A Review Paper on Erosion and Corrosion Behavior of Coal Combustion Chamber

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Abstract

Erosion and corrosion of bed coil is a major problem faced by the power plant industry today. The damage caused to the exposed surface of the tubular, due to these phenomena can be enormous. The failure of equipment during treatment can be very expensive both from the point of view of economic losses as well as personnel safety. In order to increase the steam parameters in combustion units, several new approaches have been proposed. New materials have been tested, but they seldom have been a sufficient solution. Metallic coatings sprayed on super heater tubes have been noted to reduce erosion and corrosion in selected cases. New plant designs have been tested. Corrosion of materials may represent a heavy burden for industry in general, especially for the petroleum industry where the oil and gas compositions are responsible for reducing the service life of component materials of equipment due to severe corrosion attack and, consequently, to considerable expenses related to the maintenance and replacement of parts in a processing unit. Corrosion is one of the main causes of reduced reliability in steam generating systems. It is estimated that problems due to boiler system corrosion cost industry billions of dollars per year. Many corrosion problems occur in the hottest areas of the boiler-the water wall, screen, and super heater tubes. Other common problem areas include dearators, feed water heaters, and economizers. Methods of corrosion control vary depending upon the type of corrosion encountered. The most common causes of corrosion are dissolved gases (primarily oxygen and carbon dioxide), under-deposit attack, low pH, and attack of areas weakened by mechanical stress, leading to stress and fatigue cracking.

Keywords: Erosion, Corrosion, Atmospheric Fluidised Bed Combustion (AFBC) Boiler.

I. INTRODUCTION

Atmospheric fluidized bed combustor (AFBC) boilers for steam or electricity generation is gaining popularity because of its ability to burn wide variety of fuels with low atmospheric emissions. Compared to pulverized coal fired boilers, the AFBC boilers are more susceptible to erosion along the fireside path. The erosion is caused by the direct impingement of in-bed particles on the tube surfaces. Super heater coils of an AFBC boiler are found to be affected extensively by solid particle erosion. Erosion and corrosion of bed coil is a major problem faced by the power plant industry today. The damage caused to the exposed surface of the tubular, due to these phenomena can be enormous. The failure of equipment during treatment can be very expensive both from the point of view of economic losses as well as personnel safety. Hence, the determination of material loss is very important to predict the life of these equipment under different operating conditions. A clear understanding of the effect of particle impact, while varying various parameters is needed to be able to quantify the erosion phenomenon.

Fig. 1: Corrosion of Bed Coil of Boiler

A. Introduction atmospheric fluidized bed combustion (afbc) boiler

Atmospheric fluidized-bed combustion (AFBC) boilers offer efficient, cost effective and reliable steam generation. AFBC technology promises to provide a viable alternative to conventional coal-fired and other solid fuel-fired boilers.

The traditional grate fuel firing systems have several limitations and hence are techno-economically unviable to meet the challenges of the future. FBC has emerged as a viable alternative as it has significant advantages over conventional firing system.

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FBC offers multiple benefits, such as: compact boiler design, flexibility with fuel used, higher combustion efficiency and reduced emissions of noxious pollutants such as SOx and NOx. The fuels burnt in these boilers include coal, washery rejects, rice husk, bagasse and other agricultural wastes. The fluidized bed boilers have a wide capacity range- 0.5 T/hr to over 100 T/hr.

B. Mechanism of Fluidized Bed Combustion

When an evenly distributed air or gas is passed upward through a finely divided bed of solid particles such as sand supported on a fine mesh, the particles remain undisturbed at low velocities. As the air velocity is gradually increased, a stage is reached when the individual particles are suspended in the air stream and the bed is called “fluidized”.With further increase in air velocity, there is bubble formation, vigorous turbulence, rapid mixing and formation of dense defined bed surface. The bed of solid particles exhibits the properties of a boiling liquid and assumes the appearance of a fluid – “bubbling fluidized bed”.

