The Roll-Bearing Damage Analysis of Centrifugal Pump (Zm11-W375/04)

Dedi Wardianto 1 & David Setiawan 2

1 Muhammadiyah Sumatera Barat University
Email: dediwardianto71@yahoo.com
2 Universitas Lancang Kuning, Pekanbaru, 28265, Indonesia
Email: dsetia@unilak.ac.id

Abstract: A series of activities was occupied to reveal the failure event of the pump bearing of SKF 6313 type. As the result of macroscopic and microscopic analysis, it was triggered by maintenance lack along the operation. The failure was proved by the metallographic test that there was a deformation caused heat that of the cooling distribution lack due to non-maintenance periodically. The high local temperature cause the bearing life (L.10 standard) reduces, therefore it make a degradation of strength. Bearing life tends to decrease, according to the life calculation it should operate up to 8000 hours, but in fact, it is only operate between 2000-4000 hours. The bearings was made from the high carbon steel that follow the AISI-SAE 1095 standard, the chemical composition were 0.917% C, 0.41% Mn, 0.030% S. The deformation on the surface between two sides contacted ball of bearings was visible that of the suffered erosion due to friction, it could be predicted because of the lubrication lack, so it triggered an increasing of local contact temperature.

Keywords: bearings, damage, L 10 standard, maintenance, and power.

I. Introduction

The perceived public demand for water is increasee from time to time either for domestic use, buildings, offices, shops and domestic industry as well as for large industrial needs. Regional Water Company (PDAM) is the only company that was given the assignment of responsibilities and obligations by government to produce water and should be able to ensure the availability of water for 24 hours a day at an affordable price for smooth activity and productivity of community. Regional Water Company, located in Pangilun Mount of Padang City use water from Batang Kuranji as the raw water, treat by three (3) pump unit that has 250 liters/sec. of capacity in each pump unit. Two (2) units pump run in parallel systems, and one more unit pump stand by. The operating time of each pump is 96 hours on and 48 hours off, so that the average of operating time is 6000 hours/years. System maintenance of the pump is the corrective maintenance, which of maintenance is done in case of symptoms, such as the abnormalities of engine sound, decreasing capacity, fluid leak etc.

The pump machine used by PDAM of Padang City is the centrifugal pump. In its operation, of course, need an adequate technology and science to maintain and repair in order to watch the machine running in an optimal, efficiency and effective condition, to ensure continuously the production of water. In the fact, the pump has the operating time of 4000 hours/years, there is a
decreasing of its performance that need to be overhaul. On that overaul were found a damage of several components, such as ball bearings of centrifugal pumps. This ball bearing deprave in a relative short period before reaching the standard bearing life of 8000 hours. To prevent that problem needs to be done a studies to know the uncertain cause of the ball bearings damage factor, especially the model, mechanism and main cause of damage, in such away the failures can be overcome and the same damage does not repeat.

From the above background can be described that problems, that of the damaged bearing material needs to be tested and examined to know obviously the main cause of failure/damage and finally can be justified scientifically. In observation is visually seen that the possibility of bearing failure start from the load reserved area, the bearings of the centrifugal pump are allegedly caused wear, less lubrication in overall and so significantly wear the bearing. The high stress concentrations cause a geometry change and make the bearings fail in a brittle fracture manner, its support that material properties is quite brittle visually. To make a consistent flow of research, the scope of this study is confined to the main cause of to the ball bearing damage of centrifugal pumps and the mechanisms of such damages as well as an effort to find a solution how to extend the bearing life. The activities consist of: Macro Test (such as, Fractography test, the surface area of receiving load, and the thickness of the broken bearings), Metallography test, hardness tests, and chemical composition testing and also an analysis to define the solution of problems in order to extend the bearings life in usage.

Therefore, the aim of this study is to obtain actual information about the cause of damage of ball bearings of centrifugal pumps and its damage mechanisms, so that we can provide appropriate and safe recommendations in using the materials, and also the efforts to prevent more fatal of the damage as well as its maintenance. The results of this study are expected to give a benefits and well contribution to the industry that operate the centrifugal pumps specially the Regional Water Companies of Padang city, so they are able to ensure the continuity of production water and the availability of the spare part of components in time and relative low cost.

2. Methodology

2.1 Research sites

To obtain the accurate data of the damage causation of the centrifugal pump ball bearing, it took a series of research and laboratory test. This testing is done in B2TKS-laboratory - Puspitek BPPT Serpong Jakarta.

