ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 4, October 2013

Initial Failure Analysis of Lubricating Oil Pump shaft

Pradeep Pawar[1], Pankaj Gambhire[2], N. S. Hanamapure[3]

Abstract:-This paper deals with initial detailed failure investigation against field compliant of a lubricating oil pump rotor shaft used in a Diesel generator engine. The investigation mainly included detail visual analysis for shaft failure by analyzing its chemical composition, microscopy, fractography, Millipore & hardness analysis. Analysis revealed that the basic casting manufacturing processes may responsible for the failure. The paper gives how the photographic views help to generate correct investigation path. The shaft is may failed basic requirement of casting internal cleanliness before assembly of the pump. The twist in the shaft is the main cause for the pump failure. Millipore value of the pump is at higher side and it also may be the cause for the shaft failure. All visual observations are put forwarded with the detailed photographic views to analyze the pump failure & decide the further investigation. This paper says that how the visually diagnoses gives direction for the pump failure investigation.

Keywords: **chemical composition, microstructure Millipore, torsional stress.**

I. INTRODUCTION

Lube oil pump is the heart of the engine, which supplies continuously lubricating oil to different parts of the engine components. To overcome frictional losses, wear & tear etc. Lubricating oil pump commonly known as a LOP. It consist various components like gear, rotor, shaft, casting body, casting cover, relief valve etc. Since shaft of lubricating oil pump experience a large number of load cycles during its service life.

When any pump field failure compliant raised from customer it's very important to investigate or analyses that failure and take necessary action for eliminate these type of failure in future. There are two types of actions which are taken on any company against field failure compliant primary or temporary action and final or permanent action. To analyze the failure firstly visual observations are taken to find out the causes of failure and to get a direction towards further analysis. Our paper is deals with visual analysis of lubricating pump shaft against field compliant.

In this case shaft is failed after 43 hours at customer end. In this case there is additional thing that the engine is recently launched in the market thus the analysis is leading to future sales of this engine model.

II. LITERATURE REVIEW

A Detail literature review is carried out to understand the present practices and theories in lubricating oil pump failure analysis. It will also help to obtain a better understanding of how a lubricating pump failure analysis is done both visual and analytical. It will help that how first investigation of any failure of shaft is done and how exactly cause of failure from failed components.

A paper by Gautam Das et. al., 2003 [2] deals with fatigue failure of boiler feed pump rotor shaft. His experiment included hardness and residual stress measurement which revealed that metallization process was primarily responsible for failure. The crack had initiated from one or more defect areas near the fillet and then further propagated by fatigue.

A paper by G. Das et. al. 1998 [3] deals with the analysis of premature failure of two counter shafts used in centrifugal pump was carried out which included chemical analysis, microstructure characterization, fractography, hardness measurement, tensile and creep impact test. The mechanical properties of one of the shaft were inferior to recommended values and for the other shaft hardness and UTS were inferior. It was concluded that the improper heat treatment was the prime cause for premature failure of shaft.

A paper by N. Parida, S. Tarafder, S.K. Das, P. Kumar, G. Das, V.R. Ranganath, D.K. [4] deals with Failure analysis of coal pulverize mill shaft. Failure of a ball and race type coal pulverize mill shaft has been analyzed. It was found that the shaft, made of EN 25 steel, failed by fatigue. The fatigue cracks originated from the keyway area, unusually from the top edge. The presence of elongated manganese sulphide inclusions due to improper heat treatment had reduced the ductility and CVN toughness of the material, and thus made the material more prone to failure.

