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Corrosion and Erosion in Pulverized Coal based Fluidized Bed Combustion Boiler in Power Plants

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Abstract:- Coal is a complex fuel that contains fraction of non combustible minerals called ash and varying amount of sulfur. Since the very early days of using coal for combustion to produce steam for power generation or for processing industries, corrosion and/or erosion problems at high temperatures in pulverized coal/coal based plants have been matters of concern. Up to 450°C, the problem of corrosion can occur at water wall and in range of 500°C to 650°C, this can happen with re-heater and super-heater. The scenario of these issues have been changed in last few years for the reasons which includes use of low grade coal, methods adopted for low NOx emission and demand for higher efficiency.

With fluidized bed combustion (FBC), even with low grade coals, higher combustion efficiency could be achieved due to excellent gas/solid reactivity at comparatively low reaction temperature. However corrosion, erosion and combined corrosion/erosion are major causes of degradation of material associated with fluidized bed combustion boilers.

This paper describes the investigations carried out on wear due to corrosion and/or erosion occurred in captive thermal power plant using FBC boilers for their steam requirement.

Keywords:- *Fluidized Bed Boiler, Corrosion, Erosion, Pitting, Graphitization, Steam Erosion.*

I. INTRODUCTION

Boiler and its support system in a thermal power plant are subjected to a wide variety of failures involving one or more of several mechanisms.

Most prominent among these mechanisms are corrosion (pitting, erosion), mechanical environmental processes (stress corrosion cracking and hydrogen damage), fracture (fatigue fracture, thermal fatigue fracture and stress rupture) and distortion (especially distortion involving thermal expansion).

Corrosion in the boiler tube is mostly due to dissolved oxygen which results in uniform corrosion, pitting and inter-granular cracking. Water being the uniform solvent can dissolve all the minerals present in earth crest. The presence of CO2 increases the solubility of minerals in water. Cracking occurs because of overheating. Any low melting point constituents at segregated areas may melt at the temperature used to pre-heat the metal for working, causing a weakness known as hot shortness. This can happen in steel with high sulfur contents. Another potential for cracking exists in those metals where the working causes precipitation, which can result in increased yield strength and reduced ductility. High temperature also causes the growth of grains, which results in weakening of the metal.

The fireside corrosion is generally localized to regions on the walls near the furnace. In reducing atmosphere corrosion can result due to direct reaction of water wall tubes with gaseous environment containing sulfur or with partially combusted char.

The cause of failure generally classified as design defect, fabrication defect, improper operation, improper maintenance etc. Out of these improper operation which include incident of overheating, corrosion, fouling and fabrication defects which includes poor workmanship, improper and defective material together accounts for more than 75% of all these failures in a thermal power plant. Overheating and corrosion are the main cause of boiler tube failures.

High temperature erosive wear of heat transfer pipes and other structural materials in coal fired boilers is recognized as being the main cause of down time, accounting for 50-75% of total arrest time. Maintenance cost for replacing these broken pipes in same installations is also very high and to be estimated up to 54% of total production cost.

The main cause of corrosion in boiler tubes is due to dissolved oxygen, which may be carried in boiler system along water or due to some leakage. Apart from corrosion the other cause of failure is erosion, which may due to hard partially burnt coal particles or silica from bed that is carried by flue gases or by steam escaping from the leaked tube that strikes the hot outer surface of parallel tube and erosion by steam on the waterside which washes away protective oxide layer. Metal working techniques involves plastic deformation includes rolling, explosive forming, swaging etc. this involves residual stresses being built into part, altering microstructure and limit the plastic deformation tolerance. Gas holes and porosity formed during welding also propagates cracking.

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Failure of boiler components during operation may not only be costly from an operation and personal point of view, but legal costs may well outstrip the actual physical costs.

II. EXPERIMENTAL WORK

The failed samples boiler tubes are collected from various sections of unit 2 of Guru Nanak Dev Thermal Power Plant, Bathinda.

