Failure Analysis and Prevention of Furnace Water wall Tube Corrosion on Fire side of Boiler

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Abstract - There are various types of boiler outages in a boiler that cause the shutdown of boiler and power plant. The Coal Ash corrosion and the Oil Ash corrosion on the fire side of the boiler tube is also a measure cause for the boiler outages. In this Paper there are various investigation and Laboratory corrosion failures from different boiler furnace water wall tube covered. Coal ash corrosion is fundamentally due to low NO_x burner used for Environment consult, poor design and configuration, corrosive ash deposits and overheating. Soot blower erosion/corrosion also affects. Oil ash corrosion is due to sulphur, sodium, chlorine and low grade oil contents which affects the coatings and oxidation of tube.

***Key Words*: Water Wall Tube, Corrosion, Coal Ash, Oil Ash, Welding, Overlays**

1. INTRODUCTION

The shutdown due to boiler tube failures causes great loss of power generation and there by result in revenues loss to the power station. Detecting the tube failures and analyzing the causes is an important job to avoid consecutive damages. There is more risk in running boiler with known leaks. In the boiler tube water wall tube, primary & final super heater, re heater, condensers are failed due to various reason but the water wall tube failures are in more number because it is directly affected by furnace draft condition, operation control, coal quality.. etc. So, here by Industrial approach and experience water wall tube failure reduction and maintenance is done to avoid the failures.

In the recent scenario the coal quality, technology, environment condition, worker's ability and many more changes happened in the power plant. But the failure outages are frequent in the coal based power plant. So, the main reason behind any failures is important to be known for us to reduce breakdown. The various causes of tube failure that occurs in a boiler may be due to one or many reasons as given:

- Over heating
- Due to flue gas or steam erosion
- Due to corrosion on steam or water side at inner surface of tube
- Corrosion/ Erosion on fire side
- Due to weld defects
- Due to raw material defects or mix of materials
- Tube failures due to malfunction of controls and instrumentations.

1.1 CORROSION OF FURNACE WATER WALL TUBE ON FIRE SIDE:

High temperature corrosion of boiler tube surfaces is usually caused by the combined attack of gas and fly ash deposits from the burner fuel [2]. O_2, SO_2 and SO_3 are reactive in nature. Alkali metal sulphates present in the fly ash deposits are also very reactive in their liquid state [9]. But the remainder of the ash is virtually inert. In oil firing the sulphate oil is more corrosive. Chlorine content in coal ash is also corrosive. The sulphates are volatile in the bulk of the gas.

a) Oxidising reducing conditions
b) Coal particles impingement
c) Thermal cycling
d) Gas velocity fluctuations

2. LITERATURE REVIEW

2.1 COAL ASH CORROSION

Low NO_x burner used in the coal fired boiler for the environment protection is the one of the cause of the boiler tube failure. Water wall wastage rate measured 29nm/hr to 145-350nm/hr measured after installation of low NO_x burner [1]. One another experiment shows the 49-87nm/hr to 96-226nm/hr of corrosion. The measured corrosion scale was found to be consisting of Iron sulphide and Oxide [2]. Corrosion scale of FeS (Iron Sulphide) found of 1000ppm [3]

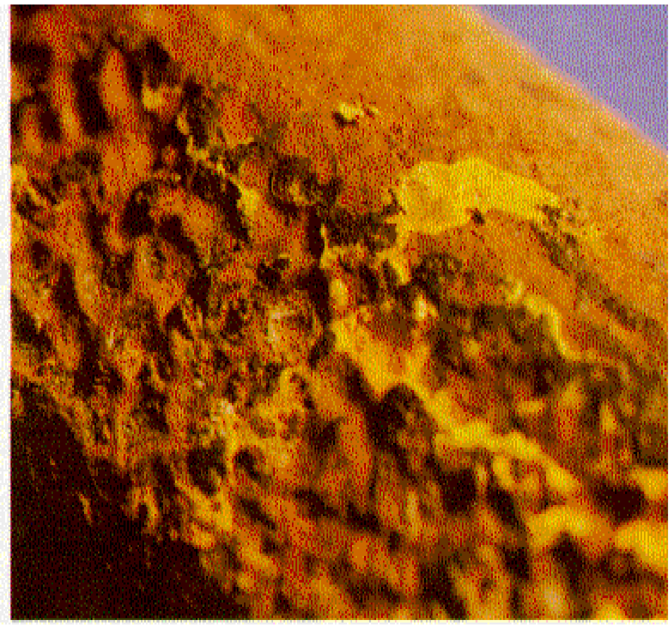


Fig -1: Coal Ash Corrosion

Boiler design and firing configuration also affects the corrosion of the water wall tube inside the furnace. The fire ball had tendency to be closer to certain burner corners, thus causing higher wastage rates. The furnace wall gas sampling tests revealed that high total reduced sulphur and CO level at the burner corners suffered high wastage where as oxidizing atmosphere at the burner corner 2 shows little wastage [4].Severe water wall outage at highly dependent on boiler design and firing configuration. In the tangentially fired boiler, the wastage was invariably highest on front wall.

