Jurnal P & PT Vol. VIII, No. 2, Desember (2010) 720 729

JURNAL PPT

FAILURE ANALYSIS OF LEAN AMINE PUMP AT A GAS COMPANY IN GRESIK

Wiwik Purwadi
Beny Bandanadjaja
M. Achyarsyah

Jurusan Teknik Pengecoran Logam
Politeknik Manufaktur Negeri Bandung
Jl. Kanayakan 21, Dago-Bandung 40135
Telp./Fax. (022) 2500241/ (022) 2502649
e-mail : wiwik@polman-bandung.ac.id

ABSTRAK

Sebuah pompa sentrifugal mengalami kerusakan pada bulan oktober 2009 setelah bekerja selama tiga tahun. Tujuan dari penelitian ini adalah untuk menemukan dan menentukan akar penyebab dari kegagalan tersebut dan memberikan rekomendasinya. Selama masa aktifnya, pompa tersebut telah mengalami tiga kali penyebarisan, sesuai dengan jadwal kerja perbaikan motor listrik. Pada saat itu, informasi tentang perubahan suhu sebelum kerusakan total tidak tersedia. Informasi yang tersedia tentang parameter yang relevan terhadap kerusakan tersebut belum mencukupi rincian data yang ada. Oleh karena itu, penelitian ini dilakukan utamanya pada bagian-bagian yang rusak, dengan tipe radial bantalan rol FAG NU 313. Penelitian telah dilakukan untuk mendukung analisis dengan data yang dapat dipercaya, dan ini terdiri dari pemeriksaan visual, fotografi makro, pemindaian mikroskop elektron, mikroskop optik, mikroskop stereo, pengujian sifat mekanik (nilai kekerasan 59,2 HRc) dan analisis kimia dengan spektrometri emisi optik. Data hasil pemeriksaan tersebut telah dianalisis dan dibuat secara terstruktur dalam bentuk alur kronologis kejadian dengan memperhatikan beberapa kondisi lingkungan yang dapat dipertimbangkan. Hasil dari analisis data yang tersedia dan pengujian yang dilakukan, ketidakseimbangan gerakan motor dan vibrasi yang telah berlangsung cukup lama sebagai penyebab kerusakan pompa amine.

Kata Kunci: analisis kegagalan, bantalan rol

ABSTRACT

A centrifugal pump has failed in October 2009 after three years of service. The objective of the work is to find and determine the root causes of the failure and provide recommendations. During its service time, the pump has experienced three times realignment, due to repair works on the electric motor. Any information about the temperature change just before the total breakdown is not available. The available information about the relevant parameters prior to the incident has not sufficiently covered the detail data. The investigation is therefore subsequently conducted mainly on the broken parts, which is Radial roller Bearing Type FAG NU 313. Observations have been conducted to support the analysis with the justifiable data, and these comprise of visual examinations, macro photography, Scanning Electron Microscopy, optical microscopy, stereo microscopy, testing of mechanical properties (hardness value of 59.2 HRc) and chemical analysis by Optical Emission Spectrometry. The data resulted from these examination has been analyzed and structured onto a *flow of chronological Occurrence by putting some environmental conditions into consideration. As resulted from the analysis of available data and testing, the long term unbalance movement of motor and vibration lead to the failure of the amine pump.*

Key words: failure analysis. roller bearing,

INTRODUCTION

The amine centrifugal pump is used to distribute amine gas for the whole system at a Gas Company in Gresik, East Java. The centrifugal pump has failed in October 2009 after three years of service, which is less then the lifetime mentioned in the manual instruction of the pump. The downtime has subsequently caused a leak time of production and high cost of maintenance work. An investigation on the material, parts, system, working parameters and environmental condition should be conducted to avoid any similar occurrence. The purpose of research is to find out and determine the root causes of the failure and provide recommendations for further pump operation.

