.

Keywords : Rolling bearing, Defective balls, Bearing life, Defect printing, Failure mode

1. INTRODUCTION

Most of all tribological components, including bearing parts, are exposed to the defect formation environments during manufacturing, fitting and servicing. The existence of dents or furrows on contacting surfaces can cause significant reduction in the contact fatigue life of gears, cam-followers and rolling bearings even under well lubricated conditions [1].

During last two decades, many of researches were carried out on the tribological behavior with the defective parts. Ai et al. [2] calculated the stress around a dent in EHL contact. Tomimoto et al.[3] prove in the experiment that larger particle than the film thickness generate the friction force and damage the surfaces. Kotzalas and Harris[4] estimate ball-raceway traction as a function of degree of spalling. Cheng et al. [5-6]. investigated fatigue crack initiation phenomena with artificial defects which were made by different samples and shapes However most of the studies prepared the all the effort is concerned with the defected parts failure and focused on the defect itself and its boundary [3-7] .

In this paper shows endurance life reduction of the rolling bearings with artificial defective balls and their failure (flaking) phenomena, and investigate their morphological characteristics. And flaking sizes of inner ring were compared with the initial depth of defects on balls.

2. TEST METHODS

In order to make the defective balls with the assembled bearing, abnormal thrust forces were applied between inner and outer rings for assembled ball bearings using the universal testing machine. After then, the balls were picked out very carefully, measured the defect (nick) size of balls by high magnification apparatus and reassembled bearings with those balls and new rings for endurance life test.

The tested bearing type was grease packed and sealed deep grooved ball bearing, ISO 6303. It has 17mm bore diameter, 47mm outer diameter and 14mm width. All bearing was packed with polyurea grease with rubber seals and installed with polyamide cages. The dynamic load rating of this bearing is 13.64kN.

The bearings were tested with 3.41kN (25% of dynamic load rating) radial load, 2,900rpm shaft rotating speed and the normal temperature. The endurance test was performed by KBC Type Ball Bearing Life Tester which can test 4 bearings simultaneously, in one shaft, with inner ring rotation while outer ring was stationary during the test runs. Table 1. shows the defect(nick) sizes of defective balls in micro meter and the remarks column shows the test duration, where T1 and T2 were 256 hours and 309 hours respectively.

Fig. 1. shows the schematic diagram of KBC Type Ball Bearing Endurance Tester, TBSS. On the top of it, the hydraulic loading actuator installed and the load applied to the two central and two side bearings with same amount but opposite directions.

Table 1. Defect(Nick) depth of balls (unit : μm)

No.	Min.	Max.	Avg.	Remarks
1	0.220	0.398	0.288	T2
2	0.314	0.616	0.419	T1
3	0.296	1.065	0.557	T2
4	0.446	1.162	0.673	T2
5	0.631	1.235	0.830	T1(Failure)
6	1.028	1.672	1.295	T2(Failure)
7	2.366	3.665	2.820	T1(Failure)
8	2.355	3.706	3.016	T1(Failure)

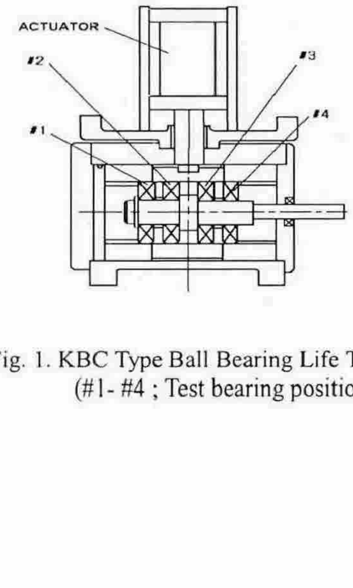

Fig. 1. KBC Type Ball Bearing Life Tester
(#1- #4 ; Test bearing position)

3. TEST RESULTS

As shown in table 1., eight different sets of balls were assembled with new rings and tested. The test was continued until the bearing failure which was monitored by acceleration type vibration sensor and the tester was automatically stopped when the vibration level exceed the adjusted value.