A paper by A. Göksenli, I.B. Eryürek[1] deals with Failure analysis of an elevator drive shaft. In this study failure analysis of an elevator drive shaft is analyzed in detail. Failure occurred at the keyway of the shaft. Micro structural, mechanical and chemical properties of the shaft are determined. After visual investigation of the fracture surface it is concluded that fracture occurred due to torsional-bending fatigue. Fatigue crack has initiated at the keyway edge. Considering elevator and driving systems, forces and torques acting on the shaft are determined; stresses occurring at the failure surface are calculated. Stress analysis is also carried out by using finite element method (FEM) and the results are compared with the calculated values. Endurance limit and fatigue safety factor is calculated, fatigue cycle analysis of the shaft is estimated. Reason for failure is investigated and concluded that fracture occurred due to faulty design or manufacturing of the keyway (low radius of curvature at keyway corner, causing high notch effect). In conclusion effect of change in radius of curvature on stress distribution is explained by using FEM and precautions which have to be taken to prevent a similar failure is clarified.

Summary/ Findings of the Literature

In the above section extensive literature review has been carried out to understand how failure analysis of any shaft is to be carried out. From literature review it appears that

- How failure analysis of any shaft is to be carried out?
- What are the different steps of failure analysis?
- How first investigation i.e. visual analysis of any failure is to be carried out.
- How correlate chemical analysis, fractography, hardness measurement, and other test with failure analysis of shaft.

III. STATEMENT OF PROBLEM

Failure analysis of lubricating oil pump shaft with the help of visual observations and some mechanical properties testing's.

IV. OBJECTIVE OF THIS WORK

The objective of the paper is failure analysis of lubricating pump shaft.

- To study procedure and all steps of failure analysis of shaft.
- Different steps of primary investigation i.e. visual analysis.
- To co-relate different primary observations or after failure evidence with failure of shaft.

V. PROBLEM DISCRIPTION

In this case failure of shaft is done very early stage, so it is very important to investigate failure analysis and find out exact root cause of failure

VII. OBSERVATION AT FIELD

Initial observations on field before failure of shaft are observed and recorded are as following.

1. Initially noise is observed from Turbo charger.
2. Play in turbo charger shaft
3. No oil in turbo oil supply hose.
4. No oil in plug of main oil gallery
5. Oil pump suction tube removed and found Sand (pieces of files)
6. Fine sand observed in filter head

A. Engine dismantled at customer end and following are observations.

After failure of shaft engine dismantle at user end and observations are recorded.

1. No oil found on entire gear train.
2. Scoring on all con rod bearing.
3. Light scoring on main bearings no. 1 to 5.
4. Heavy scoring mark on 6th and 7th main bearing. Metallic particles in 6th bearing oil groove.
5. Liners and pistons are intact.
6. Turbo impeller found out and play in turbo shaft.
7. Lube pump – one gear tooth found broken. Crack observed on body.
8. Lube pump driving gear is missing (removed at OEM)
9. Parts – Lube oil cooler, Filter and Lube oil pump are checked under black light and found oil with dye.
10. Oil sample from Oil Pan is checked under black light and found oil without dye.

B. Visual observations:-

1) Shaft, lubricating pump drive found twist as shown if fig. 1

Fig. 1 Twisted shaft and gear assembly

Shaft twist is observed on the fracture surface on the shaft OD. There is bending on the gear face observed.

Fig. 2 Dislocated shaft

The gear is bended and shaft is shifted from his place as shown in fig. 3

Fig. 3 Gear bend and shaft dislocate

2) Stereomicroscopic photographs of the step near fracture on which no any other marks

The details photographs of the stereographic view are shown in fig. 4 & 5.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 4, October 2013

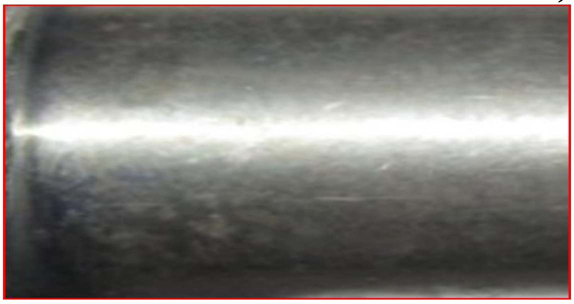


Fig. 4 Stereomicroscopic photographs of the step near fracture

Fig. 5 Stereomicroscopic photographs of the step near fracture with 12 X Magnification

3) Fracture twist surface of the shaft:

1. No ratchet marks around the periphery.
2. Beach marks are not visible.
3. The metal smearing is apparent on the fracture surface.
4. The entire fracture surface has a no smooth texture and no well-defined final fracture area.