Sample 1 is collected from re-heater [Fig. 1]. A hole from fireside but no material loss is visible. After cutting tube along axis localized corrosion around the failure is visible that is due to oxygen pitting. In pitting corrosion small area is attacked because it becomes anodic to rest of surface or because of localized concentration of corrosion contamination in water. Pitting that occurs at relatively few and scattered sites can result in rapid perforation because of large ratio of cathode to anode area.

Fig 1: Macrograph of Sample 1

Micrograph and SEM are taken which also suggest presence of corrosion particles [Fig.2 &3].

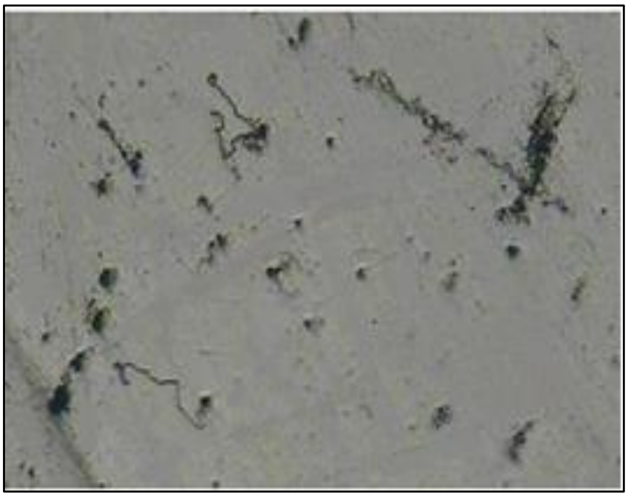

Fig 2: Micrograph of Sample 1

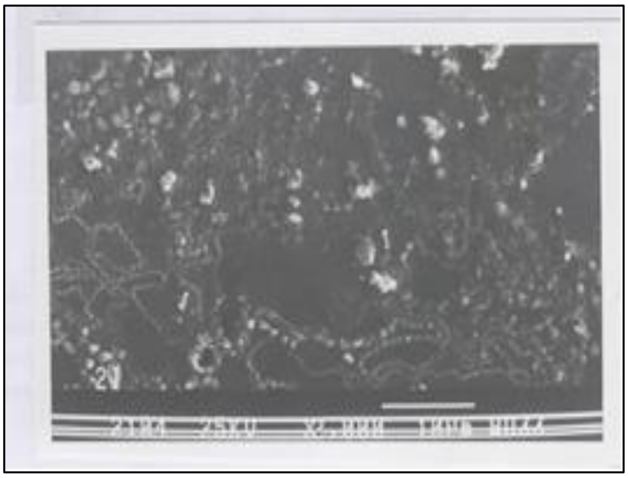

Fig 3: SEM of Sample 1

Sample 2 is collected from super-heater. No corrosion products are visible on fireside of the tube but the surface is highly eroded. A large welding patch and two holes are present. On cutting the tube along the axis two holes much bigger in size as compared to earlier ones beneath the weld patch are clearly visible. Around all these perforations protective oxide layer is washed away. The macrograph of tube is presented in Fig. 4 and cut section is shown in Fig 5.

Fig 4: Macrograph of Sample 2

Fig 5: Cut Section of Sample 2

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In the tube length of about 2.5 inches there are four points of failure which suggest that failure in the regions of super heater from where sample is collected usually occurs and steam leaked from these perforations strikes on the hot outer surface of other tubes and damage the same. This type of erosions is due to steam impingement. Erosion involves impact of large numbers of small solid or liquid particles against the surface or is caused by gas filled bubbles in a cavitating liquid. Liquid impingement erosion occurs chiefly in components that are subjected to high velocity flow of wet steam. Among the components most susceptible to liquid impingement erosion is steam piping condenser and heat exchanger tubes

Sample 3 is collected from platen super heater which makes the part of ceiling of the boiler. Very small erosion and welding patch are present on outer surface of tube. From this it can be inferred that the failure does not occurred from fireside of the tube. The cut section of the tube is presented in Fig 6.