MATERIAL AND METHOD

The amine centrifugal pump is used to distribute amine gas The working pressure at the entrance gate (suction pressure) is 3.7 bar while the discharge pressure reach the value of 50.8 bar. The pump is placed outdoor and exposed directly to the ambient temperature of 17.2°C 37.6 °C with the relative humidity of 56%-93%. In the normal condition the centrifugal pump produced a flow rate of 50.16m3/h

As described in the figure 1 (475) bearings at the both side of the main shaft support the shaft. At the Non Drive End a double angular contact ball bearing were mounted to retain the axial and the radial load as well as providing bearing mechanism for the rotational movement of the shaft. At the drive end a cylindrical roller bearing (indicated by red circle) was mounted to support the rotational movement of the shaft.

The axial load might be resulted from the shaft was retained mainly by the angular contact ball bearing. Any contraction due to the rise of temperature during its service was accommodated by the free axial movement of inner ring of the roller bearing. A sleeve was fixed to the shaft and fitted to the inner ring of the roller bearing.

Since the high rotation and misalignment of the system might be occurred, a rigid platform and mounting was built to give a damping effect. The pump and the motor were conjuncted by using

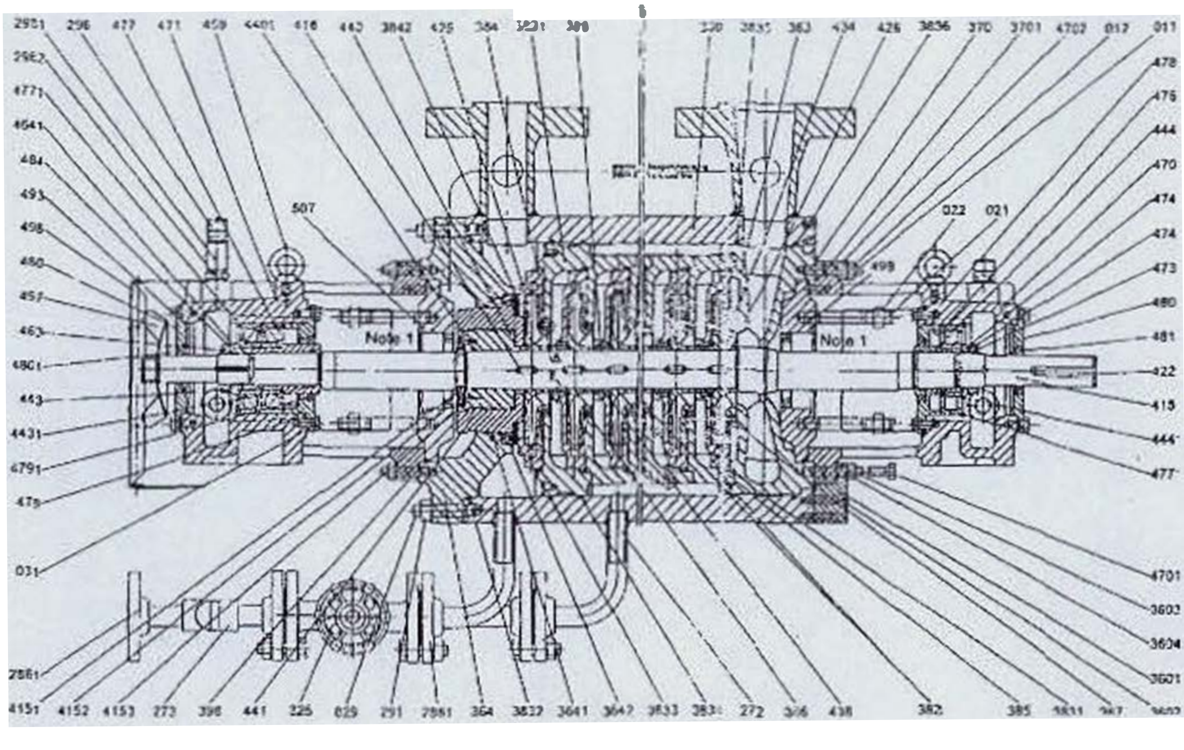


*Figure 1. Construction of Centrifugal Pump *) Manual Instruction of Centrifugal Pump*

a flexible metal coupling (see figure 2.). To avoid any leakage of the gas while the pump running at 2955 RPM, mechanical seal and O ring seal at the end of the shaft were attached in the pump

