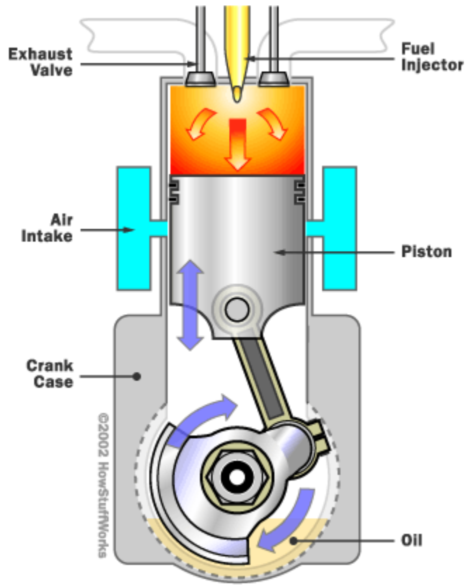
Our Professional Knowledge
Your Business Advantage

Atlas Evaluation & Inspection Services
943 EAST HAZELWOOD AVENUE, RAHWAY, NJ 07065-5633
PHONE: 732.388.7711 | FAX: 732.388.7767 | www.aeisndt.com
Failure Analysis Case Study

Failure Analysis of Diesel Engine Crankshaft due to Overload and Welding



Key Words: Diesel Engine, Stress

Material: Carbon Steel

Introduction

Three pieces of a broken crank shaft of a 1300 HP V-12 twin-turbo charged, inter-cooled Man Diesel Engine from a 61 Ft Yacht were submitted to laboratory for failure analysis. Two main bearings and two rod bearing halves were also submitted. Visual examination, chemical analysis, mechanical test, metallographic analyses were performed on the submitted crank shaft to look for the root cause of failure.

Visual examination

In figure 1，the shaft had fractured on a connecting rod journal. The fracture extended from a fillet to a diagonally opposite fillet and further extended through the wall.The middle piece in Figure 2 that had a complete fracture face was totally black in color.In figure 3 two pistons had chipped edges and connecting rod had blackening too.One cylinder sleeve showed a crack starting from the edge.No obvious damage was observed to the cylinder heads at the incident site though the possibility of valve damage was not ruled out. Six push rods were also bent.

Figure 1: Crankshaft in as received condition

Figure 2: Fracture surface on the broken middle piece.

Figure 3: Damaged pistons and connecting rods.

Figure 4: Sectioning location on broken middle piece of the crankshaft.

Chemical Analysis

A chemical analysis conducted on the crank shaft journal showed result in Table1

Table 1 Chemical analysis of crank shaft journal

Element	Crankshaft (%)	SAE 1536 (%)
Carbon	0.37	0.30/0.37
Manganese	1.24	1.20/1.50
Phosphorus	0.008	0.040 Max
Sulphur	0.056	0.050 Max
Silicon	0.3	0.15/0.30

The shaft is fabricated from an SAE 1536 carbon steel, the requirements of which are shown above for comparison only since no requirements are specified.

Macro examination

The Cut surface of section 2 in figure 5 revealed a crack connecting the fracture surface to the fillet of the connecting rod.

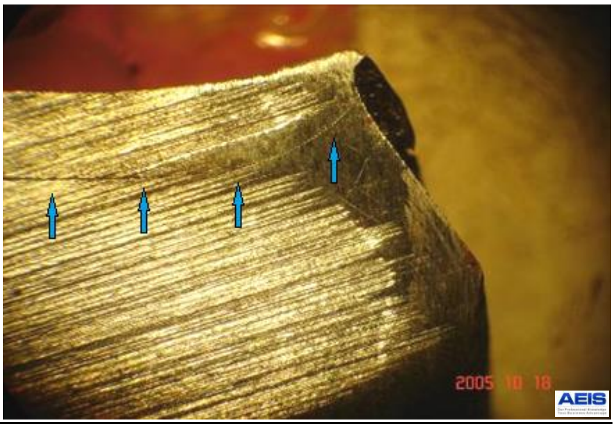


Figure 5 :Showing crack connecting the fracture surface to the filletof the rodjournal.

Microscopic examination

A section of end rod journal was cut and prepared for examination. The polished sample showed that the journal surface had been hardened and the hardened layer had a thickness of approximately 0.14 inch. The micro structure of the cross section below the hardened layer showed ferrite envelops at the former austenite grain boundaries with generally spheroids cementite matrix. Partially transformed pearlite could be observed at some locations.

The fracture surface edges at section 3 and 6 were examined under Scanning Electron Microscope. There was no indication of any fatigue markings observed in Fig 6,7.

Failure Analysis Case Study

Figure 6: Microstructure below the fillet of the fractured journal showing a trans-granular crack. 275 Magnification

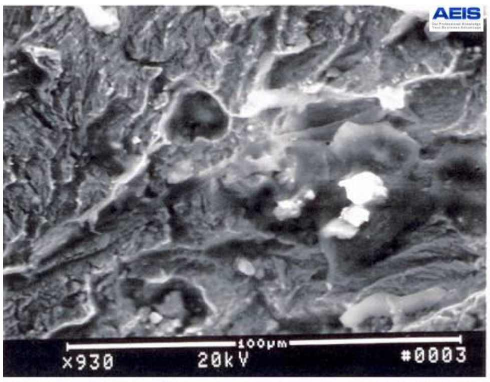


Figure 7: Fracture Surface at location 3. 930X Magnification

Mechanical Test

A Rockwell hardness survey made on the cross section using the 30N scale yielded the following obtained:

Distance from outer surface(in)	0.02	0.05	0.075	0.115	Core 1	Core 2
Hardness	82	69.5	68	68.5	44	45
Rockwell C Equivalent	C65	C51	C50	C37	C23	C24

Discussion

The blackening of the journal surface indicates that the surface had been over heated. The heating was localized and for a short duration which ruled out general starvation of oil arising from low oil level. Scoring on the surface of the broken journal suggests contact between the pad and the journal surface with hard a foreign object like a metallic fragment, harder than the journal surface. Such an event will manifest itself by interactive features such as localizes heating, softening, wear and squeezing out of the bearing metal and imbalance of the shaft.
The unexpected combination of bending and torsion stresses thus produced exceeded the design limits of the shaft which gave way along its weakest plane, the diagonal distance between the fillets. The damage on the small end of the connecting rods was consequential to fracture.

Conclusion

From above observations and discussion it is concluded that the failure of the crankshaft occurred because of a combination of bending and torsional stressed beyond design. The stresses were caused by imbalance of the shaft due to localized heating. Ingress of foreign matter could be the cause of the observed localized heating.