An oval hole, which was earlier welded from outer side and narrow longitudinal splits can be seen. These longitudinal splits are scale of some oxide of iron. The failed tube has minimal swelling and longitudinal splits that are narrow. For this type of symptoms the cause of failure is long term overheating occurred for a period of months or years. To confirm the presence of oxide of iron in the scale present on the inner side of the tube, the X-Ray Diffraction Analysis is performed, which is presented in Fig. 7. The presence of Fe_2O_3 as revealed by XRD is further evidence of formation of corrosion products.

Fig 6: Cut Section of Tube 3

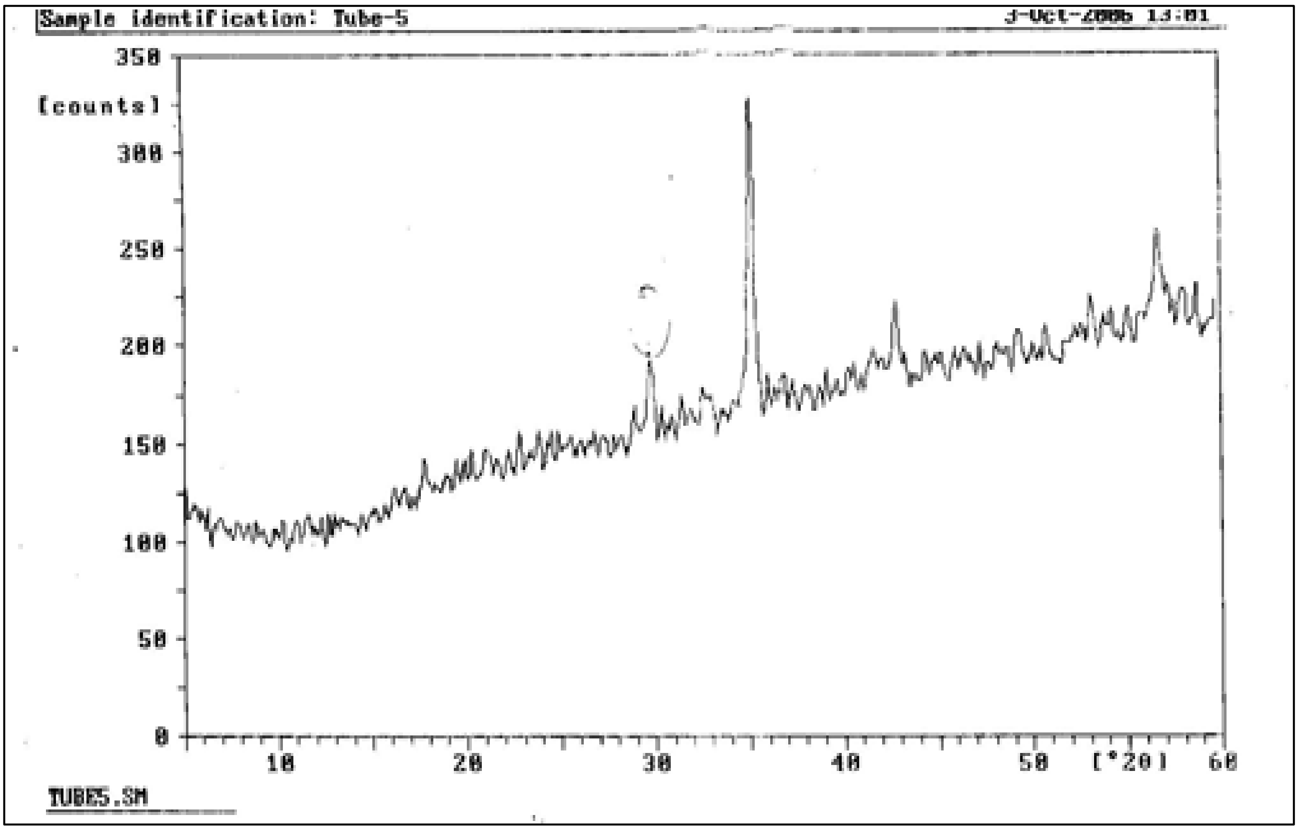

Fig 7: XRD Plot of Sample 3

Sample 4 is collected from water wall section of captive boiler. A small hole and a weld patch are clearly visible. The presence of weld patch means earlier failure of tube. Near the point of failure erosion of tube material is visible due to which thinning of wall took place but no thinning is present around the fracture surface. The material removal from fireside may be due to erosion by hard unburnt coal particles along with silica from furnace bed, which strikes the wall along with flue gases. The macrograph of tube 4 is presented in Fig. 8.

