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Failure analysis and retrofitting of superheater tubes in utility boiler

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ABSTRACT

The extreme spray water mass flow rate deviation was observed to occur in the middle temperature superheater of Sahand 2 × 325 MW Power Plant utility boiler, which severely affected its economic performance and safe operation. Boilers operating in these conditions led to failure in superheater tubes at the same place for two consecutive times in a three year span. Thus, the failure analysis of superheater tubes by investigating the visual inspection, chemical, scale and creep analysis was carried out. The brittle failure occurred in the superheater tubes after the fuel was changed from natural gas to heavy oil. Failure analysis showed that tubes were suffering from long term overheating which was instigated by high spray water flow rate. In order to rectify the boiler operating conditions, some modifications were applied in the boiler unit 1 and operating parameters on this boiler were compared with boiler unit 2. The results showed that the 8.33% reduction in heating surface area corresponds to 52.84 and 17.80% reduction in spray water mass flow rate for capacities equal to 300 and 260 MW, respectively.

1. Introduction

High temperature operation for a prolonged duration leads to significant damage in structural component, majorly caused by the occurrence of surface oxidation and decarburization processes, and temperature sensitive plastic deformation. Failures in superheater tubes may emerge from several causes, including design, material composition, and improper thermal operating conditions. Therefore, it is crucially necessary not only to identify these failures but also to determine their main cause when failures do occur.

Almost 35% of common failures in utility boilers are caused by long term overheating (creep) in superheaters, reheaters and wall tubes [1–4]. Failure investigations on water tube boilers in Iran power plants have recently been reported [5–8]. Fatah et al. [6] investigate a failure in a boiler tube of low alloy steel, SA-210 Grade A-1. In their study, SEM images and XRD results showed the presence of $NaFeO_2$ which is the main product of caustic attack. In this situation the evaporation at the waterside of the partially filled tube leads to locally caustic concentration which dissolves the protective magnetite layer and subsequently attacked the bare metal.

In this paper, failure analysis on superheater of Sahand 2 × 325 MW Power Plant was studied. Boilers of Sahand Power Plant of Iran were a tangentially fired heavy oil and natural gas furnace. In the following, the main cause of superheater tubes failure is determined, the retrofitting for the boiler unit 1 is explained, and the results are reported.

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2. Boiler operating backgrounds

In order to achieve amelioration in the efficiency of heat transfer, HRSG is structured in multi-level temperatures. Water is provided from Boiler Feed Pump (BFP) in high pressure to HRSGs low temperature header which turns into high temperature superheated steam and fed to steam turbine through multi-stages of pipe lines. In the Sahand boilers, the pipe between the middle temperature superheater header and the high temperature superheater header is connected with two attemperator, which maintains constant temperature of superheated steam that is fed to the steam turbine (Fig. 1). The arrangement of Sahand boiler heating surface was designed according to the heavy oil as the main fuel and checked by natural gas as an auxiliary fuel.

Sahand Power Plant is operating since 2004 and it was observed that superheaters and reheaters steam temperatures of Boiler unit 1 and 2, deviated the design value when firing heavy oil or natural gas. The steam temperature at the middle superheater outlet was found to be almost 40 °C higher than design value. Furthermore, high spray water is required in both fuels. Although, in the case of heavy oil the spray water found to be greater than design value, but it is within the allowable range of spray water (less than 5% of main flow). When the fuel was changed to natural gas the spray water is increased dramatically, and its mass flow rate reached to the 18% of the main flow (the main flow of boiler in the full load is 1197 t/h and the spray water in this situation reached to 190 t/h). Boiler operating in these conditions led to failure of superheater tubes in July 2006; the same failure was reported once again at the same place in May 2009, when the fuel was changed from natural gas to heavy oil. To address the issue of consecutive failures, visual inspection, microscopic examinations and chemical, scale and creep analysis utilizing available related data are carried out to evaluate the failure mechanism and its root cause. The results are reported in the following.

3. Failure analysis

3.1. Visual inspections

Visual observation of the failed tubes shows that the tubes are bent at several parts (Fig. 2). The outer surface is covered by relatively thick sediment and brittle failure in the different parts of the tube can be observed (Fig. 3). In the case of brittle failures, the micro cracks propagate in the materials and the atoms are gradually separated by tearing along the fracture plane in a very fast way. The path the crack follows depends on the material's structure and the transgranular and intergranular cleavage are important. In this case, it seems that the changing the fuel from gas to heavy oil is provided a crack propagation conditions.

3.2. Chemical analysis

In order to determine the chemical composition of the tubes, a chemical analysis was performed. The results, as shown in Table 1, indicated that the chemical composition was complied with the 12Cr1MoV original composition of the tube.

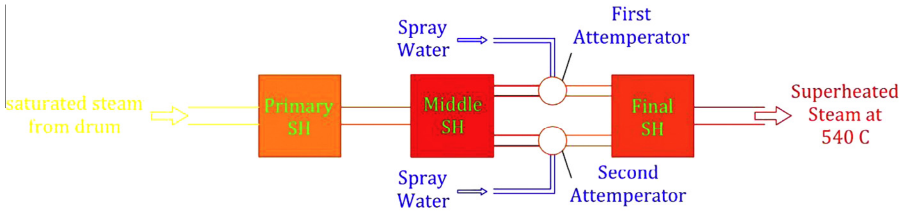

Fig. 1. Schematics of Sahand superheater system with two attemperator.

Fig. 2. The image of failed tube.