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Analysis of internal cracks in Type 304 austenitic stainless steel cladding wall of regenerator column in amine treating unit

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ABSTRACT

The present study aims at investigating the incidence of internal cracks in Type 304 austenitic stainless steel cladding wall of Methyldiethanolamine (MDEA) regenerator column in amine treating unit. The toxicity of hydrogen sulfide (H_2S) makes it difficult to reproduce the exact service conditions in regenerator column; therefore, it was substituted with thiosulfate solution. Slow strain rate testing (SSRT) was performed on specimens in simulated process environment of MDEA regenerator at 83 + 3 °C. In order to analyze and compare the data which collected, constant load (CL) and fracture mechanics (FM) techniques were applied by the researchers. After the failing, the fracture surfaces were observed through a scanning electron microscope (SEM) and were chemically analyzed using energy dispersive X-ray (EDXs) techniques. The results revealed that elongation ratio (ER), reduction in area ratio (RAR) and time to failure ratio (TTFR) increased rapidly in corrosive solution in the presence of 5%MDEA compared with the absence of MDEA. In addition, the specimen tested in thiosulfate solution (corrosive solution) without MDEA indicated a brittle type of failure, whereas those in the MDEA solution showed a ductile fracture.

1. Introduction

In amine treating units, gas and liquid hydrocarbon streams may contain acidic components such as H_2S and carbon dioxide (CO_2). These units operate at low and high pressure to eliminate, through contact with and absorption by an aqueous amine solution, such acidic components from process stream [1]. The lean (regenerated) amine solution flows counter to the contaminated hydrocarbon streams in the column and absorbs the acidic components during the process. The Amine Regenerator Column is a vertical column 38 m high, and has an outside diameter of 3 m. After exchanging heat with lean amine leaving the regenerator in the lean-rich heat exchanger, the rich amine feed enters near the top of the column, at the 20th tray, ranging from 83° to 95 °C and 10–15 psi. The rich (contaminated) amine solution is fed into a regenerator (stripper) tower, where the acidic components are removed through the reduced pressure and the heat supplied by a reboiler [2–4]. The diagram of MDEA gas sweetening process is shown in Fig. 1.

Therefore, the amine solutions, which contain chloride ions and hydrogen sulfide, lead to SCC, Chloride Stress Corrosion Cracking (CLSCC), and Sulfide Stress Corrosion Cracking (SSCC) in low alloy steels and corrosion resistant alloys (CRAs) such as stainless steels and Ni-based alloys [4–6].

Austenitic grades are types of stainless steels mostly used in refinery equipment and amine units. Stainless steels are susceptible to the partial occurrence of intergranular corrosion and intergranular stress corrosion cracking (IGC/IGSCC), which are of common

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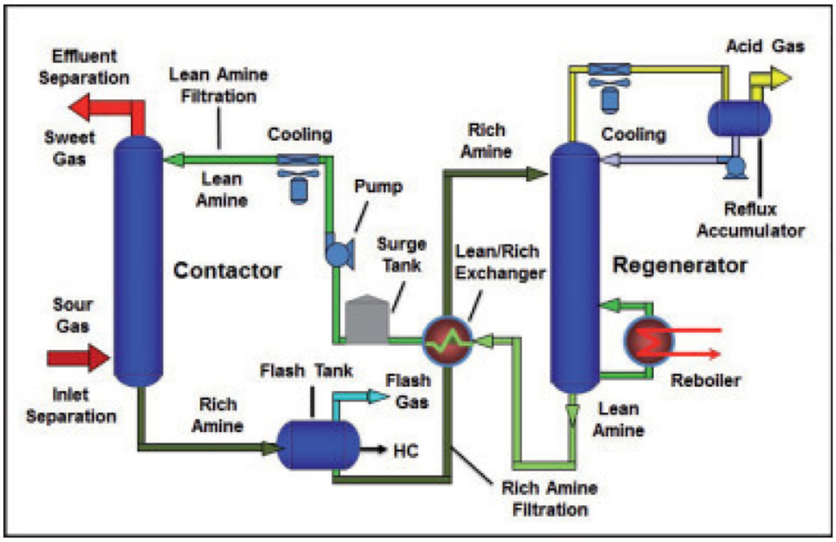