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Fig 8: Macrograph of Sample 4

The tube is now cut along the axis. After cutting the tube a fracture is visible on which steel plate was earlier welded from fireside of tube. The crack is about 30 mm along the axis of tube and is having maximum dimension of 7 mm along lateral axis of tube. The cut section of sample is presented in Fig. 9


Fig 9: Cut Section of Sample 4

The plot of wall thickness versus circumferential angle is presented in Fig. 10.

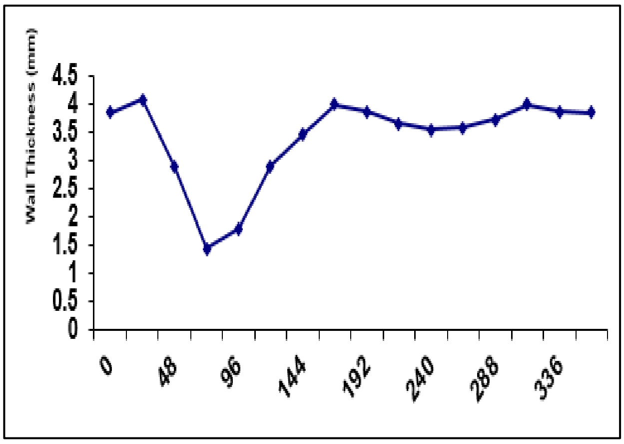

Fig 10: Plot of Wall Thickness versus Circumferential Angle

The dark brown coloured oxide is scratched from the inner side of the tube for X Ray Diffraction analysis.

