Research Paper
Volume : 4 | Issue : 5 | May 2015 • ISSN No 2277 - 8179

Hot Corrosion Phenomenon In Super Heater Tubes & Its Impact on Life of Super Heater in Thermal Power Plants

Engineering

KEYWORDS : Coal-fired systems, combustion, gasification, corrosion, materials, High temperature hot corrosion (HTHC), Low temperature hot corrosion (LTHC),

Ashok Kumar Goyal	Department of Mechanical Engg., Mewar University, Chittorgarh, Rajasthan Scholar
Dr. Sanjeev Mishra	Professor, Department of Mechanical Engineering, Rajasthan Technical University University College of Engineering, Kota Guide

ABSTRACT

Power is the basic need of every country in development is based on the power production capacity; un-interrupted power supply is needed for various industrial processes in order to maintain the production up to optimum level. Shut down of a power plant due to failure of any component may cause a great loss of power as well as revenue; Corrosion is an unavoidable and major constraint in the effective operation of boiler of a thermal power plant. Corrosion phenomenon is a most negative parameter and by having an effective control on the formation of rust, the effectiveness of power plant can be improved significantly.

Corrosion generally is defined as the process by which metals return to the form in which they occur in nature. It is due to chemicals reaction between the metal of tube & water impurities or fuel gas product at low temp, (ambient temp.) or high temperature. Here Indian coal is a complex and relatively dirty fuel that contains varying amount of sulfur commonly called ash. The coal used in indian *power stations has large amount of ash (about 50%), due to presence of some corrosive element like sulfur in the flue gases at high temperature present in the tube material undergo sulfidation which results in the formation of sulfide/sulfate. Vanadium compounds also in the flue gases undergo fluxing reaction with oxide and/or sulfate scales on metal causing hot corrosion, and the hot corrosion can cause the rupture of the tubes. This phenomenon is usually noted on fire side of boiler tubes particularly in high temperature areas like super heater tubes, re heater tubes etc., this paper includes the case study of failure of super heater boiler tubes and study conducted, relevant data, observations, analysis, and recommendations pertaining to the tube failure, It is well established that an innovative approach to life extension through conduct various tests during the plant shut down is potential alternative to improve the overall productivity of any thermal power plant at a negligible investment. These alternatives are increasingly getting importance in developed as well as developing countries, not only because of their inherent advantages for taking steps for extending life, replacement and preventing premature failure of aged components due to corrosion, but also for optimizing the maintenance schedule. Objective of this paper is to assess the hot corrosion in super heater tubes of boiler and to locate the failure point due to hot corrosion so that action plans for next five years may be proposed. Based on the visual observations, non-destructive test results, destructive test results and their analysis, recommendations are made to run the plant at rated capacity provided these are implemented and plant is operated as per design operating regime. This study is based on the observation taken at the site during, shut down and inspection and identify the problems associated with hot corrosion in super heater tubes of boiler of unit # 4 of kota super thermal power station.*

INTRODUCTION

Hot corrosion is identified a serious failure in coal based power plants in India. Hot corrosion in boilers mainly in super heater and re heater tubes are responsible for huge failure, for uninterrupted power it is essential to reduce or try to eliminate this type of failure by developing suitable protective system is essential for maximizing the utilization of such components. These failures can be prevented

- changing the material
- altering the environment
- Separating the component surface from the environment.

Super heater tubes of a boiler in power plant have finite life because of prolonged exposure to high temperature, stress and aggressive environment. These are usually designed to last for a period of 20/25 years. However past experience has showed that for a variety of reasons these may have significant remaining life beyond the design specification and in addition, one must realize that every design has a probability of failure. Old components are likely to be more prone to failure primarily due to the natural process of ageing and also due to the fact that so far no failure has taken place, a characteristic of any stochastic processes. This is best estimated by conducting the various tests during a planned shutdown. Modern high pressure coal firing boilers are designed to fire pulverized fuel. Coal is delivered to the power stations where it is crushed to a fine powder by passing it through crushing (milling) plants. The powdered coal from the mills is transported into the boiler by air where it is combusted in the furnace. Using the coal as a powder leads to higher efficiency because of the more intimate mixing of the fuel and air. A high percentage of the resulting ash passes over into the gas stream, through the super-heater and re-heater sections into the economizer, air heater and precipitators and can cause fouling in these sections. The main coal impurities that take part in the corrosion process are sulfur, sodium, potassium and chlorine whilst sodium and vanadium together with sulfur are the major corrosive elements. Generally, boiler corrosion problems can be classified into two groups:

(a) Hot corrosion, which occurs in the high heat transfer areas such as the platen super heater, re heater and super heater tubes.
(b) Low temperature corrosion, which is usually found in water wall tubes.

