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Case study

Premature failure of dissimilar metal weld joint at intermediate temperature superheater tube

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ABSTRACT

Dissimilar metal weld (DMW) joint between alloyed steel (AS) and stainless steel (SS) failed at one of intermediate temperature superheater (ITSH) tube in steam/power generation plant boiler. The premature failure was detected after a relatively short time of operation (8 years) where the crack propagated circumferentially from AS side through the ITSH tube. Apart from physical examination, microstructural studies based on optical microscopy, SEM and EDX analysis were performed. The results of the investigation point out the limitation of Carbides precipitation at the alloyed steel/welding interface. This is synonym of creep stage I involvement in the failure of ITSH. Improper post-welding operation and bending moment are considered as root causes of the premature failure.

1. Introduction

For superheater or reheater boiler tubes operating at higher temperatures (above 540 °C), it is customary to use stainless steel (SS) in the final stages covering a portion of the boiler tubing which is predominantly comprised of low alloy ferritic steel (AS). SS and AS tubes are joint by welding as in the present case of ITSH tube. Problems of premature failure of welds between the two dissimilar materials (SS and AS) have been a common occurrence in boiler industry. Three major causes of these creep failures are: carbon migration from the heat-affected zone (HAZ) of the AS into the weld metal, expansion differences between the two varieties of steel, and the differences in corrosion resistance to flue gases leading to the formation of an oxide wedge on the outside diameter of the AS tube next to the weld [1]. API 571 standard consider more details on the critical factors leading to DMW failures such as welding geometry, thermal cycling, etc. [2]. DMW failure of superheater tubes has been reported in pulverized coal-fired power plant where the difference of expansion coefficient was pointed as the main reason [3].

On the other hand, an interesting research program was conducted by EPRI institute with objective to provide guidelines for improving design and welding procedures for increasing reliability and longevity of DMW [4]. The findings of this program suggested that nickel base welding with proper heat treatment forming band of well distributed carbides (instead of sharp interface of carbides) near the fusion line would improve DMW life. Shallow weld design, low temperature and low stress region of the DMW would also provide additional margin of safety [4]. As indication of the recorded life time, nickel base welding was subject of failures in the mid-1970 after generally 15–17 years of service [5].

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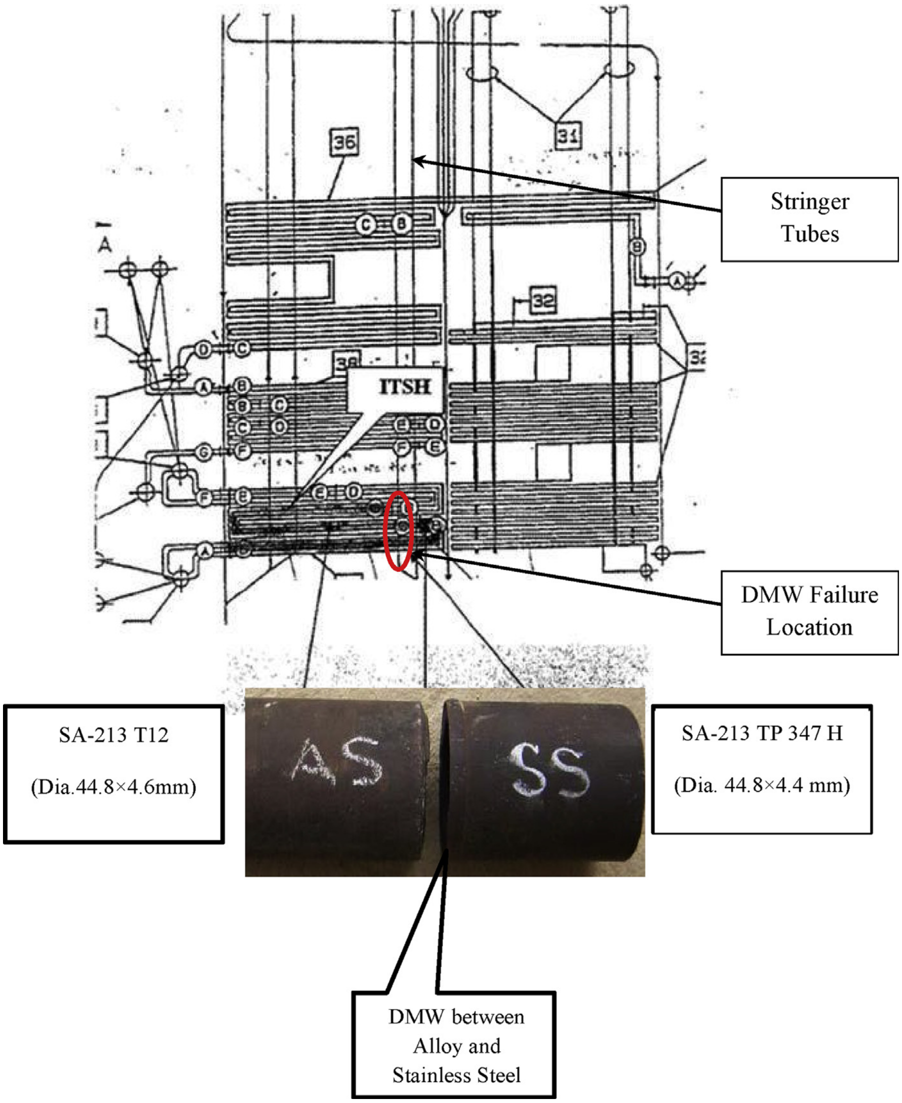

Fig. 1. Schematic diagram showing the failure location in the ITSH area.

In the present case, AS and SS superheater tubes are joined by nickel base filler welding which is known to have low tendency of carbides formation. In addition it has thermal coefficient very close to the low alloy ferritic steels such as SA213 grade T11 and T22 [1]. So, theoretically we expect low stress level at elevated temperature for this welding material.

However, premature failure of DMW occurred only after 8 years of operation at ITSH tube. All superheater tubes are drainable and horizontal type. Part of ITSH is located in second pass and the second part is located in the furnace where it receives part or all of heat by radiation. Failure location is indicated in Fig. 1 and Boiler specifications including ITSH material information are summarized in Tables 1 and 2.

Table 1
Boiler specifications.

Boiler detail	Steam capacity: 637 t/h; design pressure: 106 bar; steam temp. at S.H. outlet 525 °C
Normal fuel	Natural gas
Commissioned	2000
Failure noticed date	28/05/2008
Flue gas temp. at ITSH inlet	1121 °C at normal operating load with gas firing
Steam pressure at ITSH inlet	85.0 bar at normal operating load with gas firing
Steam temp. at ITSH inlet	50 °C at normal operating load with gas firing
Approx. tube metal temp.	480 °C