Difference in the ash deposits between the two locations the area suffering high wastage rate had an ash deposits consisting of 90% FeS and 10% Fly ash, while the low outage had ash deposits consisting of Fe_3O_4 and fly ash [5]. Higher chlorine content is also shown in the corrosion. Chlorine contents also affect the corrosion rate. Corrosion rate increase from 0.15 to 0.65 ppm [6]

Fire side corrosion of the furnace water wall tube particularly in super critical units caused carbon and low alloy steel water tubes to suffer circumferential grooves that resemble an alligator hide or an elephant hide [7] . It is more frequent in super critical boiler than sub critical boiler water wall areas that suffered this type of attack received the highest heat flux with super imposed thermal stresses. Circumferential grooving typically occurs in the areas of the water wall receiving highest heat flux and it is a result of superimposed thermal stress. It is believed that the preferential sulphidification penetration that initiates the circumferential grooving at certain location of the water wall is due to overheating under sulphidification.

One important by product of combustion of coal is ash. Sometimes during combustion products contains mineral constituent and compound in molten or plastic form deposits on the heat absorbing surfaces causing slaging and fouling. If ash reduces the heat absorbing surface at a temperature near its softening temperature. The reducing deposit likely to be porous and can be removed by soot blowing [8]. Slagging is the deposition of the molten partially fused deposits on the furnace walls. Fouling is the deposition of more loosely bonded deposits on the heat absorbing surfaces in the convection path. Soot blowers using steam are generally adequate for removing the ash deposits on the fouled surface. Damage causes the tube surface due to steam blowers is generally referred to as soot blower erosion. Super critical boiler 905 MW experienced several water wall tube failures. SA210T11 tubes subjected to steam blowing by wall blowers. Because of several tube wastage replaced in 18 months. the boiler does not consist low NO_x burner consists corrosion products iron oxide with FeS. It is soot blowing and replaced by GMAW tube sample successfully [9].

2.2 OIL ASH CORROSION

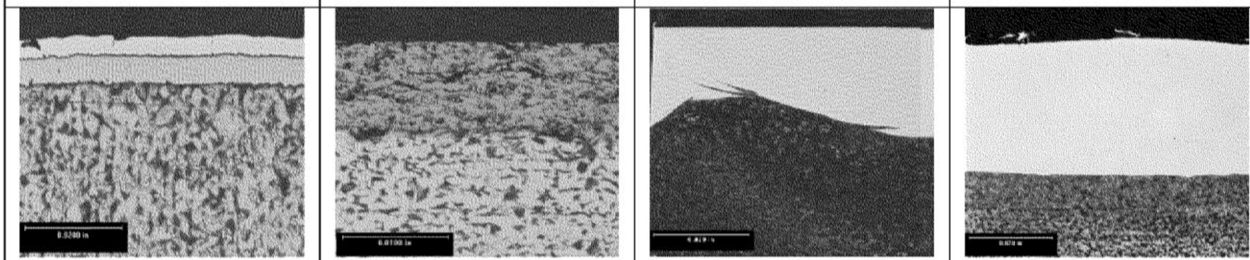
Sulphur present in lighten oil to residual oil. Vanadium and sodium is also corrosive. Ash due to this on metallic components metal temperature reaches to 540C or higher compound in the ash may become molten and corrosion attack severe [10]. Water wall corrosion of oil fired lower metal temperature 450C. 350-450C for fossil fired boiler [11].

Fig -2: Oil Ash corrosion on water Panel Bends

In case of flame impingement the furnace wall may be subjected to higher temperature exposure. Formation of oxide scale or corrosion products on the internal diameter of the water wall [12]. Tubes of the water wall can be significantly increasing the outer tube metal temperature. French indicated that a thin internal deposit can raise the tube metal temperature into the ash corrosion range into creep failure range, or rapid oxidation range, leading to serious furnace tube problem [13].Thermal cycling can lead to circumferential grooving/cracking on the water wall tubes in coal fired boiler. It is due to thermal cycling high temperature and oil ash corrosion.

A super critical oil fired boiler requires replacement of water panels, which were made of 2.225 Cr-1Mo Steel, (T22) every 2 to 3 years because of severe corrosion. Water wall tube had the dimension of 1.01 inch OD to 0.220 MWT. Several panels that were aluminised by a commercial company were tried in boiler. A tube leakage developed after 2.5 years of service. So aluminised coating failed to extend the life of the tube. Circumferential grooves had the location near to localized rupture area. Oxidation attack penetrated through aluminised coating into tube by EPX-SEM a significant amount of Vanadium with magnesium, phosphorous, sodium, zinc found[14].