All the observations clearly indicate that the failure mode is torsional shear. Also discoloration is observed on the fracture surface at some locations.

Fig. 6 Twist of shaft.

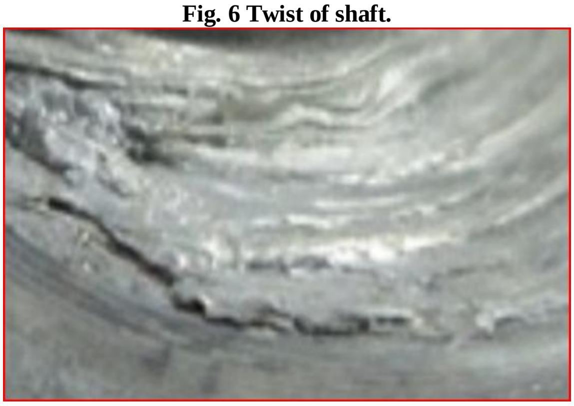


Fig.7 Stereomicroscopic photographs of fracture surface with 6X Magnification

Discoloration is observed at some locations on the fracture surface as shown in fig. 6

Bushing material found embedded near the fracture surface of shaft OD as shown in fig. 7

4) Other end of the shaft

Other end of the shaft is in the gear& it shown in fig. 8. The shaft material is removed & cracked due to high load generated at this end.

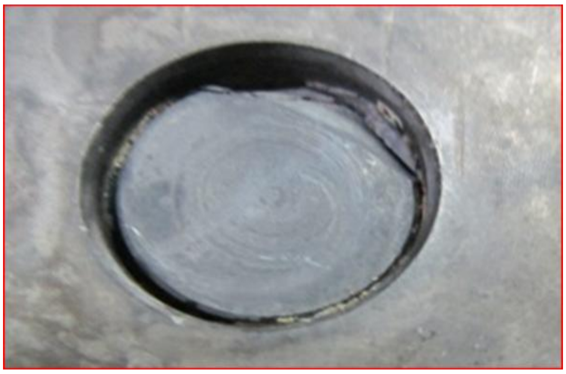


Fig. 8 one end of shaft in gear

5) Shaft middle portion contains material removal & deposition of other material.

In the below figs. 9-10 the material on the shaft is removed on one side of the shaft & other end material is deposited as shown in fig. 11

Fig. 9 Middle portion of the shaft.

6) Material deposition on the shaft

Fig. 10 Material deposited on the shaft.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 4, October 2013

Fig. 11 Shaft view with 6X Magnification.

7) The shaft is found bend near the fracture location.

Due to this bend the shaft is contacted with the chamfer at the gear. Contact marks are observed at the chamfer of the gear at one sector corresponding to the bend observed on the shaft. The detailed photos are attached in the fig. 12-15.

Fig. No. 12 Shaft bend near gear face.

