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 a Excavator Heel due to Fatigue and HAZ

Key words: Excavator heel, Cracking , Fatigue , Welding, HAZ

Material : Cast Steel

Introduction

One broken boom heel of a Liebherr excavator 995 was submitted for failure analysis. The excavator was used on a marine boat. The heel had cracked above the weld to the deck mounting. Visual examination, chemical, mechanical and metallographic analyses was performed on the submitted excavator heel sections to look for root cause of the failure.

Visual Examination

The main fracture of the beam was wrapped around an edge. The fracture ran generally along the upper toe of the weld for most of its length. There were two other cracks, both originating from the same location at the corner, figure 1. The fracture surface had lost fine features, basically, because of corrosion. The surface was wire brushed to remove rust and scale. The crack arrest marks pointed to two origins, in fig 3&4, one for the main fracture and the second for the other two smaller cracks. Both the origins were located at the upper toe of the inside weld.

Figure 1: The main crack

Figure 2: The main crack as viewed from inside the boom heel.

Figure 3: Origin of the main fracture as seen on the fracture surface

Figure 4: Origin of the other crack as seen on the fracture surface

Chemical Analysis

Chemical analyses on the cast heel yielded the following results.

Element	%
Carbon	0.21
Manganese	0.74
Phosphorus	0.016
Sulphur	0.02
Silicon	0.23
Chromium	1.02
Nickel	0.14
Molybdenum	0.18
Copper	0.1

Mechanical Test

Tensile test carried out on specimens removed from plane perpendicular to the main fracture gave the following results.

Test Piece	Yield Strength (Lbs/ sq. in).	Tensile Strength (Lbs/ sq. in).	Elongation in 2 inches(%)
1	71,600	89,100	18
2	70,000	89,500	21.5

Microscopic Examination

Micro specimens were prepared and evaluated under high power optical microscope. The examination revealed a fine grain structure consisting of ferrite and carbides in the parent casting, figure 5. Grain coarsening was observed in the HAZ near the origin of main fracture, figure 6.

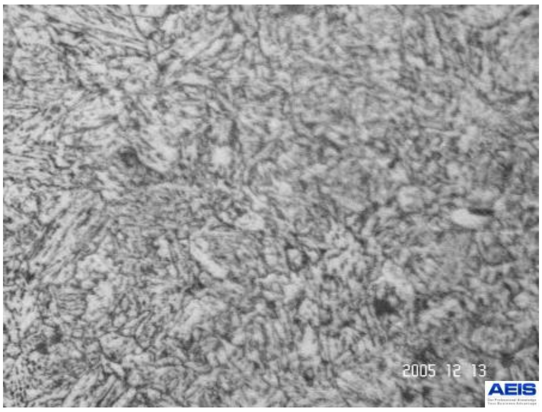

Figure 5: Microstructure of the parent casting (600X)

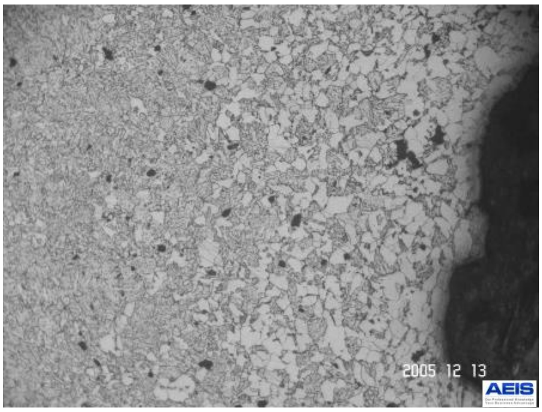

Figure 6: Grain growth in the HAZ near the main fracture origin (150X)

Discussion

The chemical composition, the mechanical test results, and the micro structure of the parent casting did not show any abnormality that could have lead to the failure.
Though fine crack arrest marks had been obliterated by corrosion at the fracture surface, the remnants suggest that the failure originated at the toe of the weld to the deck. It is significant that all the three cracks initiated from the weld toes and progressed along the fusion line. The grain growth in the HAZ lead to an in homogeneity at the micro level. The metallurgical and mechanical notches created at the edge of the toe of the weld acted as stress concentration points that lead to the failure. It can not be said with certainty whether micro cracks had been introduced during welding itself or the residual stresses along with applied stresses initiated the cracks at a later stage. From the arrest marks it is evident that the crack growth was progressive in nature and was not a result of a sudden or single time overloading.

Conclusion

The boom heel failed by a progressive mode of cracking. The failure originated at the sharp toe of the welds which acted as stress raiser points and progressed along weld boundary.