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Failure analysis of an oil refinery sour water stripper overhead piping loop: Assessment and mitigation of erosion problems

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ABSTRACT

This study investigated the integrity of the outlet nozzle and elbow of the piping system downstream the finfan cooler in sour water stripping unit. The piping system in these locations experienced severe thinning and occasional leaks. The unit was modelled using process simulation software with the use of the appropriate thermodynamic methods for electrolyte models to accurately estimate the flow rates, properties in vapour and liquid phases in the piping system. The results from the process simulation were subsequently used in the Computational Fluid Dynamics (CFD) simulation. The CFD simulation results matched the erosion pattern that caused the loss of wall thickness. The eroded nozzles were also visually and optically examined using scanning electron microscopy (SEM) and Energy Dispersion X-ray (EDX). The results have indicated that the erosion is inevitable regardless of the fluctuation in the throughputs to the unit. Iron sulfide, indicative of the synergy between erosion and corrosion, was observed in the pipes elbows. For mitigation, an option has been recommended to change the operating mode of the finfan cooler so as to alleviate alloy change.

1. Introduction

Due to recent stringent specifications imposed on fuels produced in refineries, more sour waters will be produced. Hydrogen sulfide and ammonia are the key components present in sour water. In sour water stripping units, the sour water is processed to remove H_2S and NH_3. The combination of H_2S and NH_3 in sour waters will produce ammonium bisulfide NH_4HS that is typically associated with corrosion problems. As the concentration of H_2S and NH_3 increase creating a hostile environment for the piping martial compounded with the formation of NH_4HS, erosion-corrosion will be ensued. Damin [1] reported the factors that NH_4HS formation in air coolers can cause corrosion by studying the corrosion rates at different conditions on different alloys. Cayard [2] reported that industry had been using conservative rule of thumb, for the estimation of NH_4HS corrosion, that results in alloy upgrade and demonstrated that corrosion rates were far lower and thus carbon steel is the economic option.

Toba [3,4] investigated the corrosion in tubes of air-cooled heat exchanger and found that air side temperature was the source to ensue corrosion in the tube side due to the formation of a two-phase regime. It was recommended that corrosion prevention could be mitigated by controlling the operating conditions rather than alloy change or upgrade.

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Table 1
Design and unit feed and product concentration of H_2S and NH_3 in sour water (ppmwt).

Component	Design	May 2011	April 2016	Design	May 2011	April 2016
	Feed			Product		
H_2S	7100	2100	2640	10	258	6
NH_3	500	1398	1250	100	42	81

Notwithstanding the research efforts in the area of controlling the erosion problems, the upstream, midstream and downstream industries are still facing erosion-corrosion based problems [5–8]. Zhu [9] studies experimentally the effect of velocity and NH_4HS concentration on the erosion-corrosion and used CFD simulation to highlight the thinning of the material in the affected area of the elbows in sour water stripping unit. It was reported that when high concentration of NH_4HS of about 10 wt% and higher liquid velocity, the corrosion rates increase quickly. Even though the mechanisms of erosion-corrosion in sour water stripping have been formally addressed in many investigations, the problem is still being experienced at a significant scale in the industry, and hence further research in this area is required. Notwithstanding the numerous researches in this area, the problem is still being experienced, and hence further research in this area is required.

By using various engineering tools and analytical techniques, the underlying mechanism of erosion problems was further understood and countermeasures to mitigate the erosion were established.

1.1. Case definition

The study was carried out to address a concern raised about the leak and frequent replacement of the nozzle, piping expander and elbow downstream the finfan cooler in the sour water stripping unit in a refinery. The sour water stripper unit receives sour water from other processing units in the refinery and has a design capacity of 6 m^3/h, with H_2S and NH_3 product specifications of 10 and 100 ppm, respectively. In Table 1, design and typical plant concentrations for sour water are shown for the unit investigated. A schematic diagram of the main pieces of equipment in the unit is shown in Fig. 1. Fig. 2 shows the locations where the leaks were detected.

In this work, ways to minimize the frequent failure and replacements of the various components have been investigated to address the underlying causes of failure in the nozzle, piping expander and elbow. Historical operating data for the unit performance has been

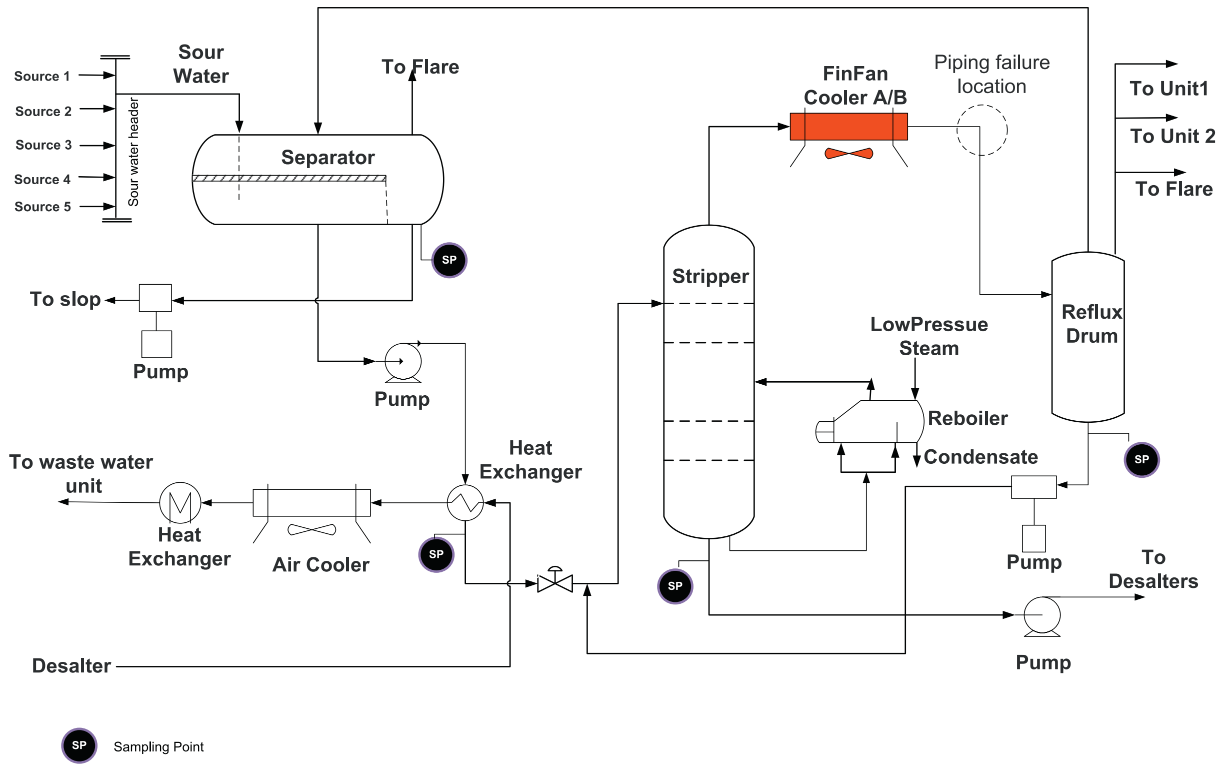

Fig. 1. Process flow diagram for sour water stripping unit.