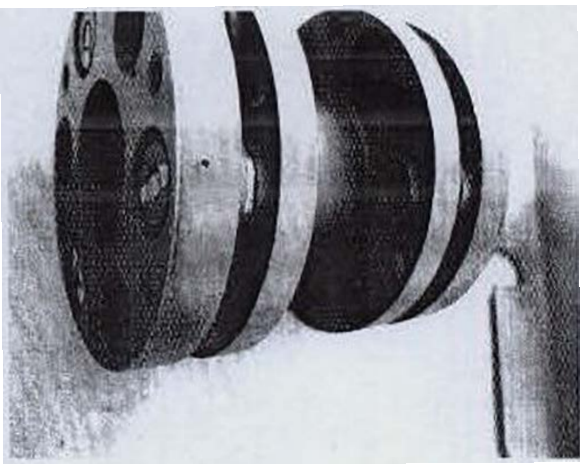


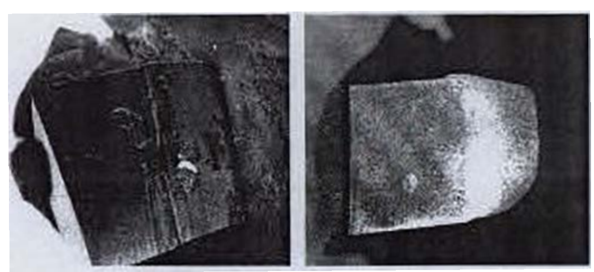
Figure 2. Flexible coupling

Visual examination and on site investigation have been conducted to gain detail information about the work principle, environmental conditions and the chronological steps prior to the occurrence/failure. Since the pump has been repaired and set up in working condition, the observation and examination are primarily focused on the examination on the damaged parts and other relevant parts. The laboratory testing for microscopical, macrocospical, chemical and mechanical observation supported the analysis and provide technically adequate and reliable data. Since the roller bearing was indicated as the failed part, the observation has been focused on this part.

The result of testing and observation are to be used for deeper analysis on the mechanism of the failure, effects and root causes. Testing and observations are conducted on the damage parts. Other parameters which might have any influence to the pump are to be put into consideration. All the observable facts are then to be constructed onto a chronological occurrence. The root cause and recommendations can be therefore pulled up from this analysis.

RESULT AND ANALYSIS

The as received bearing was carefully examined both visually and with the aid of stereoscopic microscope (magnification up to 65X). The examination covered all parts of the roller bearing. It revealed that the bearing was totally broken and experienced significant rise of temperature as indicated by the color. Almost all exposed surfaces show discoloration, wear and plastic deformations. It was interesting that the surface of the inner ring has been remarkably deformed as shown in the fig 3. Such deformed area could only be happened while the inner ring was still running. On the back side of the inner ring, at which the sleeve was attached, there was path pattern to be identified as shown in fig 4. It has indicated that the sleeve still ran on the inner ring after the bearing was totally blocked. It increased subsequently the temperature of the inner ring, which furthermore lead to the decrease of the hardness.



(a) (b)

Figure 3a and 3b. Deformed area around the race way of inner ring

Figure 4. Path pattern on the backside of inner ring

The rolling elements have experienced high temperature increase. On one side of the rolling element occurred strong deformation, while lighter deformations have been identified on the rest of the surface as shown in fig 5a and 5b.