2.2 Testing materials

The test material is a damaged ball bearing of centrifugal pump. The centrifugal pump is operated in the Regional Water Company of Padang city, West Sumatra.

Figure 1. The test material for the damage ball bearing
2.3 Laboratory testing

To achieve the objectives of this study conducted series of tests includes: visual testing of the damaged bearings and, the chemical composition testing, metallographic testing and hardness testing of material bearing in order to obtain the accurate data for evaluation and analysis in determines the cause of damage, damage mechanisms with supported and assessed by literature, finally to obtain the mitigable techniques.

2.4 Research activity

It is necessary to make an overview of the activities to be carried out, related to this damage analysis, in order to the analysis activities run systematically on the scope and constraints of the problems, for more details can be seen in the following of flow chart below:

![Flowchart]

**Figure 2** Flowchart

2.5 Method of Data Collection

In conducting to this research, the collection of the taken data was done by the method of collecting the literature that closely related to the bearing failure analysis. Technically is done by: - Direct observation in the field, Observing the direct operation in installation and examine and analyze the defective ball bearings.
3. Results and Discussion

Inspection and data collection do in water intake Regional Water Company (PDAM) Padang city for the pump overhaul, at that time we find:

1) Some damage in the ball bearings of shaft support connecting the motor to pump water. The operator inform that the bearing operated for 8 months of 4 years pump life, the previous bearings operate normally for 8000 hours (4 years operation). The bearing is the SKF 6313 radial bearings, 140 mm diameter.
2) There are some water bleeding in the pump cavity, so that make a vibrations.
3) There is a sound clank on that bearing.
4) When disassemble the pump, we found a droughty lubricant inside that bearing.

![Figure 3](image)

Figure 3 Photo makro fault cage fatener steel bals broken on the river patahan cage (from the picture a) : surface side fracture b, visible direction of crack propagation path and broken area rest (picture c).

3.1. Identification

Visual inspection of the results shows the indication of damage in Figure 4. 2. It can be seen that there are some cracks making line in the outer center.

![Figure 4](image)

Figure 4 The cracks
3.2 Metallography

Investigation of the microstructure aim for product quality control, assesses the case of damage as well as to determine the fabrication process of the metal products is done correctly. Working step are: cutting, mounting, grinding, polishing and etching.

![Figure 5 The condition of bearings](image)

3.3 Hardness test

Hardness test is done at B2TKS - Puspitek BPPT laboratory in Serpong using Frank Finotest test machine, according with the SNI 19-0409-1989 standards. The tests do to the surface of outer ring, the inner ring and ball bearings, the results as shown in the Table4.1:

| No | Value | Hardness Vickers (HV) |
|----|-------|----------------------|
|    | Outer Ring | Inner Ring | Ball Bearing |
| 1  | 753 | 632 | 653 |
| 2  | 712 | 676 | 687 |
| 3  | 699 | 699 | 739 |
| 4  | 687 | 753 | 767 |
| 5  | 550 | 725 | 795 |
| Σ  | 680 | 697 | 728 |

The high hardness is a indispensable properties. It aims to avoid the wear of bearing. In this case it need the carbon substance balance, because of the hardness violence is better for high carbon substance, while the toughness decrease if the carbon content is too high, it become brittleness. So it is necessary to use appropriate alloy composition and also appropriate heat treatment. From the hardness test, it seemed that the hardness value of ball bearings is somewhat higher than the hardness value of the outer and inner ring.

The high ball hardness make it is stronger than the ring, it is necessary for receiving a great pressure load, impact and helping the rotation. Because of the ball stronger than ring, so the ring will be wear caused friction in collision and in some cases see the surface crack. the softer material will suffer from harder material.
3.4 Chemical Composition Testing

Chemical composition test of this bearing is done at B2TKS - BPPT Puspitek laboratory in Serpong using a test machine of emission spectrometer, according with the testing standards of AISI- SAE 1095. The data of obtained test results is shown Table 4.2, bellow.

| No | chemical elements | (%) | AISI-SAE 1095. composition% |
|----|-------------------|-----|-----------------------------|
| 1  | C                 | 0.917 | 0.90 – 1.04                |
| 2  | W                 | 0.13  |                            |
| 3  | Si                | 0.12  |                            |
| 4  | Mn                | 0.41  | 0.30 – 0.40                |
| 5  | Cr                | 1.54  |                            |
| 6  | Ni                | 0.084 |                            |
| 7  | Mo                | 0.023 |                            |
| 8  | Cu                | 0.0074|                            |
| 9  | Al                | 0.00  |                            |
| 10 | V                 | 0.00  |                            |
| 11 | Fe                | 96.82 |                            |
| 12 | Ti                | 0.00  |                            |
| 13 | Nb                | 0.0007|                            |
| 14 | B                 | 0.0001|                            |
| 15 | S                 | 0.030 | 0.050 Max                  |
| 16 | P                 | 0.042 |                            |