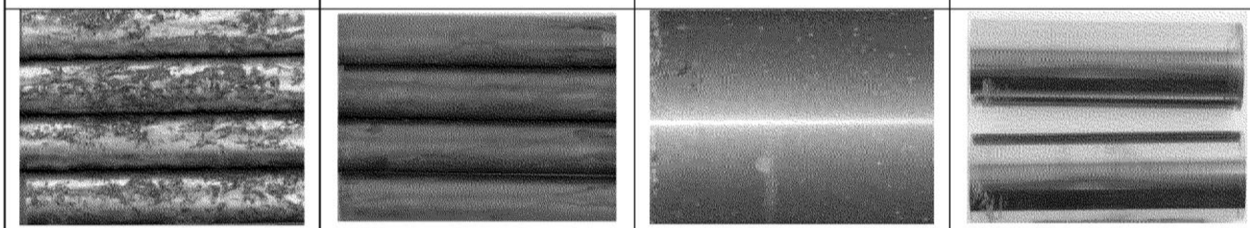
Chrome Electroplating	HVOF Thermal spray	Alloy 625 Traditional weld overlay	Alloy 625 Laser weld overlay.



2% porosity. Cracks to substrate. Corrodes rapidly.	2-5% porosity. Interconnected. Corrodes rapidly.	0.10% porosity. >20% Fe dilution. Pitting corrodes rapidly.	0.030% porosity. < 5% Fe dilution. No Corrosion.
Metallographic cross section evaluation of 12” long samples (50X).			

Figure 2 – Cyclic wet/dry corrosion results of coated rods

Chrome Electroplating	HVOF Thermal spray	Alloy 625 Traditional weld overlay	Alloy 625 Clover Laser Clad.



corrosion failure 100 - 500 Hrs	corrosion failure 50 - 500 Hrs	Pitting corrosion failure 100 - 1000 Hrs	NO corrosion. >6500 hrs
Lab evaluation of 12” long samples in cyclic wet/dry corrosion test, similar to ISO 14993 (4).			

Fig –3: Comparison of Different type of Weld Overlays and Welding to reduce Corrosion

Circumferential grooving or cracking on furnace water wall tube of 2.25Cr-1Mo Steel in an oil fired super critical unit. Thermal cycling of the water wall caused by load changes and oil as corrosion with possible higher water wall tube temperature caused by flame impingement or by oxidation penetration.

2.3 COATING & WELD OVER LAY USED TO PROTECT:

In plant test of thermal sprayed coatings, diffusion coatings & weld overlays super critical boiler with uncoated T2 tubes. After 12683 hours, T2 water wall tubes were found to suffer wastage rate of 1.6mm/year at burner elevation [15]. Arc sprayed coating and oxyfuel coating suffered minus spallation while arc sprayed coating spelled off from tube. MAW process was developed used as pad Welds to apply a corrosion resistance overlay onto to a large area of water wall in a waste to energy boiler to large coal fired boiler [17]. The weld overlay was characterized with consistency in weld width sequences and overlay thickness of each weld bead. Root cause of circumferential grooving scanning electron microscopy with energy dispersive X-ray spectroscopy (EDX-SEM) used to know chemical composition [16].

Alloy 33(UNS R 2003:fe33 Cr-32Ni) showing no cracking after slightly less than 2 years of testing. Both boilers were tangentially firing with NOx and over fire air. Alloy 33 test panels were located in the over fire air region in boiler [15]. Alloy 52 in super critical boiler has 3 years service with no reported degradation problem. Alloy 53 & 622 has no evidence of circumferential cracking for both overlaying alloys [16].Use of 309 overlays for protection of tube, metal wastage due to erosion/corrosion was significantly reduced due to formation of thin protective chromium oxide scale. Nickel based alloy 622 overlay, that formed protective chromium oxide scale is resistant to soot blower erosion/corrosion [17].

GMAW, laser cladding, corrosion resistance cladding are also useful. Circumferential grooving and cracking has been encountered as overhead water wall tubes presumably due to overheating preferential sulfidification and penetration.

3. CONCLUSION

Fire side corrosion is a serious problem in Coal with Oil started boiler with low grade fuels. High quality coal recommended by the metallurgical department with proper chlorine, carbon, and sulphur content should be used. Proper flame impingement, draft and air ingression with soot blower will protect the protective outer anti corrosion and erosion layer. Low NO_x is corrosive but environmentally full proof used with furnace water wall tube of weld overlay. It is advisable to use low vanadium, sulphur and sodium oil. It is forming low melting point molten vanadium pentoxide and sodium sulphate eutectics, which flux the protective oxide scale from the metal surface.

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