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Root Cause Failure Analysis (RCA) of Above Ground Vertical Storage Tank Damaged Plate

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ABSTRACT

The above ground storage tanks (AST's) in the refinery is experiencing an extensive damaged bottom plate of an above ground vertical storage tank. This has resulted in the 12mm elliptical hole failure of 1 tank since its commissioning (1982). This report summarizes the results of the non-destructive evaluation (NDE) carried out to investigate the root cause of damaged bottom plate removed from an above ground vertical storage tank bottom plate. The NDE techniques used for the root cause analysis (RCA) included Visual and Low-Power Optical Microscopic Examination, hardness testing, Metallographic Examination and surface roughness examination. Based on concluding facts, the plate damage is attributable to the occurrence of erosion phenomenon.

Keywords:
Above ground storage tanks (AST's), Failures, Erosion, Corrosion, Bottom plates

1. Introduction

Aboveground Storage Tanks (AST) are large containers usually made of metal and resting on top of the ground, designed to temporarily hold several different liquid or gas substances. These substances can range from water to crude oil to various chemical products.

One of the many standards which applies to aboveground storage tanks is API 653[1-2], "Tank Inspection, Repair, Alteration, and Reconstruction." It was developed and published by the American Petroleum Institute (API) and it provides guidelines for the inspection, repair, alteration, and reconstruction of steel aboveground storage tanks used in the petroleum and chemical industries. Before 2000, this was the only standard that applied to aboveground storage tanks.

Catastrophic failures of aboveground storage tanks (ASTs) can occur when explosions or flaws cause the shell-to-bottom or side seam to fail. Past tank failures have ripped tanks open releasing their entire contents and in some cases, tanks have been rocketed upwards into the air [3-17].

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Earlier study showed that 74% of accidents occurred in petroleum refineries, oil terminals or storage. Fire and explosion account for 85% of the accidents. There were 80 accidents (33%) caused by lightning and 72 (30%) caused by human errors including poor operations and maintenance [18]. Other causes were equipment failure, sabotage, crack and rupture, leak and line rupture, static electricity, open flames etc. Most of those accidents would have been avoided if good engineering has been practiced.

The failure of bulk storage tanks can be attributed to a number of causes including human error, poor maintenance, vapor ignition, differential settlement, earthquake, lightning strike, hurricane, flood damage and over-pressurization, corrosion and erosion. Such incidents have highlighted the need for the proper assessment of potential risks and the requirement for suitable methods of mitigation.

This paper primarily scope was to confirm the damage occurred due corrosion or erosion phenomenon.

2. Examination and Results

2.1 Visual inspection and Examination

It is understood that the tank bottom plate was specified to be manufactured from ASTM A283 Grade C material [19]. The general appearance and close ups of the failed sample, supplied for failure analysis are shown in Figure 1 & 2, accordingly.

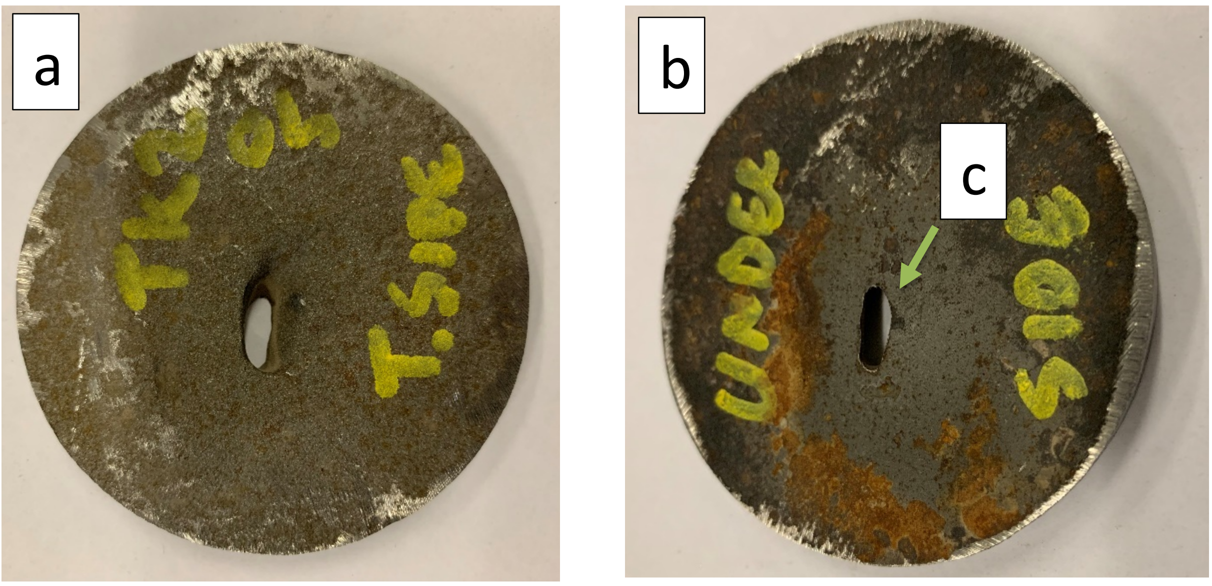


Figure 1. General Views of Portion of damaged tank bottom plate Supplied for Examination (a) Top side surface of tank bottom plate (b) Bottom side surface of tank bottom plate & (c) failed portion

