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Investigation on the deposition failure of a reactor effluent air cooler in hydrocracking unit

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ABSTRACT

The deposition failure of a reactor effluent air cooler (REAC) is investigated by the technical analysis and multiphase flow simulation. The blockages of REAC tubes are mainly induced by the corrosion products come from the upstream heat exchangers, a result of the high temperature H_2S-H_2 corrosion. Meanwhile, NH_4Cl salts crystallize upstream the air coolers and enter into the REAC tubes, flowing along with the corrosion products. Through analyzing the residence times and deposition rates of salts, it is found that the corrosion products tend to deposit on two sides of the header box, the third row of tubes and the regions of low velocities. The temperatures inside the REAC tubes significantly decrease once the tubes are blocked. Fouling of NH_4HS salts occurs when the temperature falls below 30 °C. The expansion and contraction of carbon steel with large difference in temperature lead to the bucking of tubes. The regions with high risk deposition are obtained from simulation, which agree well with the actual failure phenomenon.

1. Introduction

Reactor effluent air coolers (REACs) are used as the important equipments for cooling the hydrocarbon stream in the hydroprocessing unit. For the harsh working conditions and the corrosive multiphase flow, the air coolers operate with a high risk [1]. Caused by the blockages of REAC tubes, several unplanned shutdowns occurred in the past three years, which seriously affected the safety of hydrocracking unit.

Blockage and corrosion by ammonium salts and corrosion products are one of the main causes of equipment and piping failures in the oil refineries. Many technical analysis, experiments and numerical simulation have been conducted. Philip proposes that the wash water should be injected before ammonium salts crystallization to effectively prevent the blockage of REAC tubes [2]. The crystallization and deposition process of ammonium salts are tested in the experiments by Menasha et al. [3], results show that the NH_4HS salts firstly crystallize in the gas phase rather than on the cold metal surface. Based on the analysis on the condensation of sulfur and chloride compounds and flow simulation, Saeed Reza Allahkaram et al. find that the accumulation of corrosion products is the primary cause of fouling deposition in heat exchangers [4]. Guofu Ou et al. suggest that the process of ammonium salts deposition is influenced by the multi-physical field coupling [5]. Through the investigation on the crystal and deposition behaviors of NH_4Cl salts and multiphase flow simulation, the corrosion mechanism on the top of REAC tubes is clarified [6]. S.A. Jenabali Jahromi finds that the insoluble salts, chlorides and sulfuric compounds in the lower quality crude oil lead to corrosion and blockage of air cooler tubes [7]. However, there is less investigation on the bending deformation of air cooer tubes caused by the corrosion of upstream heat exchangers. And the research on the particles kinetics of corrosion products in the tubes and header box of air coolers is still not enough.

In this paper, the deposition failure of a REAC system in hydrocracking unit is investigated by the technical analysis and multiphase fluid simulation. In the technical analysis, the crystallization temperature of ammonium salts (NH_4Cl and NH_4HS) is calculated, and

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the source of corrosion products is determined. In the numerical simulation, the multiphase flow characteristics, the particles trajectories and the locations where are susceptible to be blocked are obtained. Compared with the actual failure morphologies and fouling location, the accuracy of failure analysis is verified.

2. Failure description

2.1. Technical process

The technical process of a reactor effluent fractionation system is shown in Fig. 1. The high temperature reactions of the crude oil and hydrogen occur in the hydro-cracking reactor DC102 and hydro-refining reactor DC103. In the cooling process, the two reactor effluent streams go through a series of heat exchangers and air coolers, respectively. The deposition failures are mainly found in the air coolers EC102, thus the cooling process series II are focused in this paper. The three phase separation of recycle hydrogen, HP oil and sour water is conducted after the two streams enter into the same high-pressure separator FA103. The HP oil is used as the raw material to produce naphtha, kerosene, diesel oil and etc. in the further distillation and refining.

