An AEIS Case Study

1601 Lower Rd.
Linden, NJ 07036
914 214 8460
www.aeis.us

Case Study: Failure Analysis of a Weld Neck Flange in a Refinery

By Nagesh Goel
Technical Director

CONTENTS

Introduction

A spool piece comprising of a three inch weld neck flange, a six inch by three inch eccentric reducer and a six inch weld neck flange, Figure 1, was submitted for failure analysis. The spool piece was installed on a Heavy Cut Naphtha line that operated at 380 Degrees F at 20 psig in a refinery. Naphtha leakage had been reported through this spool piece. The exact location of leak was not known.

Figure 1: Spool Piece in "As Received" Condition

Key Words Weld, Flange, Failure Analysis

Alloys Steel

Circumstances Leading to Failure Design deficiencies, Corrosion, Erosions and Stress

Visual Examination of General Physical Area

The spool piece had the usual steel scale on the out side and a thin film of brownish rust on the inside. No appreciable deposits were observed on the inside surface. The inside surface of the six inch weld neck flange was free from any localized depressions. However the straight wall of the reducer and the 3 inch flange had smooth grooves (hills and dales) typical of erosion corrosion, generally aligned in direction of flow, Figure 2. The outside surface had tarry and dirty white cement like deposits in isolated areas. The weld bead had 1/8 inch high reinforcement. The root surface of the weld had eroded and no reinforcement could be seen. The inside surface showed a circumferential indication, shown with an arrow head in Figure 2, that looked like a possible crack through which the leakage occurred. This area was in the same region where the tarry deposit was observed on the outside surface and below the weld cap.

The 3 inch flange had a stamping of “Class 300 A 105” material.

Figure 2: Internal Surface of the Spool Piece and the Suspected Crack

Radiographic Examination

Both of the butt welds were radiographed using Ir -192 radiation source. Existence of a crack at the suspect location was confirmed.

Macroscopic Examination

A rectangular section was cut around the above mentioned crack and examined under a low powered stereo microscope. The crack was located along the reducer side toe of the butt weld. The inside surface of the crack opening is shown in Figure 3. Two additional (smaller) crack like openings on the inside surface were observed within 1½ inch from the apparent end of the main crack. These indications had orange corrosion product spots at the lips and had similar orientation as the main crack. The longer of these cracks as observed on the inside surface is shown in Figure 4.

Figure 3: Crack Lips on the Inside Surface

Figure 4: Another Crack Lip on the Inside Surface.

Some sharp mechanical dents on the outside surface were observed near the weld zone, Figure 5. The wedge shaped dents had abrasion lines on the side and displaced metal at the lip, Figure 6. It appeared that the crack like indications on the inside surface had corresponding dent marks on the inside.

Figure 5: Outside Surface Mechanical Dent Marks in the Weld Zone

Figure 6: Abrasion Marks and Displaced Metal

Microscopic Examination

A section was cut through the confirmed crack and the cross section was prepared for microscopic examination. The unetched specimen showed that the flange side of the crack had elongated inclusions typical of forging. The weld side of the crack showed wide spherical non-metallic inclusions typical of a weld metal pool, Figure 7. The etched microstructure revealed the two sides of the crack as shown in Figure 8. Some slag was observed on the internal surface of the crack, near the outside opening of the crack, Figure 9, as well as near the inside opening of the crack, Figure 10. The variance in microstructure at 100X magnification is shown Figures 11 through 16. Figure 11 shows the microstructure of the reducer parent metal. Figure 12 shows the microstructure of the heat affected zone (HAZ) of the reducer. The microstructure of the weld metal pool is shown in Figure 13. Figure 14 shows the weld metal pool to the weld neck flange (WNF) interface. Figure 15 shows the heat affected zone of the WNF and the Figure 16 shows the microstructure of the WNF flange parent material. o internal cracks were observed. Inclusions such as mentioned earlier in and as seen in Figure 14 were observed.

The minimum wall thickness, at the location of the main crack was found to be approximately 3/64th of an inch.