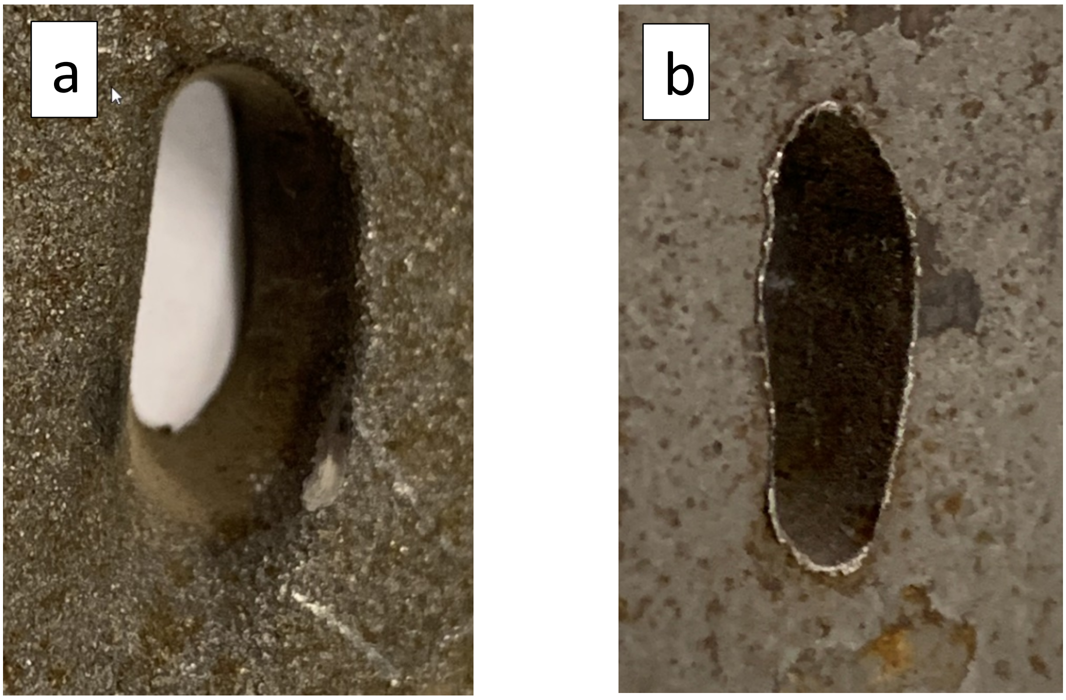


Figure 2. Close-up Views of the failed portion Indicated in Figure 1 (a) Top side plate (b) bottom side of floor plate

The visual observations of the damaged portion (Figure 1,a) along with the protruded section (metal burr) (Figure 2,b) with magnifying aid indicate partial signs of erosion phenomenon, lack of any corrosion signs. Moreover, it is also observed a characteristic variation of surface roughness between damaged area versus base metal location.