HOT CORROSION

Hot corrosion is an unavoidable and major constraint in the effective operation of boiler of a thermal power plant. Corrosion phenomenon is a most negative parameter and by having an effective control on the formation of rust, the effectiveness of power plant can be improved significantly. Hot corrosion is generally initiated by sulfur. In combustion products of fuel oil, sulfur is typically present as Na_2SO_4. At high temperature it dissociates according to the following reaction:

$$Na_2SO_4 = Na_2\,O + SO_3$$

In a typical hot corrosion reaction, molten Na2SO4 attacks protective layer on metal and undergoes fluxing reaction causing rapid metal consumption. In boilers, high temperature attack could be due to fire side corrosion, sulfidation or hot corrosion. Fire side corrosion is observed at about 550Oc. Deposition of molten or partially fused particles (non-combustible) of fuel constituents on furnace tube surfaces. It may occur in super heater tubes when temperature is very high. It generally found in radiant zone of heat transfer. It is the condensation of combustible constituent such as sodium sulphate on fly ash particles and on boiler tubes in areas of the unit where the temperatures are such that the constituents remain in liquid state. This phenomenon usually found in convectional surface. The combustibles fly ash and flue gas react chemically to form the deposits as follows:

Sodium chloride (vaporized at flame temp.) + SO_3 + Water Vapour

$=Na_2SO_4$ (Deposited on tubes in the form of corrosion)

action of this effect causes localized disruption of the surface oxide film so that corrosion pit can be produced which propagate rapidly with such type of failure. Stress corrosion cracking begins with the rubburing of the protective oxide film on the metal surface by either mechanical means or by the action of chemical species, such as a chloride ion, localized rupture of the surface film leads in time to the formation of corrosion pits. Cracking initiate at the root of the pit, the porous corrosion product cap, which forms over the pit, restricts the interchange between the local environment within the pit and the bulk embankment outside it. Thus the pH within the pit is quite different from the bulk environment and is more conductive to the initiation of cracking. The crack grows & slowly under the SCC conditions until it reaches a critical size and brittle fracture occurs cracking may be intergranular, transgranular or mixed mode upending on the combination.

General Classification of Hot Corrosion

Hot corrosion is present into two forms of attack: Type I- or High temperature hot corrosion (HTHC) above about 900°C,it is mainly by pure sodium sulfate is above its melting temperature. And Type II- or Low temperature hot corrosion (LTHC), between about 700°C-750°C it is because of liquid salt formed because of significant dissolution of some corrosion elements.

Hot corrosion in super hater tubes of a boiler is associated with the deposition of alkali sulfates onto the metal surface, their concentration being increased at the metal surface by absorption onto the porous fly ash. The salts formed are usually molten and contain free sulfur trioxide which dissolves the protective oxide film to form iron and chromium based sulfates. This hot corrosion rates increase rapidly in the temperature range of 600-650°C.Intermediate–chrome alloys are used as super heater tubing The low-carbon, intermediate–chrome steel exhibited acceptable corrosion resistance at metal temperatures up to 540°C. The low carbon steel is the worst corrosion resistance among all alloys tested.

The super heater corrosion behavior depends on three factors

- the tube surface temperature,
- the deposit chemistry and
- the local atmosphere at the vicinity of tubes.

The main steam temperature is the main parameter that affects the choice of super heater materials, this because the corrosion rate increases as the super heater steam temperature increases, it should be noted that the super heater corrosion rates are not uniform, but depend strongly on the local conditions.

SOME CASE STUDIES

Case-I: Failure of high temperature Super heater tube no.7 of assy no 3 of unit #4 (Boiler KSTPS Plant)

The boiler had been in operation for more than 20 years. The boiler has already clocked 1,30,000 working hrs, it was found that super heater tube no.7 & 3 in pent house area had failed.

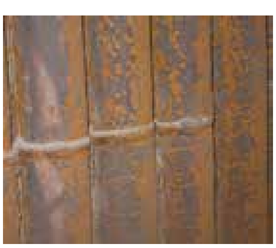

Figure1-Hot corrosion in platen super heater

Figure2-Failure in super heater Tube No.7 & 3

During service, the material or tube is subjected to higher temperature than the oxidation limit of material, bulging burst opening with thick lips, flown off the fractured portion, oxide scale on ID and OD surface of the tube are observed in the failed end of the tube

