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Case study

Thermal damage of sulfur processed chamber under Claus operating reaction conditions—A case study

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ABSTRACT

The sulfur from acid gas and sour gas is recovered to produce useful sulfur products. The claus reaction is industrially important process to recover sulfur from corrosive acid and sour gases. To achieve claus reaction, high temperature reactor is utilized under controlled conditions. The Claus combustion reaction heater made of 94% alumina refractory bricks were damaged under ideal equilibrium operating conditions. The first principle mathematical model was developed to measure the temperature profiles at hot face bricks and its interfaces to predict outer steel surface temperature. The maximum outer steel wall surface temperature was measured as 548.6 °C using thermograph experiments and compared against the predicted temperature. Large variations in temperature differences have confirmed that the refractory wall was damaged due to abnormal reactions. This thermal damage is discussed and presented with various evidences from visual inspection. The hot face wall bricks, matrix blocks and orifice throat were damaged and presented by macroscopic visual inspection. However, hardness of the steel shell is within specified limit. Therefore, the refractory repair inside the reactor and thermal insulation of external shell has been proposed to prevent steel shell from creep, graphitization, and high temperature oxidization and corrosion damages.

1. Introduction

The refractory materials are designed to resist against heat, corrosion from industrial corrosive gases, mechanical and thermal stress, strains, and abrasion at higher temperatures. The performance of refractory directly depends upon its chemical composition, manufacturing method and its implementation methods [1]. Mostly, the refractories are used in steel industries, petroleum and petrochemical industries. The right choice of refractory selection at design stage is economically beneficial. In steel industry, the basic refractories are applied to the wall of basic oxygen furnace (BOF) [2]. The quality and productivity of the liquid steel is determined by the performance of applied refractory in addition to various other parameters [3]. Similarly, petroleum industries also line various basic refractories to inner wall of the reactor and pressure vessel on its hot face sides. The service life of the reactor and pressure vessel for chemical processing directly depends on the lined refractory. Alumina refractories known for its good performance is highly essential for steel processing and hydrocarbon industries. Alumina refractories ranges from 60% Al_2O_3 to 99% Al_2O_3 and are used in various applications depending upon the type of product. For example 60% Al_2O_3 are used in general furnace and incinerator bricks, 94% Al_2O_3 are used in internals of combustion chamber reactor walls and 99% Al_2O_3 are used in certain specialty products [4]. The reduction of mullite in alumina increases the service temperature. Therefore, the performance of alumina refractory is better than fire clay refractory, particularly in better creep resistance and high temperature corrosion. However, the refractory performance will come down if it is operated beyond design temperatures.

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One such case study from petroleum refinery is discussed in this paper. In petroleum industry, sulfur will be extracted from sour gas and acid gas which majorly contains H_2S. The schematic view of sulfur recovery process flow is shown in Fig. 1. The sour water generated from high pressure cracker and coker unit supplies sour gas feed to sulfur recovery unit. These sulfur recovery unit produces sulfur as a final product from crude processed hydrocarbon. The fundamental process is that partial conversion of H_2S to sulfur-di-oxide as stated in Eq. (1) and further reaction between remaining H_2S gas and SO_2 gas will form sulfur and water as shown in Eq. (2) [6]. The first stage partial oxidation and second stage remaining combustion is called overall claus reaction as shown in Eq. (3) [7]. The amount of air feed to the process will define the amount of sulfur-di-oxide formation. Therefore, for maximum sulfur formation the ratio of $\frac{H_2S}{SO_2}$ in the process gas was maintained at the ratio of 2:1 [8] and accordingly air to gas ratio was maintained in-between 1.4 to 1.5 for clauss operating reaction [9]. The overall Claus reaction is controlled by air injection and this endothermic reaction approximately recovers 99% of sulfur from sour rich acid gas [10].