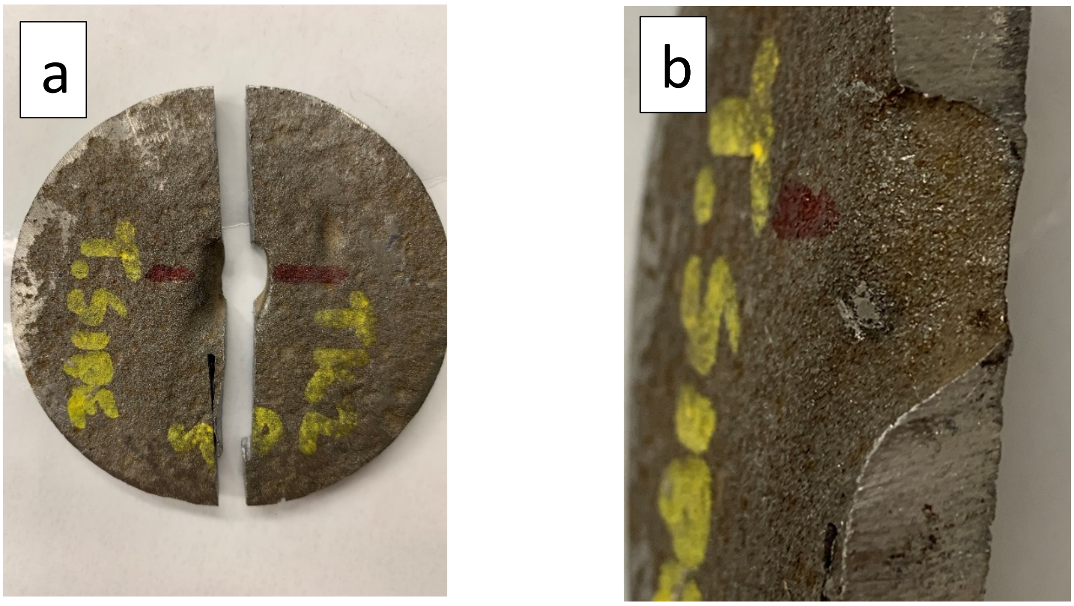


Figure 3. Cut-up Views of the failed portion Indicated in Figure 1 (a) cut view of a plate (b) closed view of failed region

In order to conduct a more detailed examination of the damaged plate, the specimen was cut into two separate pieces, as shown in above Figure 3.

2.2 Metallographic Examination

Microstructural study is performed using optical microscope. Samples were ground and polish using SiC papers of various grits from 230 to 4000 and then etched in a solution of 10 vol. % nitric acid, 30 vol. % glycerol and 30 vol. % hydrochloric acid at 303 K (Figure 5 a,b)

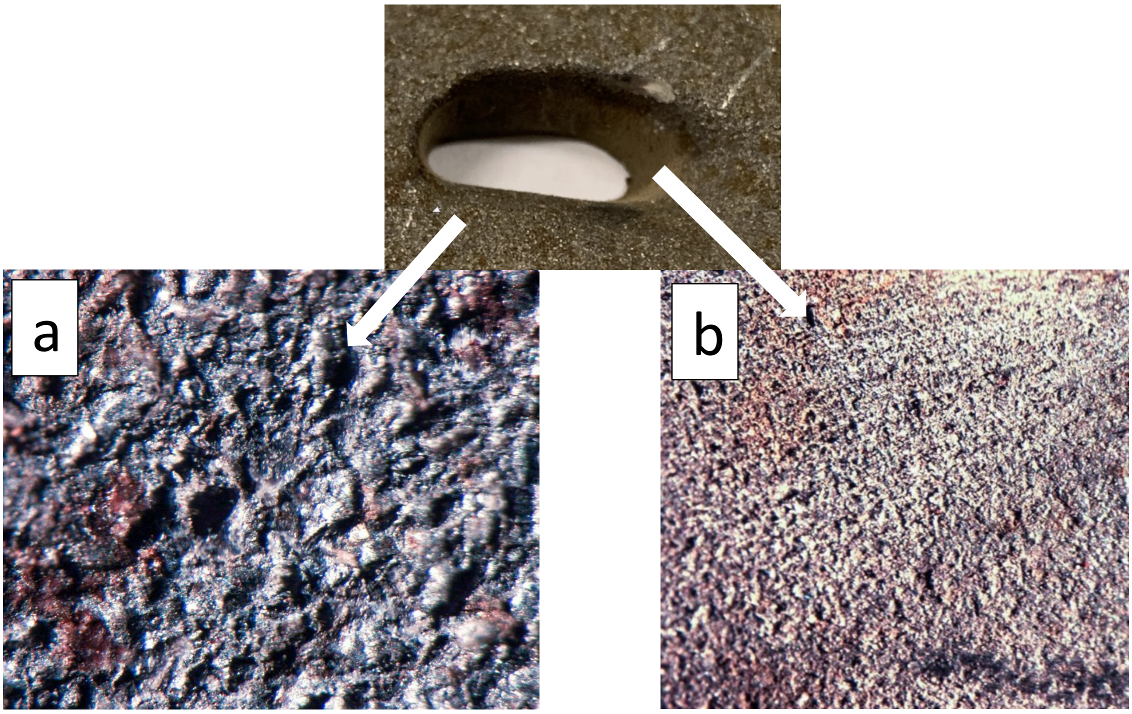


Figure 4. Optical Micrographs of Metallographic Sections at 50x (a) Un-affected Region with minor corrosion (b) Damaged region

As shown in Figure 4a, the un-affected region's surface texture is significantly deviated in the direction of the normal vector of a real surface from its ideal form, resulting the surface in much rough texture as compared to the damaged region (Figure 4b). The same observations were supported by the surface roughness examination analysis.