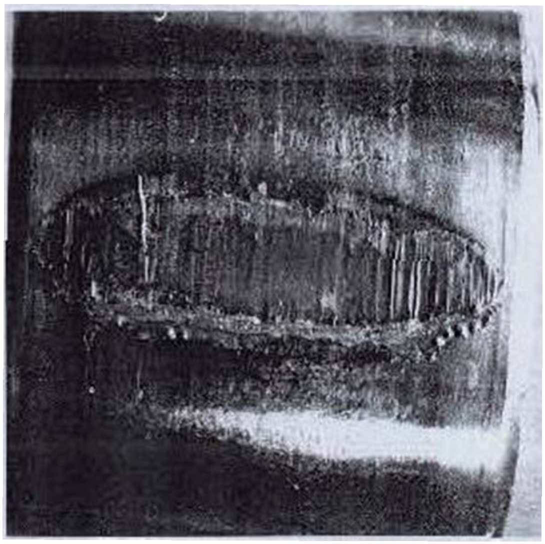


Figure 5a. Strong deformation on the surface of the Rolling element

The strong deformed area did not have any indication of comet. The deformation happened when the bearing had stopped.

Figure 3b. Light deformation on the surface of the Rolling element

The light deformation on the surface of the rolling element indicated loads due to vibration while the bearing was still running.

The inner ring experienced strong deformation caused by the high pressure of rolling element as shown in fig 4a and 4b. The curve of the deformed area matched to the curve of the rolling element (outside diameter of the rolling element). Considering the shape of the deformed area and the color of the inner ring, the deformation took place after the bearing totally blocked and the temperature increased. Becker, WT and Shipley RJ (2002) described in his work "Failure Analysis and Prevention" that the increased temperature caused a softening effect to the material, which enabled the material to be deformed without any crack occurring.

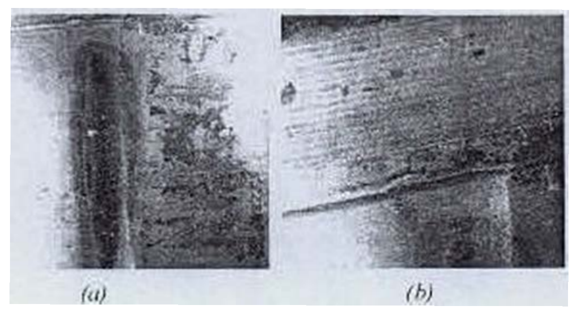


Figure 6a and 6b. High temperature deformation

After the bearing collapsed, the rolling element experience light arcing and increase of temperature, as shown in fig 7. The positions of arcing area are similar for all rolling element.

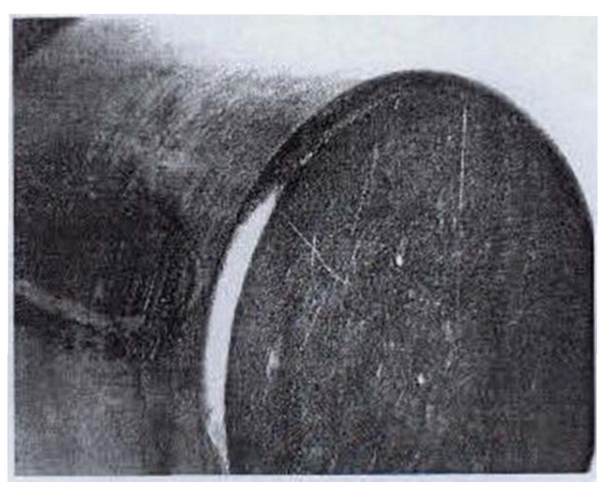


Figure 7. Arcing on the rolling element

The metallographic observation was focused on the rolling element and inner ring. The sample were cut of by applying low current at the wire cut machine to avoid any change of the microstructure. Nital was used as the etchant after the grinding and polishing process had been completed. On the surface of large deformed area, a deposit of foreign metal has been identified as shown in fig 8. The clear cut parting line between those materials could be used as evidence that the white area is deposit material. By deeper look into the material, it could be seen that there was diffusion along the parting line as shown in fig 9. The base material of the deposit is basically similar to the material of the rolling element.