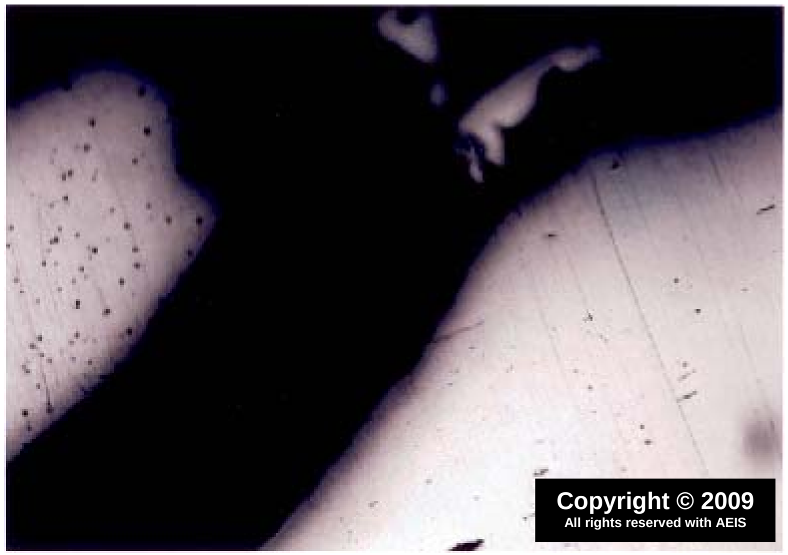

Figure 7: Both Sides of the Crack before Etching 250X Magnitfication

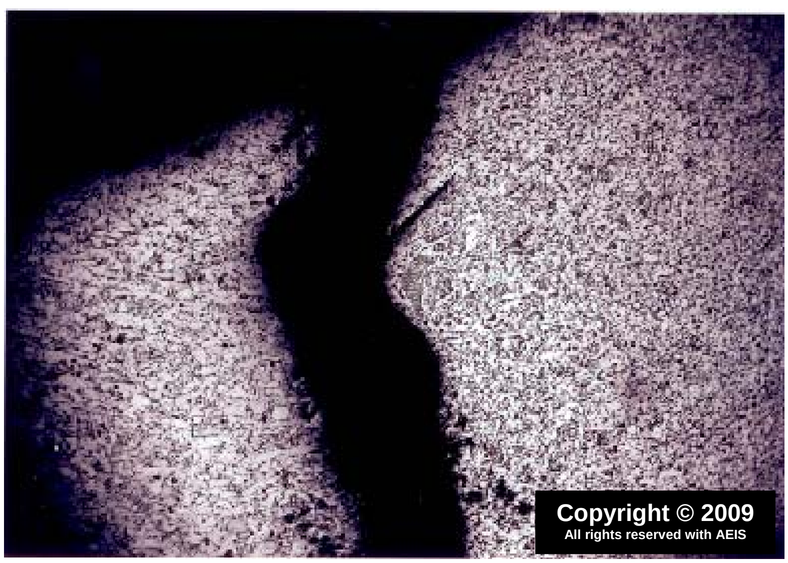

Figure 8: Both Sides of the Crack after Etching 250X Magnification

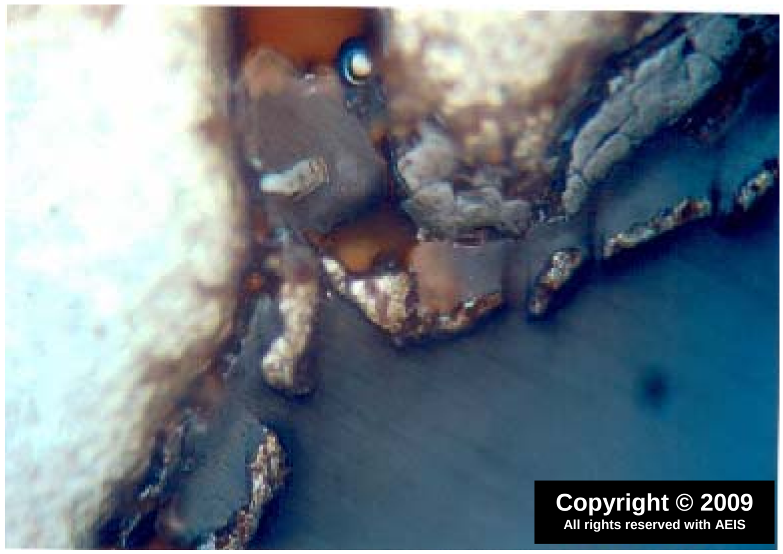

Figure 9: Slag on the Internal Surface of the Crack near the Outside Surface