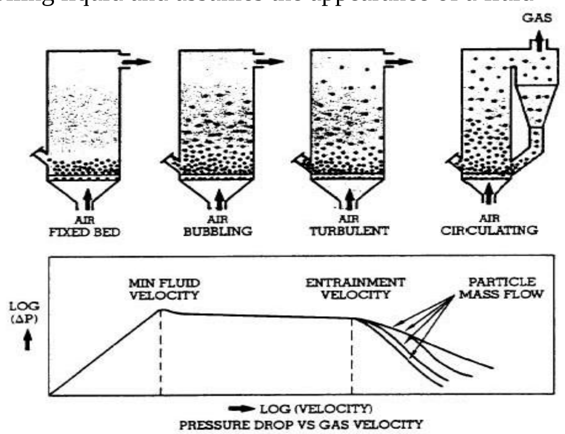

Fig. 2: Principle of Fluidization

At higher velocities, bubbles disappear, and particles are blown out of the bed. Therefore, some amounts of particles have to be re-circulated to maintain a stable system and is called as “circulating fluidized bed".

Fluidization depends largely on the particle size and the air velocity. The mean solids velocity increases at a slower rate than does the gas velocity. The difference between the mean solid velocity and mean gas velocity is called as slip velocity. Maximum slip velocity between the solids and the gas is desirable for good heat transfer and intimate contact. If sand particles in fluidized state are heated to the ignition temperatures of fuel (rice husk, coal or bagasse) and fuel is injected continuously into the bed, the fuel will burn rapidly and the bed attains a uniform temperature.

The fluidized bed combustion (FBC) takes place at about 840°C to 950°C. Since this temperature is much below the ash fusion temperature, melting of ash and associated problems are avoided. The lower combustion temperature is achieved because of high coefficient of heat transfer due to rapid mixing in the fluidized bed and effective extraction of heat from the bed through in-bed heat transfer tubes and walls of the bed. The gas velocity is maintained between minimum fluidization velocity and particle entrainment velocity. This ensures a stable operation of the bed and avoids particle entrainment in the gas stream.

Any combustion process requires three “T”s - that is Time, Temperature and Turbulence. In FBC, turbulence is promoted by fluidization. Improved mixing generates evenly distributed heat at lower temperature. Residence time is many times higher than conventional grate firing. Thus an FBC system releases heat more efficiently at lower temperatures. Since limestone can also be used as particle bed (in case the fuel with sulphur content is used) control of SOx and NOx emissions in the combustion chamber is achieved without any additional control equipment. This is one of the major advantages over conventional boilers.

C. Effect Of Corrosion And Erosion On Fbc

Heat-exchanger tubes in fluidized bed combustors (FBCs) often suffer material loss due to combined corrosion and erosion. Most severe damage is believed to be caused by the impact of dense packets of bed material on the lower parts of the tubes. High temperature erosion–corrosion of heat exchanger tubes and other structural materials in coal-fired boilers is recognised as the main cause of downtime at power-generating plants, which could account for 50–75% of their total arrest time. Maintenance costs for replacing broken tubes in the same installations are also very high, and can be estimated at up to 54% of the total production costs. Combustion of coal generates erosive–corrosive media particularly near the super heater tubes of the boilers.

Any tube leakage leads to costly shutdown of the power plant. Considering the revenue loss and practical difficulties in repairing/ replacing the tubes, the customers are demanding increased life of boiler tubes to prevent abnormal sudden failures. Further they would like repair work to be carried out quickly on site during the planned shutdown. Conventional techniques such as weld deposition and shielding are used to prevent tube failures but without success. Thermal spraying techniques have also been considered for erosion–corrosion protection because they are economical and suited for on-site job.

The occurrence of furnace wall and super heater corrosion in fluidized bed combustor systems has caused some operational and economic concerns.' It is generally accepted that chlorine and sulphur may play roles in this corrosion. In order to predict the performance of high chlorine or high sulphur coals in these combustion systems, it is necessary to have a better understanding of

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the different corrosion mechanisms in which chlorine and sulfur may be involved. It is also important to evaluate the critical point of coal chlorine content which may cause initial corrosion.

II. LITERATURE REVIEW ON EROSION AND CORROSION BEHAVIOR OF COAL COMBUSTION CHAMBER

A. Wei Xie, Shi Su, Brian Sisk, Jeremy Bowles, Wei-Ping Pan and John T. Riley "The effect of coal chlorine and sulfur contents on high temperature corrosion in an AFBC system." [1]

It was generally accepted that chlorine and sulphur may play roles in this corrosion. In order to predict the performance of high chlorine or high sulphur coals in these combustion systems, it was necessary to have a better understanding of the different corrosion mechanisms in which chlorine and sulphur may be involved. It was also important to evaluate the critical point of coal chlorine content which may cause initial corrosion.