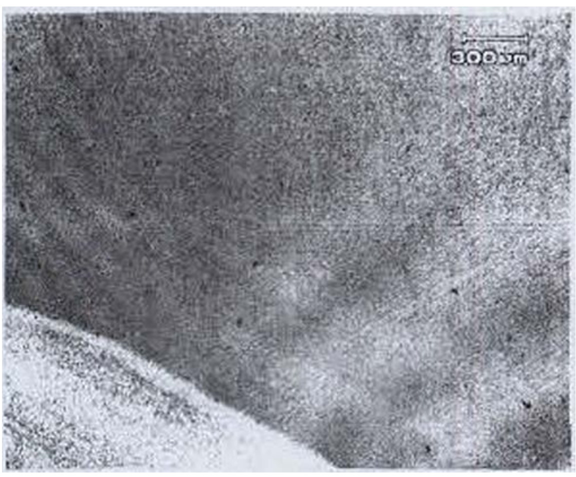


***Figure 8.** Deposit of material*

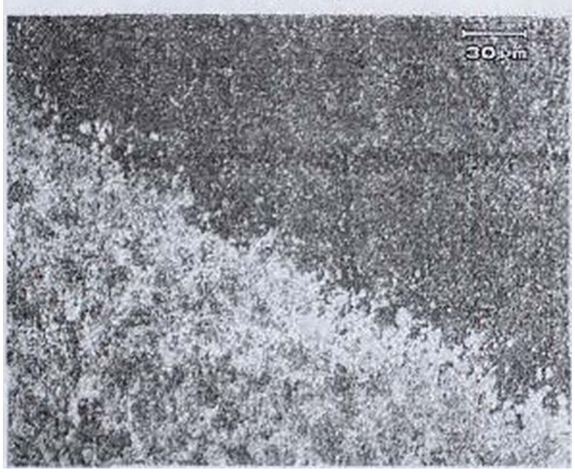
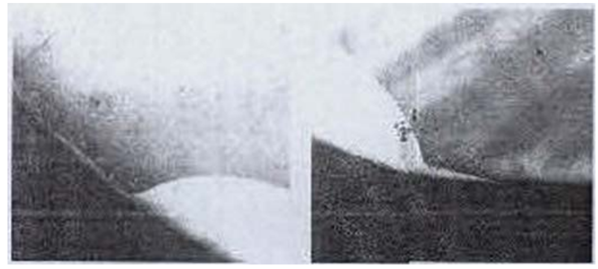


***Figure 9.** Diffusion along the parting line*

The material deposit caused the blockage of bearing which then followed by the increased of temperature. The edge of the deposit as shown in fig 10a and 10b proves that there was no movement of the rolling element after the deposit material bonded on the rolling element.



(a) (b)

***Figure 10a and 10b.** Deposit Material*

Microstructural change has occurred in the area of arcing. Gradual change of microstructure always indicates a slow increase of temperature occurred to the material (Jones, DRH, Engineering Failure Analysis). The gradual change of microstructure as shown in fig 11 indicated a slow increase of temperature. The high electrical shock is therefore not considerable.