Figure3 Detailed view of failure in super heater Tube N0.7

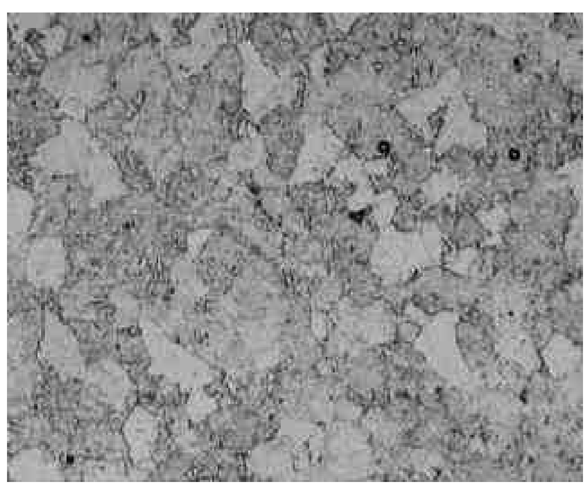

Figure4 Micrograph shows microstructure of parent metal. Location tube no.7 of SH(X200)

Volume : 4 | Issue : 5 | May 2015 • ISSN No 2277 - 8179

Microstructure shows ferrite grains along with bainite/pearlite. Micro/macro cracks are observed in parent metal; cracks appear to have formed in oxide/slag inclusions. Fine bainitic structure is observed in cracks region. Spheriodization of pearlite is observed. Cracks are parallel to circumferential weld.

Discussion

The presence of sulpher, nickel, chromium and vanadium in coal forms SO_2 and SO_3 and react with alkalis forms Na_2So_4, NaCl and V_2O_5 which then condense with fly ash on the super heater tubes as a molten deposits and this deposition in the fractured super heater tubes would result in depletion of protective oxide layer on the tubes leading to fracture under operating pressure-temperature conditions. The presence of trans and intergranular fracture further proves the consequences of this failure.

IN-SITU Metallographic indicate the cause of failure of super heater tube is degradation in microstructure level

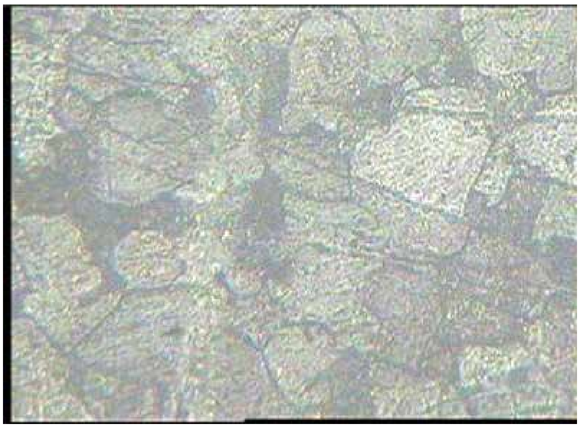

Figure5- Degradation in microstructure

Microstructure analysis

Micro-examination shows structure of ferrite & bainite whereas at parent metal shows ferrite & bainite structure. Significant decomposition of the bainite phases is observed, Corrosion is intergranular, and degradation is observed, many grooves starting from the surface going deep into the matrix from fire side, grooves showing corrosion products within the canals. Scales very fragile. The molten deposits dissolve protective oxide scales causing accelerated corrosion of the tube. Corroded areas of the boiler tubes have revealed selective corrosion at the grain boundaries. Sulfur is one of the major causes of failure of fire side surfaces.

Presence of intergranular and transgranular multi-branch cracks and occurrence of thick walled fracture indicates failure caused by stress corrosion cracking (SCC). It is suspected that earlier during replacement this particular portion of the super heater tube could have been used without identifying the material because failure is due to use of incorrect material.

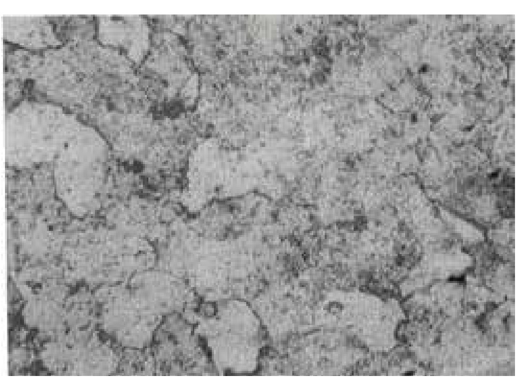

Figure6 Microstructure of SH Tube No:7

Microstructure reveals uniformly distributed pearlite & ferrite. Pearlite completely spherodised but carbide still included in primary pearlite grains.

Conclusions

Hot Corrosion is pervasive in the power plants because of the high operational temperatures. Corrosion processes like other chemical or electrochemical processes generally occur faster at high temperatures but high temperatures are required to improve the thermodynamic efficiency of the steam cycle and therefore, limiting the temperature is not the preferred mitigation strategy. The failure of tube is attributed to external metal wastage and subsequent wall thinning. Chemical composition of material is also not confirming to the specification. The significant microstructure degradation is observed, the failure of the tube is attributed to use of incorrect material & degradation of tube metal structure, which is subjected to high temperature in service.