Scale failure was observed in both 1000-hour test bums with low and high chlorine coals. The second test bum with the high chlorine coal showed more scale failure than that obtained with the first run with the low chlorine coal. Chlorine in the coal may enhance the scale failure but the evidence was not conclusive.

B. Krishnarao Venugopal, Manish Agrawal "Evaluation of arc sprayed coatings for erosion protection of tubes in atmospheric fluidised bed combustion (AFBC) boiler" [2]

In this work, different wear resistant coatings named Alpha 1800, Armacor M and Ducor were deposited using TAFA 9000 wire arc spray equipment for their application in atmospheric fluidized bed combustion boilers.

The erosion behaviour of these coatings was evaluated in a test rig and compared with that of carbon steel. Evaluation of coatings up to 600ºC indicated that the lowest erosion rates were observed for Alpha 1800 coating, the erosion rate of this coating being 5–10 times lesser than steel base depending upon the test temperature and erodent impact angle. Therefore, Alpha 1800 coating was sprayed on the super heater coils of an AFBC power plant.

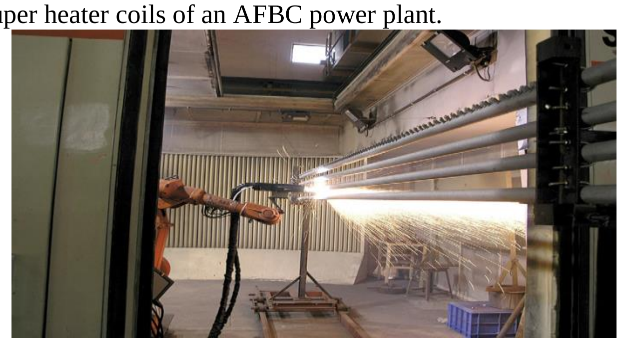

Fig. 3: Alpha 1800 Spraying of Superheater Coil For An AFBC Power Plant

Fig. 4: Failure of In-Bed Evaporator Tube

C. Vikas Chawlaa, Amita Chawlab, D. Puric, S. Prakashc, Prema G. Gurbuxanid and Buta Singh Sidhue "Hot Corrosion & Erosion Problems in Coal Based Power Plants in India and Possible Solutions-A Review". [3]

Hot corrosion and erosion are recognized as serious problems in coal based power generation plants in India. The coal used in Indian power stations had large amounts of ash (about 50%) which contain abrasive mineral species such as hard quartz (up to 15%) which increase the erosion propensity of coal. Hot corrosion and erosion in boilers and related components are responsible for huge losses both direct and indirect in power generation. An understanding of these problems and thus to develop suitable protective system was essential for maximizing the utilization of such components. These problems could be prevented by either changing the material or altering the environment or by separating the component surface from the environment. Corrosion prevention by the use of coatings for separating material from the environment was gaining importance in surface engineering.

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D. T S Sidhu[1], S Prakash[2], R D Agrawal[2] and Ramesh Bhagat "Erosion-Corrosion behavior of Ni-based super alloy Superni-75 in the real service environment of the boiler" [4]

The super-heater and re-heater tubes of the boilers used in thermal power plants were subjected to unacceptable levels of surface degradation by the combined effect of erosion–corrosion mechanism, resulting in the tube wall thinning and premature failure. The nickel-based super alloys could be used as boiler tube materials to increase the service life of the boilers, especially for the new generation ultra-supercritical boilers. The aim of this investigation was to evaluate the erosion-corrosion behaviour of Ni-based super alloy Superni-75 in the real service environment of the coal-fired boiler of a thermal power plant. The cyclic experimental study was performed for 1000 h in the platen super heater zone of the coal-fired boiler where the temperature was around 900◦C. The corrosion products had been characterized with respect to surface morphology, phase composition and element concentration using the combined techniques of X-ray diffractometry (XRD), scanning electron microscopy/energy-dispersive analysis (SEM/EDAX) and electron probe micro analyser (EPMA). The Superni-75 performed well in the coal-fired boiler environment, which had been attributed mainly to the formation of a thick band of chromium in scale due to selective oxidation of the chromium. Figure 5 shows the micrograph of suprni-75 after 1000 h exposure to platen superheater zone of the coal-fired boiler at 900◦C.