Figure 10: Slag on Internal Surface of the Crack near the Inside Surface

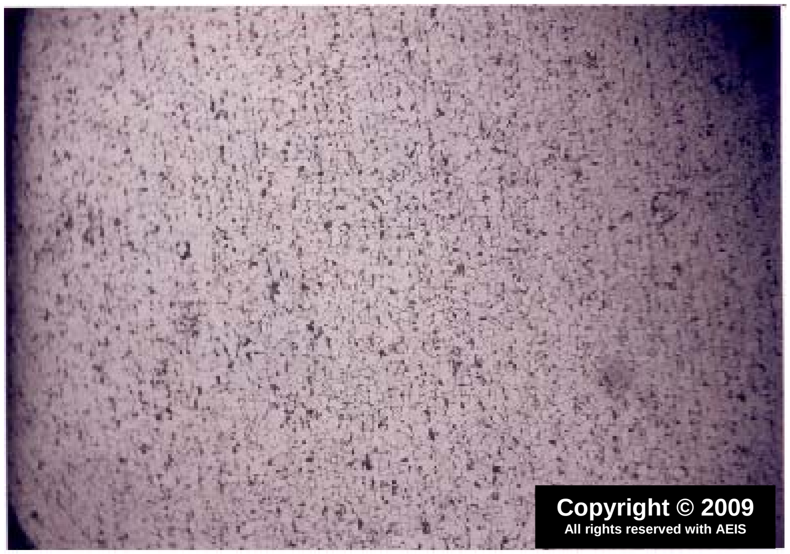

Figure 11: Microstructure of the Reducer Parent Metal 100x Magnification

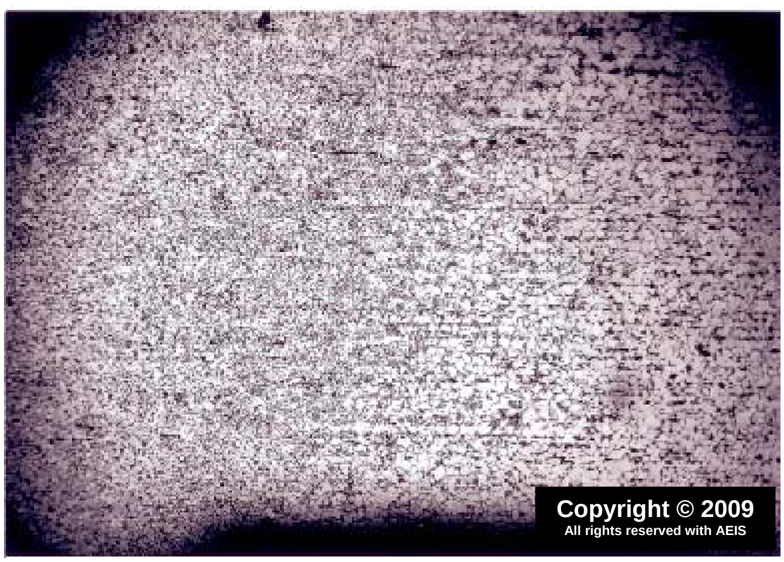

Figure 12: Microstructure of the Heat Affected Zone of the Reducer 100X Magnification.