Fig. 1. MDEA Sweetening Gas Process and Amine treating unit.

types of damages in these plants [7–10]. Sensitization is resulted from the formation of chromium carbides (usually $Cr_{23}C_6$) during the heat treatment or welding in the manufacturing process of cladding materials or other equipment. Moreover, it was found that cold work leads to the precipitation of fine particles of chromium carbide on grain boundaries. The segregated chromium carbides make the locations around the grain boundary less passive; therefore, the grain boundaries corroded more easily compared with the substrate. The applied or residual stress helps the crack to be opened at the grain boundary, resulting in intergranular SCC. Consequently, both IGC and IGSCC are of a similar electrochemical nature [7,11–13]

On the other hand, cladding is a surface engineering process, protecting substrate materials to maximizing their performance. Cladded steel is characterized by the economic efficiency and improved corrosion resistance. The improvement can be achieved simultaneously by combining the great corrosion resistance of the cladded material and the appropriate toughness and strength of the base metal, particularly at high temperature applications [13–15]. In many cases, it is difficult to simulate actual service experience using conventional statically stressed specimens under laboratory conditions that simulated those manufacturing in-service failures. However, when slow strain rate testing was employed, better correlation between laboratory and plant experience was achieved. Fig. 2 shows Type 304 austenitic stainless steel internal cladding of amine regenerator column in amine treating unit which have been suffering from cracking after a long-term operation.

For working safely in plants that contain toxic elements like H_2S, it is necessary to find root cause and failure analysis of these equipment to aware of damage mechanisms in order to extend their life and reduce the costs associated with component replacement. Furthermore, it is necessary to improve the repairmen of the applied method [1]. The NACE-TM0198 standard presents the testing method “SSR” for screening CRA materials like stainless steel to be resistant to SCC in simulated oil production environments. Given the fact that this testing method is one of the screening kind, the need is felt for supplementary evaluation or additional experience before materials selection [16–20].

In a project, the Japan Society of Corrosion Engineering (JSCE) addressed pitting corrosion in sour environments and found that thiosulfate might be the most suitable ion substituting H_2S in order to help examine the corrosion tendency of stainless steels in sour environments [17]. The findings reveal that thiosulfate could be used as a substitute for H_2S in the investigation of SCC susceptibility of CRAs and low-alloy steels in sour environments [17,19]. During the last decade, many studies have been done on the corrosion behavior of stainless steels in H_2S or/and Cl^- environments. Tsay et al. concluded that sulfide stress corrosion cracking of Type 304 L stainless steel in saturated H_2S solution was susceptible to rolling temperature and sensitization treatment [21–23].

In most cases, the SSR technique was known to be better than other sensitivity testing techniques. The main function of SSR testing is to analyze cracking susceptibility, or conversely, cracking resistance. This is usually accomplished by measuring the ratio of ductility parameters to that measured in an inert environment such as air, inert gas, or oil. Quantitative criteria for passing/failing based on the fracture surface morphology have been incorporated into the test standards developed by ASTM, NACE, or ISO. For most applications, SSR test ratios have been required based on time to failure, elongation, or reduction in area, or a combination there of, with no evidence of environmentally assisted cracking in the gauge section of the specimen [24–26].

In this work, the incidence of internal cracks in Type 304 austenitic stainless steel cladding wall of Methyldiethanolamine (MDEA) regenerator column in amine treating unit were examined using slow strain rate testing (SSRT), constant load, and fracture mechanics. SSRT was performed on specimens in simulated process environment of MDEA regenerator. Finally, SEM-EDS was employed for analysis of fracture surface and elongation ratio (ER), reduction in area ratio (RAR) and time to failure ratio (TTFR) were measured.