Fig. 5: Macrographs Of The Superni-75

E. B.Q. Wang, M.W. Seitz "Comparison in erosion behavior of iron-base coatings sprayed by three different arc-spray processes." [5]

In this investigation the elevated temperature erosion behaviour of three iron-base coatings sprayed by high velocity continuous combustion (HVCC) process was determined in a laboratory elevated temperature erosion tester and compared with the behaviour of coatings sprayed using combustion arc-spray and standard arc-spray processes. Test conditions attempted to simulate erosion conditions found at the heat exchanger tubes in the coal-fired boilers. Two bed ashes A (highly erosive) and B (medium erosive bed ash) retrieved from two operating boilers were used as erodent materials. In addition, some other properties, such as micro hardness, porosity, and oxidation rate, of coatings were also measured and compared.

Erosion test results indicated that the three iron-base coatings sprayed with HVCC process demonstrated higher erosion resistance than the ones sprayed with the other two arc-spray processes, when eroded by bed ash B. When eroded by high erosive ash (bed ash A), the three arc-sprayed iron-base coatings exhibited similar levels of erosion resistance, the ones sprayed with HVCC process being slightly better than those sprayed with the other two processes. The difference of erosion behaviour between sprayed coatings produced by different processes closely correlated with their microstructure and the characteristics of ash materials rather than the micro hardness of coatings. The erosion mechanism of coatings was also discussed and compared.

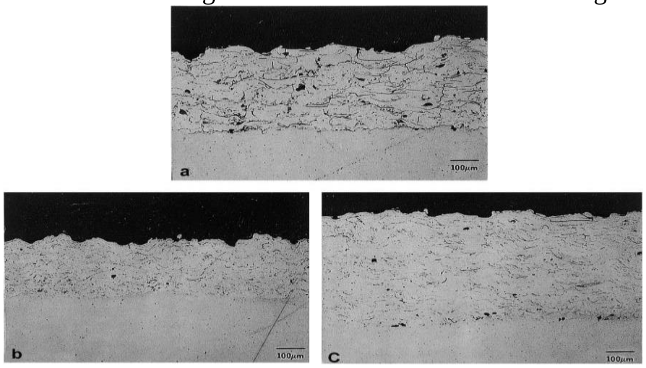

Fig. 6: The Cross-Sections of Three Armacor M Coating Specimens

In figure 6 a, b, c indicate cross-sections of Armacor M coating specimens with standard arc-sprayed, CA sprayed, HVCC sprayed respectively.

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F. ANKUR B VAIDHYA, ASHWIN BHABHOR"CFD Analysis Of Bed Coil Tube Using Advance CAE Tools & it's Optimization Of Erosion And Corrosion" .[6]

The boiler tubes are located in the bed area and the wastage is caused by both corrosion and erosion. Erosion rate increases with increases in both particle angularity and size. If the studded tube is used in place of plain plane, erosion-corrosion rate will be reduce and if the coating cover is placed on tube or bed coil, sulphur, chlorine alloy do not affect on the tube so life of the bed coil will be increased and over all plant efficiency increased.

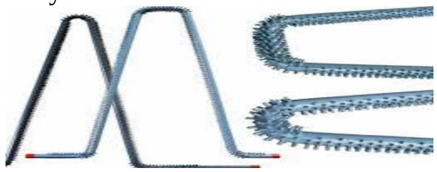

Fig. 7: Studded Bed Coil Tube

III. CONCLUSION

After analysing and understanding all the above literatures, we can conclude that it is generally accepted that chlorine and sulphur may play roles in this corrosion. The boiler tubes are located in the bed area and the wastage is caused by both corrosion and erosion. It is concluded that low sulphur or low chlorine content coal has low corrosion and erosion. So we should use the type of coal to a low chlorine or sulphur and also set the elevation of the boiler tubes to a higher position in the unit. Hot corrosion and erosion in boilers and related components are responsible for huge losses both direct and indirect in power generation. It can be prevented by either changing the material or altering the environment or by separating the component surface from the environment. Erosion rate increases with increases in both particle angularity and size. If the studded tube is used in place of plain plane, erosion-corrosion rate will be reduce and if the coating cover is placed on tube or bed coil, sulphur, chlorine alloy do not affect on the tube so life of the bed coil will be increased and over all plant efficiency increased.

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