After test, the bearings were cleaned by kerosene, disassembled carefully and examined the dimension and the morphology of failure shape. The investigation results are showed on table 2. In this table the mark '0 ' shows safe and good appearance, '◑' shows discoloration and/or wear of the raceway and '★' shows the failure on the contacting parts. The number of stars shows the severity of failure shape.

Table 2. The failure severity of components for tested bearings.

No.	Inner Ring	Outer Ring	Balls	Remarks
1	0	0	0	
2	0	0	0	
3	0	0	0	
4	◐	0	◐	
5	★	0	◐	
6	★★	◐	◑	
7	★★★	◐	★★	
8	★★★★	◐	★★★	

Fig. 2 shows the failure morphology of inner ring of the tested bearings and the number is the same one on table 1 and 2. It is easy to compare the severity on table 2 and the inner ring failure on Fig. 2. The failed balls on bearing 7 and 8 are shown in Fig. 3. The arrows in the figure show the failure spots of the components.

Followings were found with the investigations after the life test.

1) The severe defective ball bearings, nick depth over 1 ㎛, showed premature failures and showed short life compare to the calculated L10 life as well as normal bearing life in spite of the using standard bearing components. Whereas the less severe defective balled bearing tested without failures.

2) It is founded that the inner ring failed severely compare to the balls even though the balls had artificial defects (nicks) before testing. Although the test T1(2, 5, 7, 8 bearing) was tested in one shaft for 256 hour, the flaking shapes of the test bearings were different each others. No. 5 had one spot flaking, no. 7 had two spots of flaking and no. 8 had long flaking area but No.2 bearing has no flaking. And the flaking range were limited only two ball contact distance on the inner ring.

3) The bearing with the severe defect (nick) depth balls showed the more severe inner ring failures. The no. 8 bearing showed most severe failure compare to the other bearings.

4) The failure occurred on the center of inner ring curvature for all failed bearings. It is well accord with the fact that the test condition was only radial loading. And it can be explained that the failure caused not by the irregularities of the inner ring by the ball defects and loading.

5) Some of bearings showed safe balls and outer rings where as the inner ring failed. The maximum stress of outer ring is lower than the inner ring but the position of it was stationery in one position. So, it is considerable that why inner rings were affected by the nicks of balls.

4. CONCLUSIONS

In this results, inner ring failure in the defected ball bearings, imply that the failed component could be caused by imperfection of the other tribological mating components as well as itself. It is considerable in the bearing that the failure of inner ring for normal application is strongly related with not only the quality of itself but that of the other mating components, for example ball and outer ring.

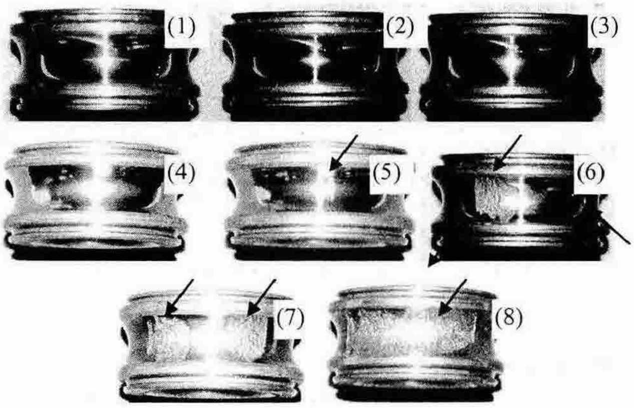

Fig. 2. Inner rings of tested bearings.

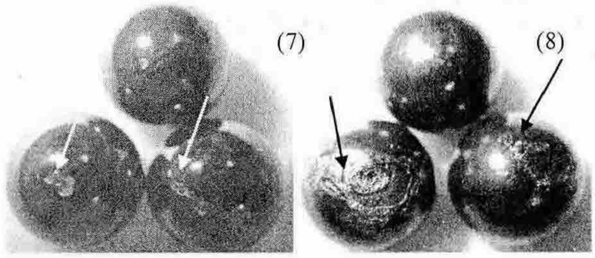

Fig. 3. The failed balls on bearing 7 and 8.

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