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ROOT CAUSE FAILURE ANALYSIS FOR THE NOZZLE SIDE OF SHELL AND TUBE TYPE HEAT EXCHANGER

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ABSTRACT

Rising demand for renewable energy sources, as well as the necessity for high pressure and temperature vessels for petroleum refineries and chemical plants, have fuelled advancements in pressure vessel technology during the last few decades. Many advances in the field of pressure vessel engineering, such as fracture mechanics, have been made. In this paper the effect of temperature embrittlement of SA-387 grade 11 and 22 sheet was discussed.

KEYWORD

Failure analysis, fracture mechanics, heat exchanger, steel SA-387, shell and tube

INTRODUCTION

A pressure vessel is a closed container designed to retain gases or liquids at significantly higher pressures than the surrounding atmosphere. The majority of pressure vessels, such as reactors and heat transfer devices, used in industry are heat exchangers. Shell and tube heat exchangers are the most frequent and widely used basic heat exchanger structure in the process industries due to benefits such as a high ratio of heat transfer area to volume and weight, ease of construction and cleaning, and mechanical toughness to survive fabrication.

It was discovered in 1950s that low alloy steel such as SA-387 grade 11 and 22 sheet, SA-182 and SA-336 grade F11 and F22 forging, and SA-335 grade P11 and P22 pipe, is particularly suited for high pressures at high temperatures, for the building of pressure vessel bodies, primarily in refinery applications. However, after a few years (about 8 to 12 years), the Japanese discovered that these heat exchangers frequently break and fail from the connection point of the nozzle to the shell. (Regarding to loading and unloading which leads to thermal cyclic stress). This issue prone several researchers to explore the cause. The findings of these studies and investigations, which identified the cause of failure as Temperature Embrittlement (TE) in the temperature range of 350 to 600 degrees, are now available to us as ASTM standard.

Figure 1: Nozzle side failure of a shell and tube heat exchanger.

BACKGROUND OF STUDY

Pressure, temperature, external piping and nozzle loads, wind and earthquake stresses, and other factors primarily affect pressure vessels. Excessive loads, poor design, and manufacturing flaws are only a few of the variables that contribute to pressure vessel accidents. Some of the components that frequently fail are the shell, head, attachments, and piping. Pressure vessel failures have been attributed to the following conditions and factors:

1) Exceeding the maximum allowed working pressure.
2) Elevated temperature.
3) Improper heat treatment causes caustic Embrittlement.
4) Fabrication flaws, discontinuities, and weld issues
5) Vessel fire exposure.
6) Cracking, fatigue creep, and stress rupture are all examples of failure modes.
7) Improperly sized or pressure-set relief devices, leaking
8) Faulty inspection and damage during field manufacturing and erection Faulty inspection and damage during shipment and storage

Out of roundness, lifting analysis, and shock load analysis for fabrication, erection, and transportation problems, transient coupled thermal for over pressure and temperature conditions, fatigue failure analysis, and weld simulation using residual stress extraction are some of the major conditions or factors that can lead to pressure vessel failure. The findings of these studies and investigations, which identified the cause of failure as Temper Embrittlement TE in the temperature range of 350 to 600 degrees, are now available in the form of API RP 934.

RESULT AND DISCUSSION

The following is a summary of results of the reasons of TE (for the most sensitive grade of this steel, 2.25Cr1Mo or the same grade 22):

1) The TE failure mechanism lowers the toughness of the material in systems that operate at temperatures ranging from 350 to 600 °C or that are continuously heated and cooled.
2) The TE failure mechanism occurs only in the presence of tramp elements, lead, tin, antimony, and arsenic in the chemical composition.
3) The amount of manganese and silicon elements determines the TE intensity.
4) Most crucially, the lost hardness can be regained by heating the material to 600 °C and gradually lowering its temperature. This discovery led to the development of the step cooling test.
5) As the TE intensity increases, the fracture mode shifts from trans-crystalline to inter-crystalline, and the fracture route (despite the material's quenching) travels to the austenite grain boundary.

CONCLUSION

Of course, despite the fact that API has established very rigorous standards for this material, no case of failure of this material has been reported in recent years.

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