Based on the obtained data of chemical composition testing, this bearing material classify as the high-carbon steel with 0.917% of Carbon, In accordance with the standard AISI_SAE 1095 (UNS designation 10950), the composition of this material constrained by: 0.90-1.04% C, 0.30-0.5% Mn, 0.04% P and 0.050% Smax Discussion. The cage of ball between two ring is functional to hold the ball out from rotation line. In the macro investigation, there are the visible fracture at the ring surface like a crack propagation shown in Figure 4.5, while in the micro investigation see that in this crack presence corrosion pitting. (figure 4.6.), the corrosion may be accelerated according to this crack making gap that of dirt of material impurity. This material impurity contaminate with oxygen to make anode, the surfaces lack produces the crust and so on, there was a pitting caused corrosion seem an uneven surface.

The phase form of ring micro structure are ferrite and pearlite, while ferrite form is a dominant, so the surface of ring as a cage is softer than ball. Because of direct contact between ball and ring, the precision ball erode the soft surface of ring, it is happen in a low oil lubrication condition. This effect shown in Figure 4.6. The ball of bearing become oval like egg, the contacted surface of ball become carbide and in the other side is martensite phase. in a contacted surface micro structure changes shape (oval), the direct contact in outer and inner ring corrode to form incrustatioin. the ball of bearing is difficult to rotate and making the higher friction force. This surface of inner and outer ring shown in . The corroded surface make a sound clank in that bearing when the shaft rotate past.

On the inner side of the ball bearing, shown in , there are impurities of sulfur binding Ferro to form FeS, this compound decrease the melting point lower than basic metal triggering the shortness effect. In a chemical composition investigation, the percentage of sulfur 0.03%. The microstructure phase of the ball bearing is marten site. On the outer ring shown in, occure the pitting corrosion, while
in the center side there are the impurity substance of Sulfur. On the inner side happen vibration in operation to make a groove deformation and surface uneven.

3.5 Ideal bearing life calculations

Bearing Life (L) = \( \frac{10^6 \cdot C^3}{60 \cdot n \cdot P^3} \).

In pump specification data, pump power is 145.5 Kw at rotating speed 1450 rpm making the rotating inner ring assembling to shaft is 10.48 m/sec. Consequently, obtaining the dynamic load to the inner ring is 1369 kg or 684.5 kg (1509 lbf) each bearing, for 1 Hp = 75 kgm/sec.

So that, \( L = \frac{10^6 \cdot 20700^3}{60 \cdot 1480 \times 1509^3} = 29.000 \) jam

This implies that the bearing life is 4.8 year operation, if it is deemed one day equal to 24 hours and a year equal to 250 days.

4. Conclusion and Suggestion

Based on the discussion results data, we can be concluded:

1) Hardness of bearing components are 680 VH (Vicker Hardness) for outer ring, 697 VH for inner ring and 728 VH for ball. It is on the range of bearing standard,

2) The bearing material is high-carbon steel, with 0.917% carbon

3) The bearing heatreatment do to form sementite phase by heating to remove the residual stress. Material become ductile and able to damp the vibration.

4) From the fact of examination, ball bearing into an oval shape changes occur due to the side that rotated on its outer and inner are in phase whereas sementite side on the cage turned into a martensite phase, it is caused by the triggered heat and rapid cooling rate. Ones of the tested ball bearings contained sulfur of caused impurities.

5) The other substance of impurities also contaminate the bearing.

6) There is a deformation in inner ring, caused of the dynamic load and the centerless of rotating shaft. The outer ring corrode as a result of impurities.

7) In investigation, there is a bad clutch that is still used.

8) The general conclusion of this examination (point 1-7), this centrifugal pump run without maintenance. Actually the maintenance in manual books has to be intantion.

Therefore, this study would like to suggest below:

1) In order to conduct periodic routine control on the operation of the pump

2) To prevent bearing damage should be measured motor drive shaft alignment with the pump shaft.

3) The pump shaft on the side of the bearing seat should be measured equality.

4) Installation pads should be done with the equipment recommended.

5) In order to do a good lubrication of the bearings in accordance with the procedure.
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