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Microbiologically induced corrosion of austenitic stainless steel equipment in coastal environment

Subir Kumar Mitra
Indian Oil Corporation Ltd, Paradip Refinery, Paradip, Odisha, India
mitrask2@indianoil.in

Ashish kumar Singh
Indian Oil Corporation Ltd, Paradip Refinery, Paradip, Odisha, India
singhashishk@indianoil.in

ABSTRACT

Stainless steel materials are used in countless applications in Oil Refinery services due to their high corrosion and high temperature resistance properties. Material is extremely good in general, but they are susceptible to various damage mechanisms such as Stress corrosion cracking, MIC, pitting corrosion etc. Proper choice of stainless steel grade as per service conditions is also extremely important to avoid in-service failures. This localized dissolution of an oxide-covered metal in specific aggressive environments is one of the most common and catastrophic causes of failure of SS metallic pressure containments. The pitting process has been described as random, sporadic and stochastic. Prediction of the time and location of events remains extremely difficult.

The pitting corrosion in Stainless Steel equipment & piping is a big area of concern for the industries operating in Coastal environment. The presence of water/ moisture layer contaminated with sea salt aerosols, which are the main atmospheric pollutants in maritime coastal regions, makes very favorable condition for the growth of microbiologically induced corrosion.

This paper discusses the microbiologically induced corrosion that lead to severe pitting & perforation of the austenitic stainless steel equipment and piping which were kept in open environment during construction stage of plant. Paper also focuses on the preventive/ monitoring measures to avoid MIC of Stainless Steel equipment at construction site.

Key words: *MIC, pitting corrosion, austenitic stainless steel, coastal, atmosphere, etc.*

INTRODUCTION

Corrosion of metal by micro-organism known as Microbiological induced corrosion(MIC) is one of the major cause of concern faced by refineries .It is estimated that 20% of the cost of corrosion is due to microbes[1].It takes place mainly in the buried pipelines, firewater lines, jetty platforms etc. made of carbon steel. Main type of bacteria associated with MIC is iron oxidizing, iron/manganese oxidizing and sulphate reducing bacteria in the medium.[2] It has been observed that even austenitic grade steels such are SS316 are vulnerable to microbiological induced corrosion.[3]

MIC in stainless steel has been reported and documented in many journals.. Failure due to severe pitting of two number of underground vessel made-up of austenitic stainless steel grade 316 was reported at one of the iocl refineries. The vessels were not yet taken into service. Vessel was found to be filled with rainwater which was left undrained for long time. Although it is known that 316 grade of stainless steel is considered to be highly resistant to pitting even in the marine environment, severe pitting was found caused due to stagnation of rainwater. On detail investigation, it was found that the stagnant water has led to colonization of microorganisms which subsequently led to localized attack near the weld joints. These localized attacks manifested as sub-surface tunneling in the vessel. Natural water contains various microbes which might seem relatively harmless but might turn aggressive. To prevent failures due to MIC in stainless steel, water shall not be left in it for a long time. Many times water is left undrained in stainless steel piping and vessel after hydrotest.

OBSERVATION AND METHODOLOGY

One of the units of IOCL refinery was to be commissioned and inspections of all the equipments were being carried out prior to its commissioning. During inspection, it was found that the underground located amine closed blows down vessels were filled with water. Inspection of the vessel was carried out once the water was drained out. Considerable pitting & grooving type corrosion of SS316L was observed on the inside surface of the vessel. Corrosion deposits were found at few locations. Tubercule marks were found around the pits. All the 04 nos. circular weld joints and HAZ portion were found severely pitted/ grooved/ cracked/ perforated. The shell and dome portion was also found severely pitted in the form of grooves.