Stereomicroscopic photographs at magnification 6X

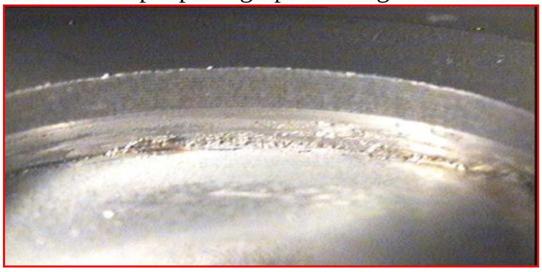


Fig. 13 Chamfer mark on gear with 6X magnification

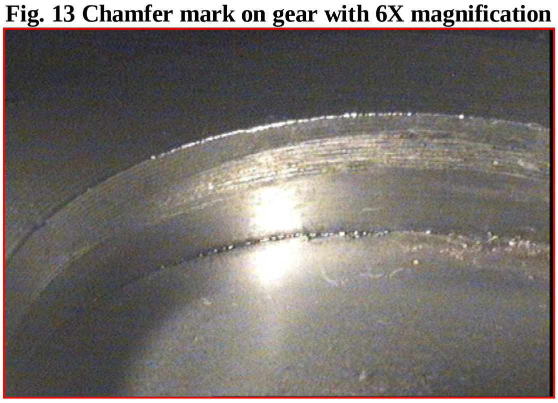


Fig. 14 Both ok and contact mark with 6X magnification

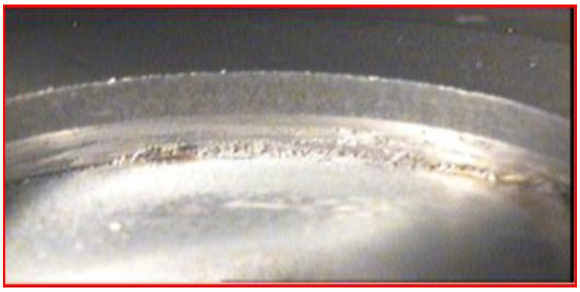


Fig. 15 Gear Contact mark

8) Sand found below rotor in casting pocket of suction.

The photo is shown in fig. 16

Fig. 16 Sand at casting pocket

C. Millipore report & microstructure of the failure pump.

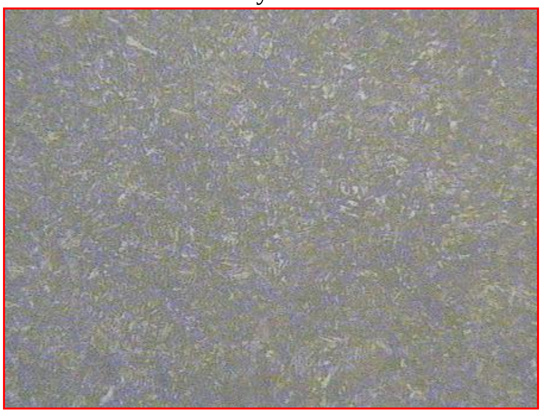
The millipore report of the pump has checked to see the level of foreign particle or loose material available in the pump.

Millipore Report		
	Pump Identification No.	Customer returned pump
	Paper Size	5 microns
	Calculations	
	Paper weight millipore report(A)	6 mg
	Paper weight after millipore(B)	294mg
	Millipore value(B-A)	288 mg

Fig. 17 Millipore report.

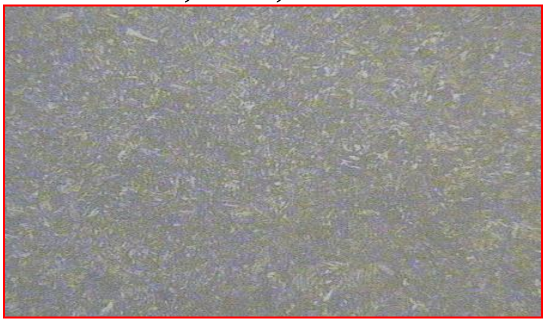
According to above report the Millipore valve of the pump is at higher side and gives initial intimation of failure.

The microstructure of the failure pump is taken at three different cut sections and they are:-

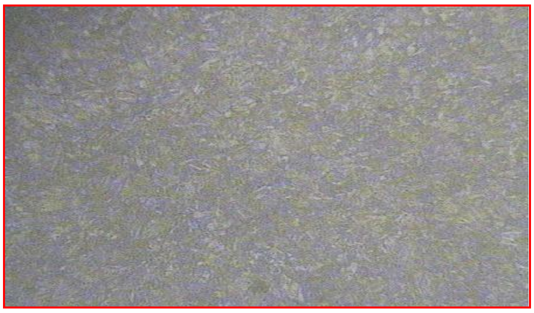


Cut section 1.

IJEIT
ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 4, October 2013



Cut Section 2.



Cut section 3.