The feeding flow rates of crude oil in series I and II are 175 m^3/h and 125 m^3/h, respectively. The sulfur, nitrogen and chloride contents in the crude oil are approximately 20,000 ppm, 1420 ppm and 1 ppm, respectively. The presence of these impurities usually results in the crystallization and deposition of ammonium salts. To keep salts from deposition on the heat-exchange equipments, wash water is injected into the reactor effluent stream. The water can dissolve and wash away the sediments, thus preventing the accumulation of ammonium salts. In this case, the amounts of injecting water in series Iand II are 15.5 t/h and 8.6 t/h, respectively.

2.2. Air cooler structure

The structure diagram of air cooler is shown in Fig. 2. This equipment utilizes the atmospheric air to cool the reactor effluent stream. The indirect heat transfer from fluid (within the tube) to the cold air is conducted by the forces of draft fan. Each air cooler is consisted of two tube passes. There are three tube rows in the first tube pass but only one tube row in the second tube pass. Each row contains 49 tube bundles made of 20# carbon steel, and the specification of tubes is 10.5 m × 25.4 mm × 3 mm (length × diameter × wall thickness). The tube ferrules, manufactured by Monel alloy, are installed in the entrance of inlet tube bundles to enhance the resistance of erosion-corrosion induced by multiphase flow. The length of tube ferrule is 200 mm and its wall thickness is 0.5 mm. The inlet and outlet temperatures of air cooler are 145 °C and 50 °C, respectively, and the operation pressure is 15.8 MPa.

2.3. Typical failure case

During the processing of crude oil with poor quality, serious bending and distortion of tube bundles occur in the air cooler EC102, result in the high-risk of operation. The morphology of bending tube bundles is shown in Fig. 3. Through detecting on surface temperature of the first tube rows, the uniform distribution of temperature field is observed, as shown in Fig. 4. The photograph of

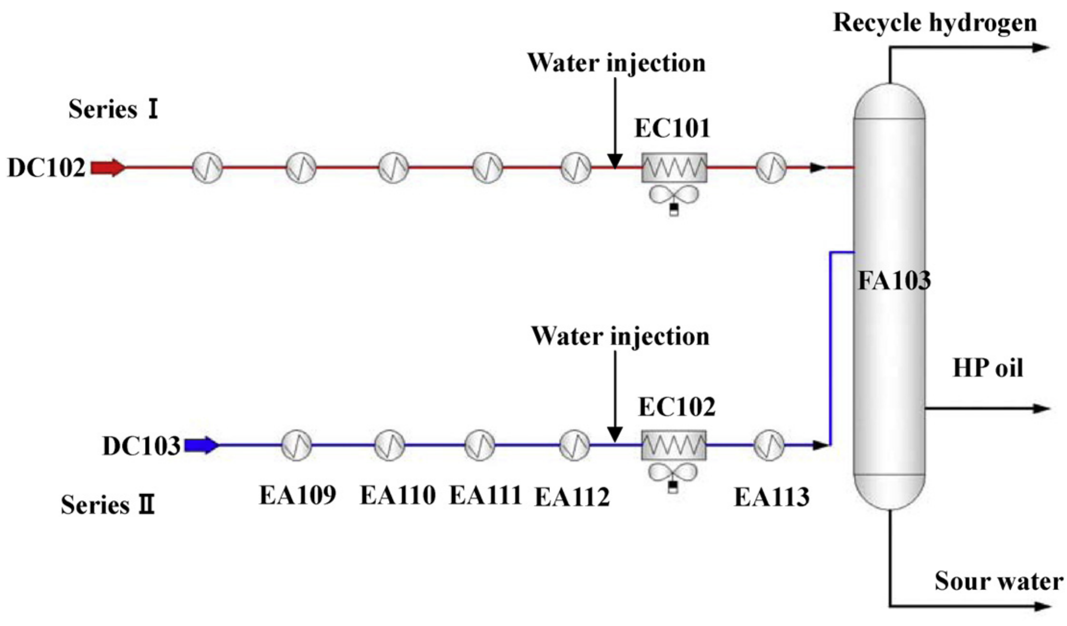

Fig. 1. Process scheme of the reactor effluent and fractionation system.