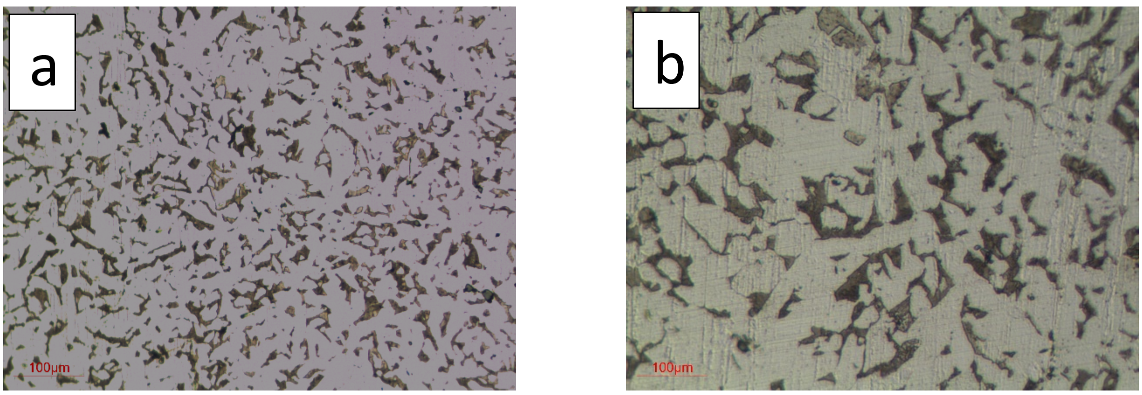


Figure 5. Optical Micrographs of Metallographic Sections at (a) 200x (b) 400x

Figure 5 shows the microstructure of a typical carbon steel[20], which is composed of ferrite and pearlite, consisting of around 60% ferrite and around 40% pearlite. There are no signs of a failure due to the combination of general internal corrosion and more localized corrosion.

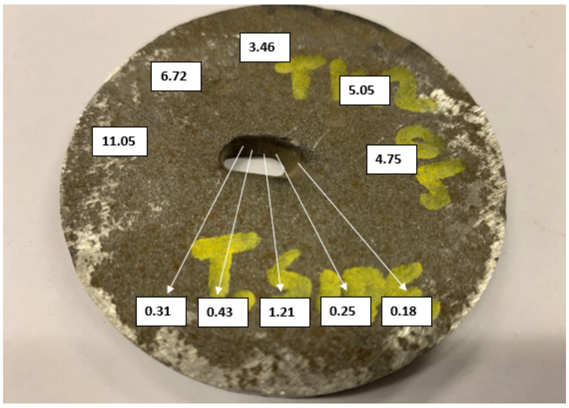
2.3 Hardness measurements

Hardness test was carried on the samples to check any variation in the values due to reported damage. Surface was polished upto 600 grade grit paper and hardness test was done using Vicker's Hardness Machine under 5 kg load. A total of 10 indents were taken, 5 indents each were taken, both, near the damaged and at un affected region. Recorded deviation was ±5 with minimum hardness value to be 114 HV5 while maximum recorded value was 120 HV5. No drastic deviation was recorded for measured hardness values at both regions.

2.4 Surface Roughness Examination

Surface finish typically refers to a level of polishing or texture intended for, or resulting on, a surface. Surface roughness – also known as surface profile Ra – is a measurement of surface finish – it is topography at a scale that might be considered "texture" on the surface. Surface roughness is a quantitative calculation of the relative roughness of a linear profile or area, expressed as a single numeric parameter (Ra).

Below figure presented various surface roughness values (µm) of un-affected and damaged region locations of the specimen received.



Observed values clearly shows a marked difference in both regions, making the un affected area as rougher than the failed region.

3.0 Results and Discussion

The visual examination of the plate shows one hole with marked cavities besides some pits on the both surfaces (working side) of the plate. A closer view of the plate showing large perforation (hole) in the plate sample. Moreover, there weren't any observation of severe corrosion pitting in a localized band at the surface of plate and the associated damaged region.

Microstructural studies also revealed no signs of a failure due to the combination of any general internal corrosion and more localized corrosion. Hardness measurement also shows no drastic deviation at both regions. The un-affected region's surface texture is significantly deviated in the direction of the normal vector of a real surface from its ideal form, resulting the surface in much rough texture as compared to the failed region. The same observations were supported by surface roughness examination results.

4.0 Conclusions

1. Visual examination revealed no metal loss near damaged region as we as no visible signs of corrosion scaling. The protruded section (metal burr) from the bottom side clearly shows a forced mechanical entry from the top side, leaving a 12 mm elliptical hole in the damaged vicinity.
2. Based on the microscopic surface and Surface roughness examination, both areas have different roughness appearances, showing dissimilar damage mechanisms at respective regions. This may be attributed to the mild corrosion attack at non-affected region as contrary to the damaged portion of the plate. Moreover, the damaged/inside surface exhibit the directional pattern as evident in typical erosion phenomenon.
3. Microstructural observations illustrate a typical carbon steel microstructure with a pearlite and ferritic bands.
4. There is not a marked deviation observed in hardness values, negating any environmental effects.

Based on above concluding facts, the plate damage is attributable to the occurrence of erosion or mechanical phenomenon.

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