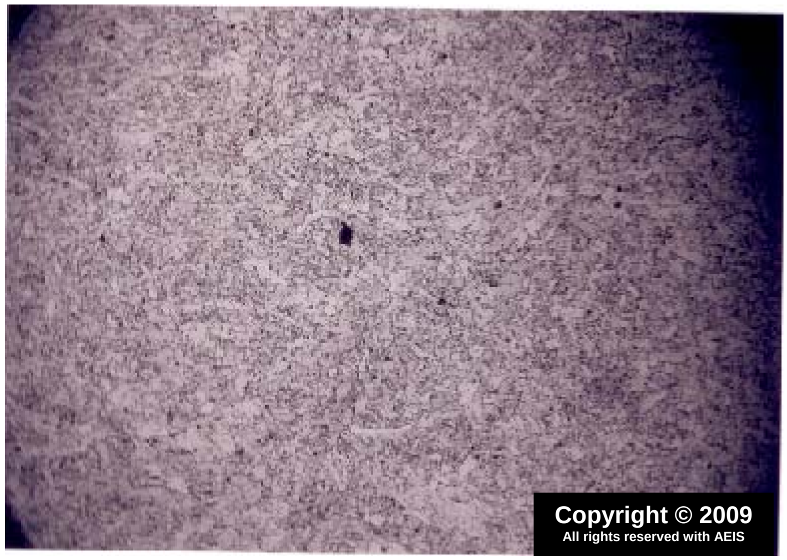

Figure 13: Microstructure of the Weld Metal Pool 100X Magnification

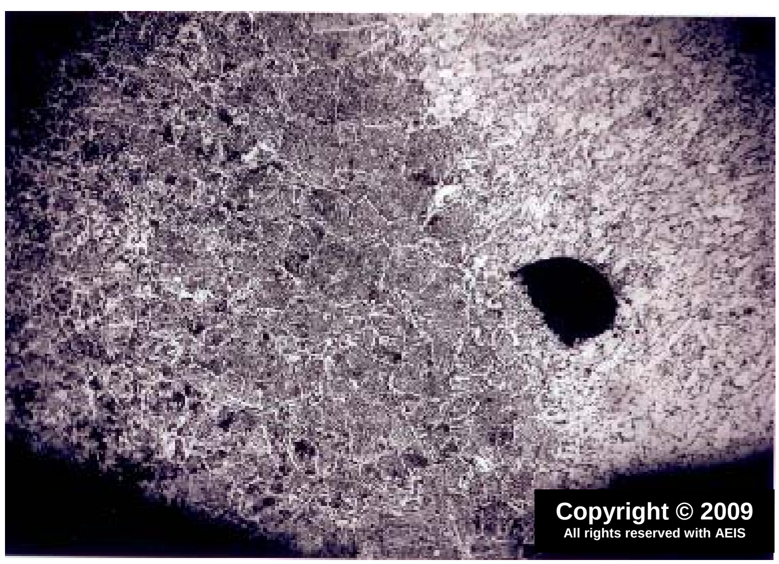

Figure 14: Weld Metal Pool to Weld Neck Flange Interface
100X Magnification

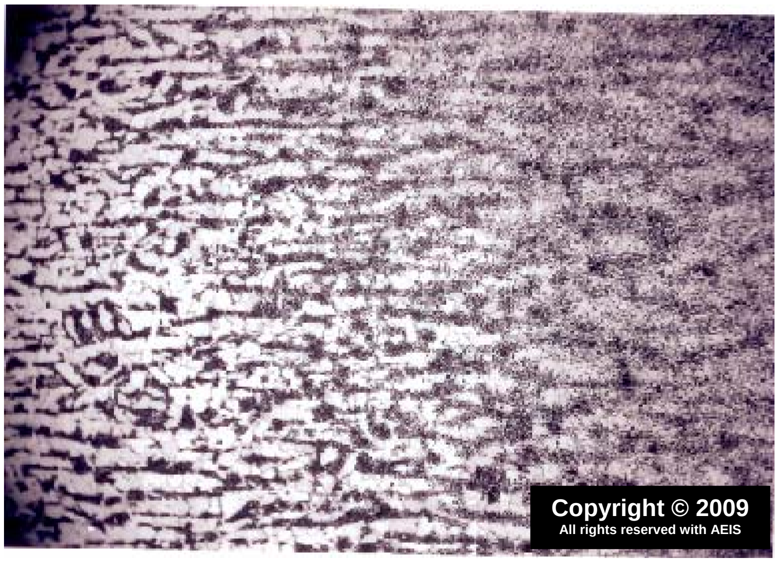

Figure 15: Heat Affected Zone of the Weld Neck Flange
100X Magnification

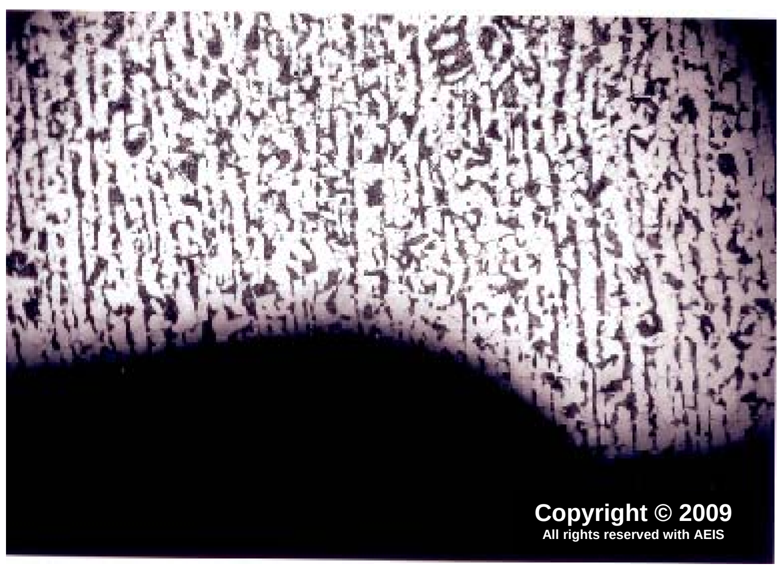

Figure 16: Microstructure of the Weld Neck Flange Parent Material
100X Magnification

Discussion

The grooving pattern on the internal surface shows that considerable loss of thickness took place because of erosion/corrosion. The smooth surface and absence of deposits indicate that erosion played the key role. Since there is little metal loss on the 6 inch flange the flow parameters of fluid at that point are within the acceptable range. The gradual increase in attack along the reduced cross section is in accordance with the change in flow pattern from lamellar to turbulent and increase in velocity because of the reduced cross section. Obstruction in flow by weld root reinforcement and increased vulnerability of the weld metallurgy lead to washing away of the root bead preferentially and completely. The remaining thickness of 3/64 inch is considered low from structural stability and perhaps close to or past the minimum allowable wall thickness (MAT)