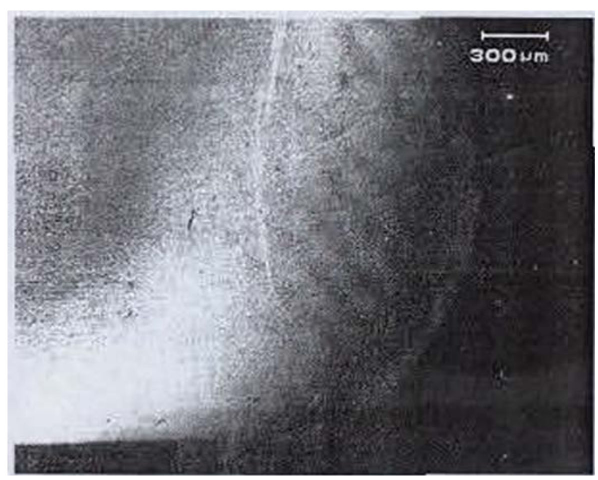


***Figure 11.** gradual change at the arcing area*

Due to the increase of temperature, there was no preferred orientation (texture) to be found in the inner ring. Paula J. Dempsey, Gary Kreider and Tom Fichter in their work "Investigation of Tapered Roller Bearing Damage Detection Using Oil Debris Analysis" have been proved that friction on the surface always caused texture in radial direction. Smooth surface of the raceway is considerably an indication that the deformation was mainly caused by excessive load, rather than wear as shown in fig 12. There was no texture of deformation in radial direction, which is characteristic for the increasement of friction. Figure 13 and 14 show that the excessive heat (up to 700 ºC) has caused a change in the microstructure of the inner ring. Closed under the raceway, spheroidal carbides are finely dispersed in the matrix of martensite. Away from the raceway (closed to the sleeve) austenite and martensite are to be found.

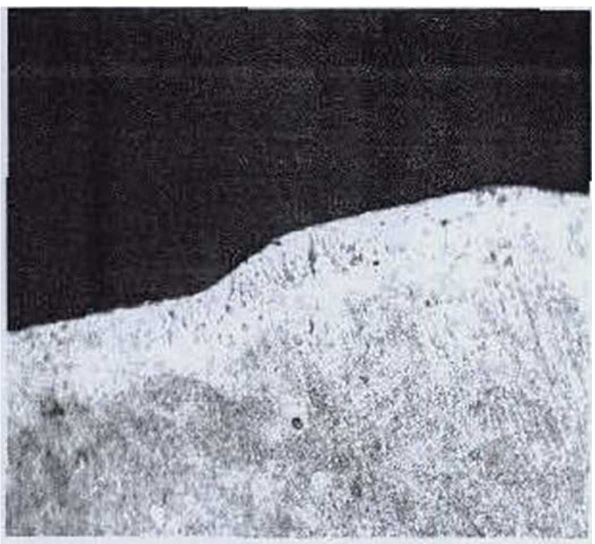


Figure 12. Smooth surface of the uniformly deformed area of the raceway

Figure 13. Microstructure closed to the race way by different magnification

Figure 14. Microstructure closed to the sleeve by different magnification

One of the rolling element and inner ring have been subjected to optical emission spectrometry (OES) elemental analysis. The results were compared to ASTM A295 grade SAE 52100 and SEW 350 grade 100Cr6 material, which is widely used as material for roller bearing. Chemical composition in weight % for both material is shown in Table 1.

*Table 1. Chemical composition of standard bearing material *)*

Standard	C	Si	Mn	Cr	Cu
SAE 52110	0.98-1.10	0.15-0.35	0.25-0.45	1.40-1.60	Max 0.30
100Cr6	*0.90-1.05*	*0.15-0.35*	*0.25-0.40*	*1.40-1.65*	

The chemical composition of the analyzed roller bearing as shown in Table 2 complies with the standard. The chromium content is slightly less than the required value, but it has no significant influence to the hardness of the material (59.2 HRc).

Table 2. Chemical composition of the bearing material

C	Si	Mn	Cr	Cu
0.94898	0.23783	0.34867	1.3118	0.13428
S	P	Mo	V	W
0.00473	0.00683	0.03148	0.0025	0.00392
Sn	Al	Ni	Ti	Fe
0.00599	0.03192	0.15922	0.00219	balance

Figure 15 described the Hardness Value in HRc for the rolling element.

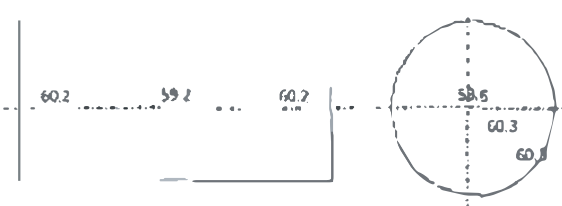


Figure 15. Hardness value of the rolling element

There was no significant difference in the hardness of the material. The surface area showed slightly higher value. In general the hardness value met the standard requirement of the bearing hardness. The inner ring experienced work hardening, which lead to the increase of hardness as shown in the Table 2 and Figure 12.