Fig. 23 Shaft microstructure reports with magnification 100X

Shaft microstructure checked found ok as per fig. no. 23

D) Overview of visual observations:-

Failure	Probable causes	Investigation Actions	Outcome	Remarks
Shaft failed in torsional shear	Material defect in shaft	Metallurgical analysis: Hardness, chemistry, microstructure, case depth etc.	No material defect is observed on the fracture surface of the shaft. Hardness, microstructure, chemistry meets the specification (Refer annexure for MLR)	Not a cause of failure
	Torsional overload on shaft due to Restriction on gear rotation	Visual observation of gear& shaft	Sand is observed in the suction pocket of the pump and a material erosion of the shaft has done. It shows the entry of foreign particle in the bush area. The foreign material (sand) has also stuck upped on the shaft and it shows the high friction in between shaft and body. The shaft is found bend near the fracture location. Due to this bend the shaft is contacted with the chamfer at the gear. Contact marks are observed at the chamfer at some locations which in turn had restricted the rotation of gear.	Probable cause of failure.
		Check for foreign particle in the bush area.	Bush found Ok.	Not a cause of failure

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 3, Issue 4, October 2013

VIII.DISCUSSION

The shaft, lubricating pump drive was failed in torsional shear. Following are the observations on fracture surface.

1. No ratchet marks around the periphery.
2. Beach marks are not visible.
3. The metal smearing is apparent on the fracture surface.
4. The entire fracture surface has no smooth texture and no well-defined final fracture area.
5. Sand in the suction pocket.

Also discoloration is observed on the fracture surface at some locations indicating that the shaft is seized. Bushing material found embedded near the fracture surface of shaft OD. Step observed near the fracture surface on the shaft OD. The shaft is bending near gear pressuring area. Due to the presence of twist near failure the shaft appears to be bend. In view of this one OK pump was opened to see the condition of the shaft & gears. No any scratches and abnormalities are there in the opened pump. Rotor, lube pump found OK. The sand is observed in the suction pocket but failure does not show its effect. Mechanical damage is observed on the other adjacent gear as the broken gear pieces entrapped in the gear.

The probable failure mechanism is:

1. Shaft got bend during gear pressing. Contact marks on the chamfer of matting gear.
2. Restriction to the gear rotation due to bend shaft
3. Torsional overload on shaft which resulted in breakage.
4. for frequent time shaft & body are jammed & at the same time engine speed has increase to 2500rpm. The earlier generated crack has propagated and shaft failed with occurring twist. The generated twist is only up to disengagement with mating gear.

IX. CONCLUSION

The all visual observations shows microstructure, hardness & other technical parameters are OK & does not shows the reason for the failure of the shaft. Against this the presence of the sand in the suction pocket & high Millipore value shows presence of the foreign particles in the pump pockets. This causes a jamming of shaft and a bush & such marks are observed in the fig. 9 so jamming may be the main cause of the shaft failure. The shaft is twisted until driving gear of the pump & crankcase gear disengagement. To conclude this result of investigation we needs to cross verify the results with the help of FEM software with fatigue life investigation.

REFERENCES

[1] A. Göksenli, I.B. Eryürek "Failure analysis of an elevator drive shaft" Science Direct, Engineering Failure Analysis, May 2008, Vol- 16, page 1011- 1019.

[2] Gautam Das, Ashok Kumar Ray, Sabita Ghosh, Swapan Kumar Das, Dipak Kumar Bhattacharya "Fatigue failure of a boiler feed pump rotor shaft" Science Direct, 2003.

[3] G. Das, A.N. Sinha, S.K. Mishra, D.K. Bhattacharya "Fatigue analysis of counter shaft of Centrifugal pump" Engineering Failure Analysis, Sep.1999, Vol-6, Page 266-276.

[4] N. Parida, S. Tarafder, S.K. Das, P. Kumar, G. Das, V.R. Ranganath, D.K. "Failure analysis of coal pulverizer mill shaft" Science Direct, Engineering Failure Analysis, October 2002, Vol-10, page 733 – 744.