



Short communication

Stress corrosion cracking failure of a SS 316L high pressure heater tube

M. Ananda Rao^{a,*}, R. Sekhar Babu^b, M.V. Pavan Kumar^c^a CSIR, National Metallurgical Laboratory Madras Center, Chennai, India^b Paradeep Phosphates Limited, Paradeep, India^c Department of Chemical Engineering, National Institute of Technology, Calicut, Kerala, India

ARTICLE INFO

Keywords:

Stress corrosion cracking

Caustic corrosion

Chlorine attack

HP heater tube

Thermal power plant

ABSTRACT

A service failure by environmentally induced cracking in austenitic stainless steel 316L is presented in this work. Extensive research has been carried out on stress corrosion cracking of different materials and environment combinations by various established experimental procedures. The list of alloy/environment combination that causes stress corrosion cracking is continuously increasing. Stress corrosion cracking is a great concern in corrosion resistant alloys exposed to aggressive environments. Stainless steel 316L material used as high pressure water heater tube failed by stress corrosion cracking was evaluated by various metallurgical characterisation techniques. Results and apparent causes leading to failure were explained in detail.

1. Introduction

Almost all process equipment in thermal power plants are prone to corrosion due to high interconnectedness of the hardware elements with potential corrosive nature of the process streams. For the successful avoidance of operation failures caused by the corrosion of the equipment, it is vital that the root cause of the corrosion and its progression are investigated and understood thoroughly. As any thermal power plant is an extremely important generator of electrical energy, many case studies pertaining to the failures in boilers due to corrosion phenomena were reported earlier [1–3]. In a comprehensive study on the failure of feed water tube of a boiler by Hales et al. [1], the failure was attributed to a specific phenomenon called “flow assisted chelant corrosion”. Some useful recommendations were enlisted for the safe operation of boilers. Ranjbar [4] highlighted the aspect of the control of feed water chemistry to prevent corrosion of the cold and hot reheater tubes in the boilers. Nevertheless, the makeup feed water undergoes a series of physical/chemical treatments for to be compatible in the boiler operation. Hence, the contact/accumulation of the chemical agents inside the equipment with or without chemical transformation at the prevailing operation conditions thus becomes an important and crucial aspect in the sustainability of the whole operation.

Caustic soda is a widely used as water softening agent to control feed water pH in the operation of boilers. However, if present above the critical levels, it can lead to caustic gouging [5] [6]. The corrosion of steels due to caustic soda was discussed by Fontana [7] and Rondelli et al. [8]. It is also reported that low alloy steels of 300 series are more prone to caustic corrosion above 366 K [9] [10]. The mechanism of corrosion inside boiler pipes due to caustic and phosphates was presented by Khajavi et al. [11]. Pritchard et al [12] studied the deposition of NaCl, NaBr and NaOH on the surface of AISI Type 316 stainless steel tube. Their study revealed that the deposition is possible even with low concentrations of the salts at high pressures and low to moderate temperatures. Poulson [13] systematically investigated the stress corrosion cracking of stainless steel 316 in caustic solutions. A relation between crack

* Corresponding author at: National Metallurgical Laboratory, Madras Centre, Taramani, Chennai, India.

E-mail address: anandm04@gmail.com (M. Ananda Rao).

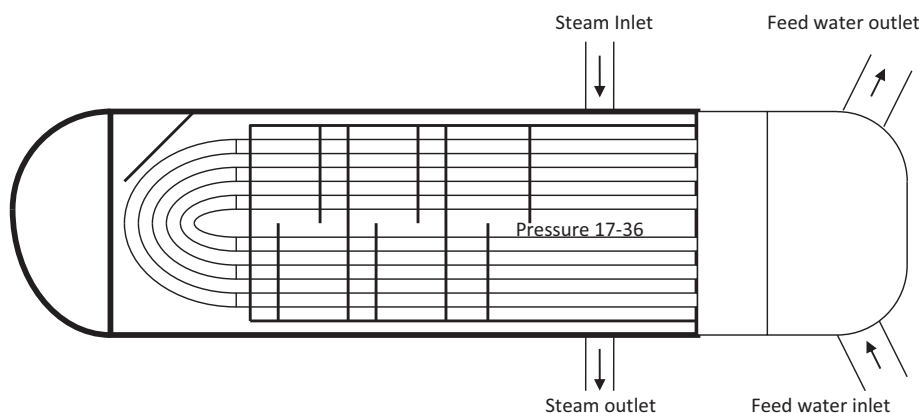


Fig. 1. Schematic of the high pressure water heater.

Table 1

Chemical analysis of water and condensate (15 days average data).

DM Water		Condensate	
Conductivity	0.08 $\mu\text{S}/\text{cm}$	Conductivity	5 $\mu\text{S}/\text{cm}$
pH	7.01	pH	9.22
Silica	11 ppb	Silica	11 ppb
		Total iron	10 ppb
		Ammonia	0.8 ppm
		Cationic conductivity	0.25 $\mu\text{S}/\text{cm}$

velocities and molar concentration of NaOH was established. In another seminal work by Poulson [14], the effect of the heat transfer on the deposition of caustic and subsequent stress corrosion cracking of 316 steel was studied in an artificial crevice. The relevant literature on the subject was also reviewed and the advantages of the devised experimental approach were discussed in detail. The corrosion resistance of 316 L type stainless steel in caustic environment reported is [15–16]. Stress corrosion cracking of different materials with possible alloy/environment combinations been tabulated and failure mechanism in stainless steels with respect to stresses, microstructure, effect of cold work, protective films, sensitisation was discussed in detail [17–19].

In recent years, steels of higher corrosion resistance in alkali environment are desired. The objective of the current work is to analyze the corrosion damage of a high pressure heater tube made of stainless steel SA213 TP 316L in a thermal power plant.

2. Description of high pressure water heater

To enhance the energy efficiency in a power plant, the incoming feed-water to the boiler is pre-heated by the outgoing steam. The corrosion damage case study reported here was happened in a coal fired thermal power plant. The heater tubes are made of SA213 TP 316L PI material. The diameter of a tube is 16 mm and the wall thickness of in the tubes is 1.6 mm. The heater tubes are designed to withstand for high pressure operation (above 104 bar) and hence referred as high pressure heater tubes. The heater in the discussion is an heat exchange of horizontal shell and tube type as shown in Fig. 1. heat exchanger. Schematic of the heater with operational data is presented in Fig. 1. Steam inlet (shell side) and outlet temperatures are 573 K and 373 K respectively at 17–36 bar pressure. Feed Water enters roughly at 323 K and gets preheated to 373 K, tubes are designed to operate up to 180 bar. Laboratory analysis of water and condensate is tabulated in Table 1. Few tubes failed in the desuperheating zone (where steam enters) of the heater after 11 months of service life, against the prescribed service life of 25 years. The failure was in the desuperheating zone of the heater, incoming steam enters in this zone and transfers most of the super heat to the boiler feedwater.

3. Details of experimental evaluation

The failed tube sample was first examined visually. The chemical composition at the failed regions of the tube were found using optical emission spectrometer (OES-Spectrolab, Germany). The failed tube's inner and outer surfaces were examined by stereo-microscopy (Leica, Switzerland). For further examination of the failed tube, the metallographic samples were prepared by conventional polishing and examined in both etched and unetched conditions. The nature of the corrosion deposits and the presence of any other deposition of elements were examined using SEM-EDS (Model: SEM-JEOL JSM 739A).

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