

Wear Analysis of Linear Bearings

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INTRODUCTION

A manufacturer had repeated failures with a linear bearing used to move parts being treated up and down. The linear bearing was flat and about a foot long and circulated small balls in a rectangular raceway. The first symptom of malfunction was that the slider parts of the bearing resisted motion, instead of floating freely. A failed bearing was submitted to Herguth Laboratories on May 5, 2003, for analysis of the problem. Following is their report as an example of procedures in wear analysis.

DETAILS

Linear Bearing Operation

It was stated that the sliders or bearings move up and down on the guide approxi-

mately one inch per second, over short distances, under load and at room temperature. The rolling parts were reportedly 440 C stainless steel. The operation causes the balls to roll back and forth in the raceways of the guide. The bearing was lubricated with a perfluoroalkylpolyether gelled with polyterafluoroethylene.

Method of Examination

The unit was examined as received for grease condition. The lower bearing was disassembled to release its balls. Parts were cleaned with various solvents and the balls cleaned ultrasonically in solvents. Damaged areas were examined and photographed with a stereo zoom microscope.

RESULTS

Observations (Unaided Eye)

The rolling areas on the two upper bearings and the mating raceways on the guide, as well as the grease, appeared to be in good condition with insignificant wear. One row of balls on the lower bearing and the mating ball raceway on the guide, about 12 inches from the bottom and about eight inches long, were severely damaged. The grease on the damaged areas was contaminated with metallic wear flakes and there was also a large accumulation of wear particles where the balls enter the recirculation tunnel. Elsewhere, the grease was plentiful and in good condition, though, the bearings were not starved for lubricant.

Microscopic Observation (Ball Raceway on Upper Areas of the Guide)

We assume the equipment was exposed to

Figure 1. MICROGRAPH OF DENTS IN BALL RACEWAY OF STAND



(30X Shows Original Grinding and Dents in Center of Raceway)

shop air, which may be dusty. As shown in the micrograph in *Figure 1*, the raceway on the far upper end of the guide was dented. This was not visible to the unaided eye. Further down the raceway, significant damage in the form of disturbed metal was observed. At the beginning of the severely damaged area, isolated shallow pits with cracked metal adjacent to the pit were observed (*Figure 2*). Pits and associated cracks are evidence of rolling contact fatigue. In the severely damaged area, cracks, pits and deformed metal were observed, as shown in *Figure 3*.

Microscopic Observation (Balls in the Lower Slider)

The balls in the upper row of the linear bearing were in good condition. But the balls in the lower row were severely damaged, the same as the stand raceway. The micrograph of the ball in *Figure 3* shows a large crack, pits and deformed metal characteristic of several balls examined.

DISCUSSION OF CONTACT FATIGUE AND PREVENTION

Lubrication of Unit

It is commonly understood in tribology that oil weeps out of the soap gelling agent and is the primary lubricant. The bearings should operate in the elastohydrodynamic regime of lubrication where a full-fluid oil film is generated by the rolling action, elastic deformation of the balls and adequate oil viscosity. The oil in the grease has a viscosity of 146 cSt at 40 C, which is adequate. The back-and-forth rolling causes many stops, or zero rolling velocity, where the oil film will be thin or squeezed out. Reduction in oil film thickness increases stresses and promotes cracks. Therefore, the stop-and-go and reversed rolling direction contributes to shorter bearing life.

Rolling Contact Fatigue

The damage found is characteristic of advanced rolling contact fatigue. The appearance is the same as published by Zaretsky (1), which is labeled "Point sur-

Figure 2. MICROGRAPH OF ISOLATED PITS IN BALL RACEWAY OF STAND



(30X Shows Pits and Associated Cracks)

face-origin spall caused by surface stress concentration." Pitting accounts for the generation of large amounts of metallic wear debris. The particles are loosened by the extended cracks. Then most of the free chunks are rolled upon to form flakes.

Time of Operation

Rolling contact fatigue is a result of cyclic stress. Bearing catalog life is determined by the occurrence of contact fatigue under ideal conditions. A large number of stress cycles, or a long time of operation will eventually cause contact fatigue. The author presumes the linear bearings in the unit had not exceeded their catalog life.

Metals Used

Zaretsky shows that 440 C stainless steel has a life factor of 0.6 compared to the carbon steel 52100 of 3.0. This indicates that shorter bearing life could be expected if 440 C steel was used. Perhaps the corrosion resistance of 440 C is not required in this application and 52100 should be considered. Plain carbon steel is not used in high-quality rolling element bearings.

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Figure 3. MICROGRAPH OF SEVERELY DAMAGED BALL AND RACEWAY



Ball With Large Crack



Raceway with Cracks and Pits

Load

The most common cause of premature contact fatigue is overload because it increases stress and thins oil films. The localized damage of the contact fatigue on the linear bearing suggests overload on one row of bearings. This could be due to misalignment due to twisting or some other mechanical condition, such as uneven distribution of load. Therefore, a re-examination of load distribution is suggested.

Grease Contamination Solid Particulates

Dents in the guide raceways indicate solid particles were rolled between the balls and the raceways. Dents are known to create stress-raising sites and cause early surface-initiated contact fatigue failure. Cracks can be subsurface or surface initiated. The dents indicate that the grease contains solid particulates, probably contamination from the environment. The author assumes the stand is exposed to laboratory air that may be dusty. Dirt in lubricants could be an exacerbating factor. Therefore, protection of the unit from dust should be considered.

SUMMARY AND RECOMMENDATIONS

The raceways and balls of the upper left side of the lower bearing and the mating raceway on the guide were severely damaged by contact fatigue. This diagnosis confirmed our report of May 6, 2003, on fresh and used grease analysis from the unit.

To reduce contact fatigue failures one should consider several measures: the use of steel 52100 with better fatigue resistance, the possibility of non-uniform loading, and the reduction of solid and water contaminants in the grease. <<

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REFERENCES

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- (2) Moyer, C. and Derner, W.J., "Rolling Bearing Fatigue Life," *Handbook of Lubr. and Trib.*, 3, pp 469-489, (1994).