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Effect of Leachable Chloride on Pitting Initiation of Austenitic Stainless Steel 304 under Thermal Insulation: Case Study

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Abstract

Stress corrosion cracking (SCC) of Austenitic Stainless Steel type 304 under thermal insulation is a classical failure case, but recurrent failures require further analysis of possible mechanisms which lead to the damage particularly on the effect of leachable chloride from thermal insulation. The objective of the research was to investigate the effect of chloride leached from thermal insulation material on pitting initiation of Austenitic Stainless Steel. The study was based on an actual failure case sample whereby proposed parameters such as temperature and chloride concentrations were derived. An experiment was carried out by using ASTM G-30 standard for the U-bend test. The investigation was carried out to simulate (SCC) of Austenitic Stainless Steel 304 under chloride environment. The test parameters used were various chloride concentrations of 200 ppm to 30 000 ppm at 40, 60, & 85°C temperature.

Keywords: Stress Corrosion Cracking; Chloride; Temperature; Thermal Insulation

Abbreviations: SCC: Stress Corrosion Cracking; CISCC: Chloride Induced Stress Corrosion Cracking NDT: Non Destructive Test; DPT: Dye Penetrant Test

Introduction

Corrosion damage is a significant deterioration of a metal which leads to (SCC).Chloride induced stress corrosion cracking (CISCC) of Austenitic Stainless Steel under thermal insulation is a severe problem which causes production downtime. Prevalent (CISCC) mechanism is triggered by initiation of localized pitting or crevice corrosion. This results from breakdown of surface passive film due to the existence of chloride ions which eventually lead to the formation of pits. Pits open up subsequently leading to the initiation of the cracks and the propagation of cracking occurs due to the presence of cyclic temperature and the integrity of the system fail after exposure to longer period of time [1]. One of the important aspects of (CISCC) is the understanding of the accumulated concentration of leachable chloride role in initiation of pitting which then leads to cracking. However, there are many contradicting parameters explaining possible mechanisms leading to cracking case. This is best studied from failure cases whereby real parameters can be investigated and duplicated in a laboratory set-up [2].

Research Significance

It is generally understood that the primary factor that controls the initiation of cracking is related to damage of passivation due to chloride. A general understanding of (CISCC) leads to higher control of chloride in process stream and tolerance of chloride in insulation material. In order to understand actual factors that lead to cracking case, industrial failure case can be used to scrutinize cracking mechanism.

Materials and Methods

The research focuses on the failed knock out drum which was found leaking during the operation at the site. The work was mainly based on the root cause derived from this leakage case. The purpose of this research is to study the parameters such as chloride ion concentrations, temperature and any other contributing factors for the initiation of cracking. U-bend test as per ASTM G 30 Standard method was used to carry out the experiment for 3 months each set. The laboratory experiment were repeated with the same U-bend specimen [3], but with different chloride concentrations (200 to 30 000 ppm) for each set at 40, 60, and 85 °C temperature.

Parameters based on Failed Pressure Vessel Case

The schematic design of the failed pressure vessel as shown in Figure 1. The design data for the failed pressure vessel as shown in Table 1 below. Data received based on the failure case study from gas processing plant pressure vessels.

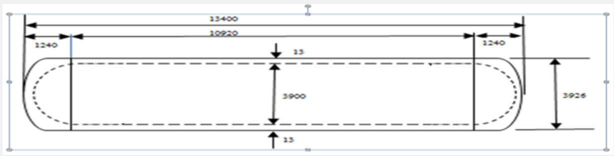


Figure 1: Schematic design of failed Pressure vessel tank.

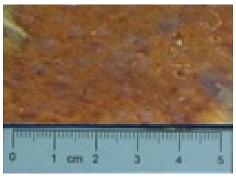
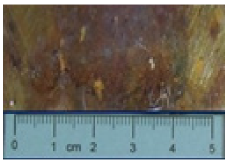
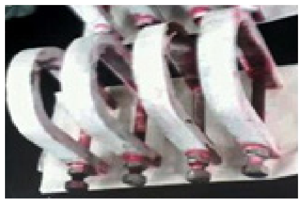
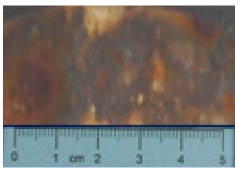
Table 1: Operating parameter of the failed Pressure vessel.

Parameter	Value
Operating Temperature	-150 °C
Design Temperature	-160/60 °C
Operating Pressure	90.5 Psi (624 kPa)
Design Pressure	350 Psi (2413 kPa)
Insulation classes	Perlite(thickness 50 mm)
Vessel Material	AISI type 304 Austenitic stainless steel

Results and Discussion

The results of these experiments are summarized in Table 2. The indication caused by U-bend specimen surface corrosion groove/pits or defects less than 1mm in length were not considered and U-bend specimens with such minor defects were also noted as " No evidence of cracking". Based on the results, general localized corrosion was the major corrosion attack for all the U-bend specimens at 40°C, Metastable pitting corrosion attack for all the U-bend specimens at 60°C and black film formation for all the U-bend specimens at 85°C with different chloride concentrations between 200 ppm to 30 000 ppm. It was observed that the pitting severity rate were gradually increased with increasing Cl- ion concentration for increasing temperature for each set 3 months of experiments. Both general and pitting corrosion of Austenitic Stainless Steel type 304 is dependent on the passive film breakdown to initiate the (CISCC).

Table 2: DPT results of U-bend specimens at 40, 60, and 85 °C after a total of 6 months (200 to 30 000 ppm).

Temp°C/ Stereo results	[Cl] ppm	Mode of Corrosion	Result of Evaluation	Visual inspection results	NDT results Dye Penetrant Test (DPT)
40 °C 	15000	General Corrosion	No evidence of cracking		
	20000	General Corrosion	No evidence of cracking		
	25000	General Corrosion	No evidence of cracking		
	30000	General Corrosion	No evidence of cracking		
60 °C 	15000	Metastable pitting	No evidence of cracking		
	20000	Metastable pitting	No evidence of cracking		
	25000	Metastable pitting	No evidence of cracking		
	30000	Metastable pitting	No evidence of cracking		
85 °C 	10000	Black film formation	No evidence of cracking		
	15000	Black film formation	No evidence of cracking		
	20000	Black film formation	No evidence of cracking		
	25000	Black film formation	No evidence of cracking		
	30000	Black film formation	No evidence of cracking		

Conclusion

In conclusion condition of chloride level ranges between (200 to 30 000 ppm) were tested at 40,60, and 85 °C temperature, no initiation of cracking was found in Austenitic Stainless Steel type 304. In contrast, only severe pitting corrosion significant difference was noted between the high and low temperatures.

Reference

1. R Parrott, H Pitts, Harpur Hill, Buxton, Derbyshire (2011) Chloride stress corrosion cracking in austenitic stainless steel: Assessing susceptibility and structural integrity. UK Health and Safety Executive.
2. N RP (2010) The Control of Corrosion Under Thermal Insulation and Fireproofing Materials-A Systems Approach. Houston, Texas, USA.

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3. A G30 97 (2000) Standard Practice for Making and Using U-Bend Stress-Corrosion Test Specimens. Metallurgy, BSI Corporate, USA.

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