Service	**Amine**
Capacity	21.9 m^3
Design Temperature	144 ^oC
Design Pressure	3.5 Kg/cm^2
Shell/ Head Thickness	13 mm / 18 mm (NOM)
Dimension	ID:2.5M, Length : 3.5M (T.L to T.L)
MOC	SS316L

Design condition of the Vessel

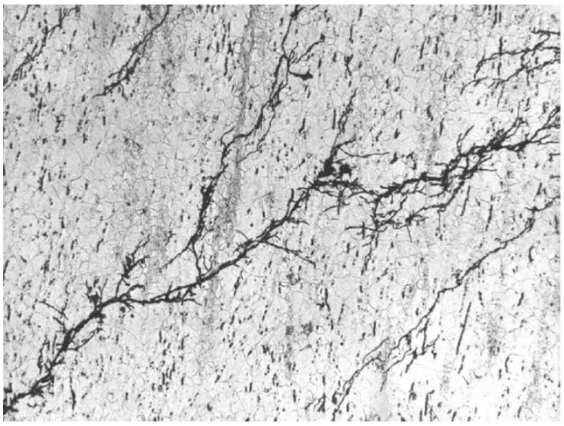
Extensive repair job had to be done in the vessel in order to commission the unit. The vessel was removed from the pit after breaking the concrete over it and removing the sand of the pit. Extensive die -penetrant test of the vessel was carried out to identify the pittings which were not visible to naked eyes. All the identified defective locations were removed by grinding. Penetrant test was carried out again to confirm that all defects have been removed. Once confirmed that all the defects have been removed, welding was done. Since most of the pitting were concentrated around the weld joint of the vessel, circular seams were patched externally using SS316 plate. Vessel was steamed with LP steamed for 07 days. After steaming, the Vessel was filled with water and quaternary ammonium compound (QUAT) biocide was mixed with it so that the remaining microbes present in vessel are killed and further damage to the vessel is prevented. The same was again kept for 10 days before water draining and taking the vessel into service.

To find out what caused such extensive pitting of the vessel, water samples were collected from the vessel and chloride level in water was checked. Chloride level in the water was found to be only 25 ppm.

Severe pitting observed near the weld joints as well as parent metal of CBD vessel

Tubercle marks were seen around the pits indicative of the microbial induced corrosion. Cross-sectional examination of the pit was carried out which revealed the presence of sub-surface tunneling in the stainless steel. Corrosion deposit was also found near the pitting.

Cross section of the pit



Metallographic image of pit near HAZ at 250X

Sectional metallography of the pit interior close to HAZ was carried out.. Branched transgranular cracks were observed in the HAZ region suggesting the presence of wet chloride condition inside the pit.[3]

DISCUSSION AND CONCLUSION

The chloride content in water stagnant in the vessel was found to be only 25 ppm. Under normal conditions low chloride water is not harmful to SS316. Chromium, molybdenum and nitrogen present in the stainless steel grade 316 provide greater resistance to the localized corrosion. Generally, 316 grade of austenitic stainless steel is used up to 5000 ppm of chloride at 40 C. Corrosion is not caused by microbes directly. They rather initiate or accelerate the electrochemical process. The presence of bacteria in the stagnant water causes the noble shift of open potential of stainless steel. Weld and HAZ have generally low pit initiation potential due to which the pitting generally initiate at weld joints and HAZ.

It is believed that Iron and Iron/Manganese bacteria colonize and form mounds at the weld seam to create concentration cell. Under these mounds, dissolution of ferrous and manganese takes place. Although the chloride ions are present in low concentration they are most abundant form of ion present in water. They are attracted towards the dissolved ion to maintain charge neutrality. The ferrous and manganous ions are oxidized by bacteria to form ferric and mangenic. They form highly acidic chloride solution in the pit.[4]

Multiple cases of similar failures have also been reported in past. To prevent the failure of stainless steel equipments and piping due to formation of microbes, it is recommended that that for hydrotest, ballast testing etc, cleanest possible water i.e. demineralised water , steam condensate etc shall be used. Regardless of water quality, water from the vessel shall be drained, dried and inspected within 3-5 days after hydrotest. Proper isolation and preservation of the idle equipment and piping shall be done to prevent the ingress of water[5].

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