The stresses concentration is inherently high at the weld toes. Cracking will initiate at the edge in absence of any other weakness. The larger crack, in this case, had an additional deficiency. Microscopic examination showed the presence of slag inside the crack, implying that there was a lack of fusion and or undercut in the weld. Gradual gouging of metal from inside continued till the wall thickness at the weakness gave way. Another weld weakness can be observed in Figure 14.

The acute dent at the outer surface was observed to be opposite to the second crack seen on the internal surface. This dent had abrasion marking on its side and metal flow at the lip suggesting that this was caused by a sharp tool such as chipping hammer used for slag removal. A similar dent was also observed opposite the third crack which was the smallest observed in the vicinity. The mechanical notches initiated these cracks.

From the above discussion it is concluded that excessive wall thinning by erosion corrosion was the primary cause of cracking. The weaknesses introduced during fabrication lead to preferred sites of the leakage path. The erosion corrosion may be because of operational excursions in absence of design deficiencies. Introduction of an aggressive ion or an additional phase could also be a possibility.

Conclusion

The leak took place through cracks at the three inch butt weld in the vicinity of the toe. The cracks had taken place because the intensified stress had crossed the thresh hold limits locally. The stress was high because of reduced wall thickness caused by erosion corrosion and local deficiencies introduced during fabrication. The erosion corrosion may be because of operational excursions in absence of design deficiencies.