Table 3. Hardness of inner ring

Position (mm)	Hardness (VHN)
0	613
0.1	557
0.2	494
0.3	441
0.47	401
0.6	353
0.8	362
1.4	358

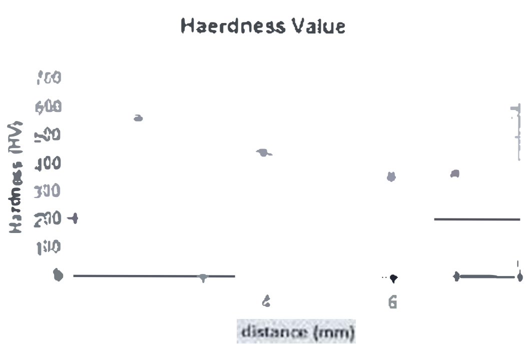


Figure 16. Hardness of inner ring

At the surface area the inner ring experienced stronger work hardening and resulted higher hardness value while the inner part of the ring experienced increased temperature and softening effects.

Scanning electron microscopy examination, sample was removed from the inner ring. SEM examination revealed a crack on the border of deformed area. Figure 16 shows the location of the crack and its propagation. The shear stress was caused by the deformation of the race way. The surface area of the race way experienced high compression load, which is indicated by the thin layer of deformed grain as shown in Figure 17. The smooth surface of the raceway indicated the absence of corrosive attack.

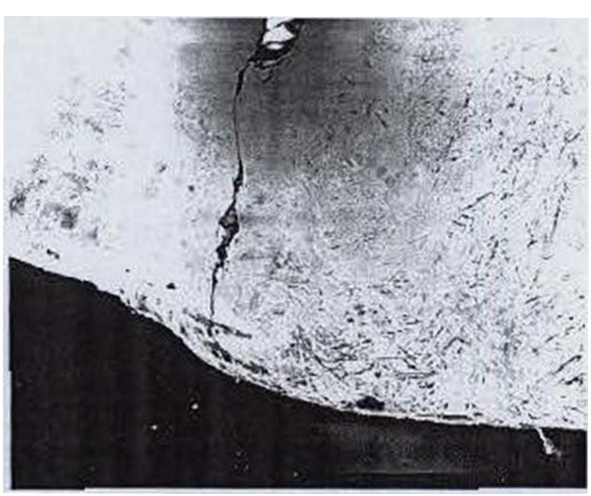


Figure 17. crack on the race way of inner ring

Figure 18. Thin layer of deformed grain

The flow of the analysis is described in the Attachment 1. The uniform deformation of the race way of inner ring was the entry point to the analysis.

CONCLUSION

The purpose of research is to find out and determine the root causes of the failure and provide recommendations for further pump operation. The pump primarily deteriorated by static load at the driven end which was due to the unbalance and misalignment of the electric motor. The load caused excessive deformation and clearance on the surface of the raceway and increased the gap between rolling element and the rings, which subsequently lead to the vibration and total blockage of bearing. Excessive wear caused by abrasive material and the inappropriate lubrication is not considerable. The ambient temperature (30oC) and other parameter such as hardness value (59.2 HRc) were considerably still in range. It is recommended to conduct the alignment properly by avoiding any excessive load and knock. The platform of the pump and electric motor should be maintained and leveled periodically.

REFERRENCES

Jones, DRH (1994). Engineering Failure Analysis. UK: Pergamon.

Becker, WT and Shipley RJ (2002). ASTM Handbook Vol. 11. Failure Analysis and Prevention. USA: ASM International.

Paula J. Dempsey, Gary Kreider and Tom Fichter (2004). Investigation of Tapered Roller Bearing Damage Detection Using Oil Debris Analysis, NASA Center (Glenn Research Center), Document ID: 20040082336; Report Number: ARL-TR-3133, E-14297, NASA/TM-2004-212883