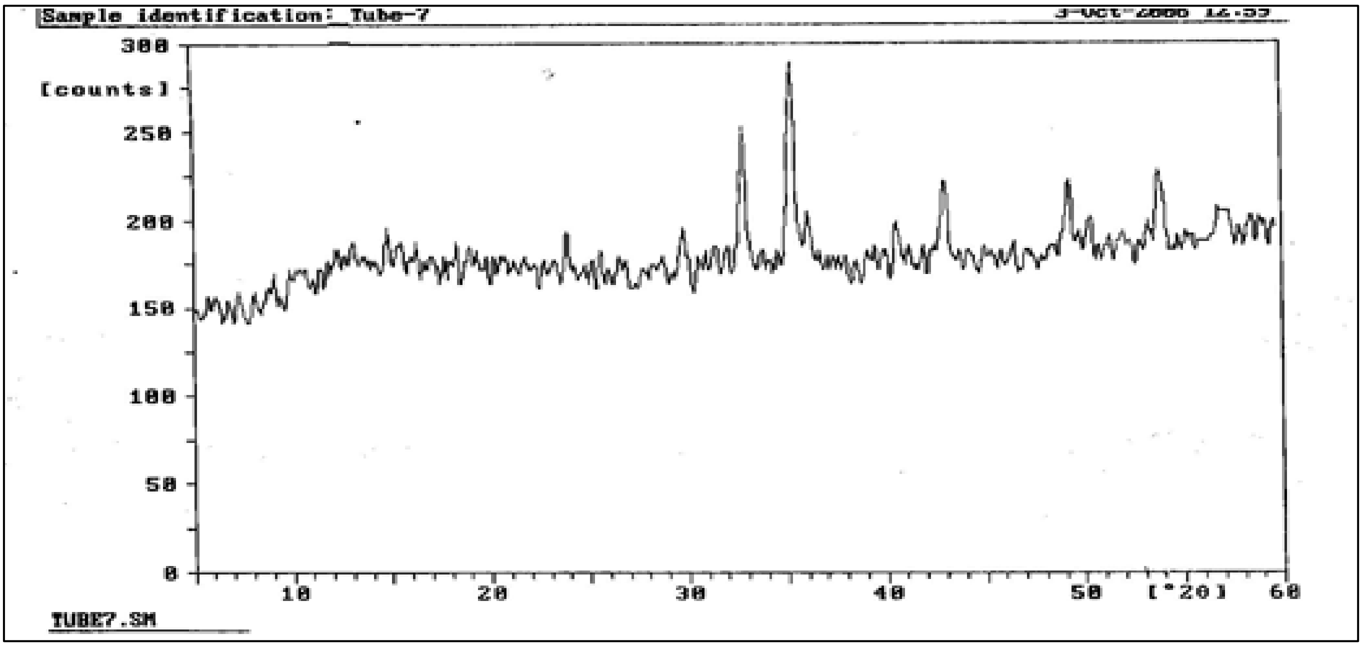

Fig 11: XRD Plot of sample 3

The presence of Fe2O3 as revealed by XRD is further evidence of formation of corrosion products.

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III. CONCLUSION

The causes of failure in the tubes under consideration are of various types as discussed here. The main cause of failure of the sample 1 is corrosion which is further due to oxygen pitting. Due to this localized corrosion the material of the tube is lost and resulted in a perforation.

Sample 2 is failed due to the impingement of steam on the hot outer surface of the tube. The steam had come from some parallel tube due to leakage. The four perforations i.e. point of failure in a short length of 2.5 inches suggests that usual failures are there in this region of Super-heater. The failure in this sample is due to steam erosion.

Sample 3 and 4 are failed due formation of compound of iron and oxygen i.e. Fe2O3¬. If it were reacted with any other compound to form Fe3¬O4, the protective oxide of iron then the life of the sample may have increased.

From above discussion it can be said that the failure in this unit of captive power plant are due to oxygen pitting, steam impingement and the formation of iron oxide. In three out of four samples collected the main cause of failure is corrosion. Improved material with higher chromium percentage is the replacement for above tubes as presence of more than 10 percent of chromium in steel alloy helps in preventing corrosion.

REFERENCES

[1]. Chattoraj, I., (1995), “Corrosion in Power Plants”, pp.3-5.
[2]. Dr. Sahid Tufail Sheikh Pso, Dr. Shahid Tufail Sheikh Pso, (2020), “Failure of super-heater of Boiler Tubes”, The Journal of Corrosion Science and Engineering, Vol-6, Paper-C 100.
[3]. Hidalgo, V.H., Varela, F.J.B. & Rico, E.F., (2017), “Erosion Wear and Mechanical Properties of Plasma Sprayed Nickel and Iron Based Coatings Subjected to Service Conditions In boilers”, Trib.Inp., Vol.30, No. 9, pp. 641-649
[4]. Hertfeid, W. H. (2022), “Corrosion as Affecting the Metal used in Mechanical arts Engineering”, Vol-134. pp 639-643.
[5]. Khanna. A.S.,(1995), “Fire Side Corrosion and Erosion Problems in Coal Based Power Plant”.
[6]. Krishnaswami, N. & Bhattacharya, P.S., (1995), “Water Side Corrosion in Boilers – Tata Steels Experience”, pp 3-5.
[7]. Natesan. K, 1997, “Corrosion Performance of Materials in Coal Fired Power Plants”.
[8]. Reid, W.T., (1978), “Exteranl Corrosion & Deposits: Boilers & Gas Turbines”, American Elseiver, New York, pp. 112-119.
[9]. Stringer John, 1997, “High Temperature Corrosion Problems in Coal Based Power Plants and Possible Solutions”.
[10]. Walker, W.H., Anna M. Lederholm and Bent, L. N., (1907) “The Corrosion of Iron and steel”, J.Am. Chem. SOC., Vol-28, PP. 1251-1254.