$$\frac{1}{3}H_2S + \frac{1}{2}O_2 \rightarrow \frac{1}{3}SO_2 + \frac{1}{3}H_2O + 41.3\,\text{kcal per mole} \tag{1}$$

$$\frac{2}{3}H_2S + \frac{1}{3}SO_2 \rightarrow \frac{2}{3}H_2O + \frac{1}{2}S_2 + 7.4\,\text{kcal per mole} \tag{2}$$

$$H_2S + \frac{1}{2}O_2 \rightarrow S + H_2O \tag{3}$$

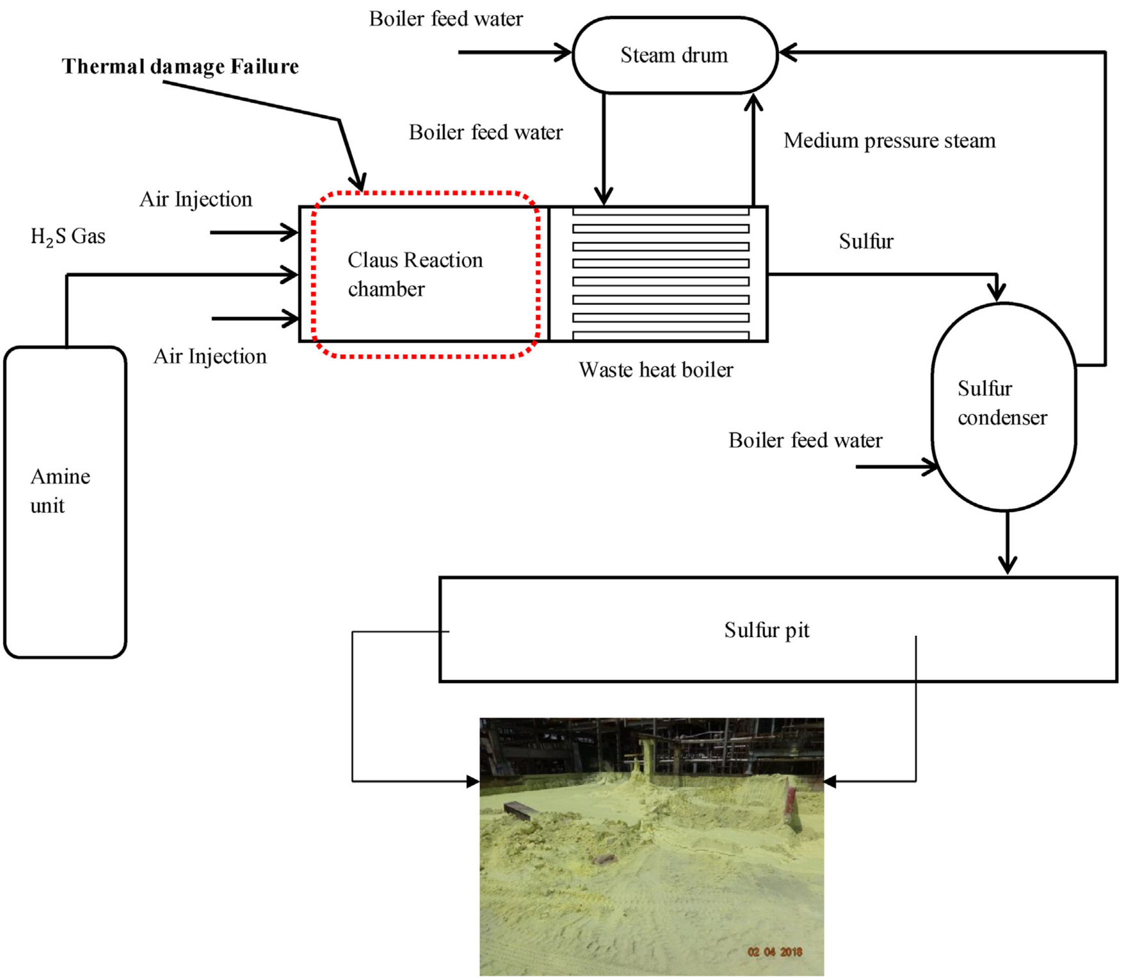

Fig. 1. Schematic view of sulfur recovery process flow and sulfur reactor thermal damage encircled within unit.