The chemical composition of the tube no. 7 does not meet the requirement of standards but corresponds to typical carbon steel. In failed side of the tube graphitisation is very much found, presence of S in the fuel oil ash deposits on the fire side surfaces of the tubes appears to be the main cause of failure because this molten deposition is damaged the protective surface oxide. Failure of the tubes is most likely due to hot corrosion. Presence of sulpher had accelerated the corrosion leading to perforation of the tubes.Use of Cr - containing steel SA 213-T22 will recommend minimizing corrosion.

A coal fired boiler of a power plant where out of 49 failures occurring in two year duration, 21 failures were found to be due to hot corrosion. These studies emphasize the need to develop more and more corrosion resistant materials for such applications.

Hot corrosion preventive methods to the existing environment are

(a) Change of metal i.e. use of super alloy
(b) Use of inhibitors and
(c) Use of coatings. Regarding change of metal or use of super alloy, alloying elements which can improve the hot corrosion resistance of materials such as Cr, Al, etc.

The use of alloys which are corrosive resistance for e.g. Carbon steels with low percentage of chromium or other additives are mentioned for hot corrosion issues such as flow-accelerated corrosion of super heater tubes and specialized heat treatments at grain boundaries,stainless steels and other alloys can be governed by specialized heat treatments, and this heat treatments must be designed to optimize the mechanical properties of the structural materials with its corrosion resistance.during manufacture and subsequent heat treatment as well as in-situ stress reduction techniques are important strategies for SCC,designers are careful to eliminate SCC in super heater tubes, where impurities can accumulate by local boiling and electrochemical mechanisms,concentrated impurities can lead to hot corrosion. Fire side corrosion on the other surface of super heater and reheater tubes can lead to rapid thinning and, hence, subsequent premature failure. For plant with final steam temperatures of 565°C and combustion of coal with chlorine around 0.15% showed that these low alloy steels did not possess sufficient fireside corrosion resistance. Consequently, the 1000 MW units required selective re-tubing with the austenitic steels.

If the steam temperatures are to be only moderately increased and the hot corrosion potential is low then the improved medium chromium ferrite/materials steels could be considered as possible alternatives.Austenitic stainless steels which possess adequate hot corrosion resistance are available for use in the final super heater tubes of advanced PF-fired plant operating with steam parameters up to 290bar/580ºC, provided the inherent flue gas corrosivity (Cl content) is low. Use of nano materials to improve corrosive strength of platen super heater tubes may play vital role in prevention of hot corrosion as nano materials provide excellent resistance to corrosion at high temperature. Nano materials may works as passive catalyst and reduce the probability of hot corrosion at higher temperatures the vision and mission of this paper is to improve hot corrosion strength of super heater tubes of boiler and to locate the failure point due to hot corrosion so that action plans for next five years may be proposed.

REFERENCE

• [1] Anees U. Malik, Ismail Andijani, Mohammad Mobin 2005-Published in the Proceeding of 4th SWCC Acquired Experience Symposium held at Jeddah in Corrosion of boiler tubes some case studies. pp. 739-763. | • [2] A.S. Khanna, "Introduction to high temperature oxidation and corrosion", ASM International, ISBN 0-87170-762-4, SAN: 204-7586, 2002, pp 1-322. | • [3] P.R. Gilli, Mitt. V.G.B. (1963) 86, 288 | • [4] M.H. Li, X.F.Sun, J.G.Li, Z.Y. Zhang, T. Jin, H.R. Guan, Z.Q. Hu, Oxid. Metals, Vol.59 (5/6) (2003). | • [5] Encyclopedia of Material Science | • [6] Thermal Non-destructive Charaterization of Corrosion in Boiler Tubes by Application of a Moving Line Heat Source" by K. Elliott Crammer and William P. Winfree | • [7] "MECHANICAL METALLURGY" by George E. Dieter University of Maryland | • [8] Power plant engineering by Domkundwar | • [9] RLA Analysis by energo Ltd. | • | • [10] Porta R. D. and H. M. Herro, 1991. "The Nalco Guide to Boiler Failure Analysis. New York : McGrawll Hill, | • [11] Calannino J., 1993 "Prevent Boiler Tube Failure Part I : Fire-side Mechanisms", Chemical Engg. Progress, p. 33 | • [12] Reid, W. T. 1971 External Corrosion and Deposits - Boilers and Gas Turbines. New York :Elsvier,. | • [13] P.V. Ananthapadmanabhan , K.P. Sreekumar, K.V. Muraleedharan, N. Venkatramani, " Plasma-sprayed composite coatings for high temperature applications", Surface & Coating Technology, Vol. 49, 1991, pp 62-66 | • [14] French, D. N. (1983), "Liquid Ash Corrosion Problems in Fossil Fuel Boilers", Porc, Electrochem Soc., 83-85, p. 68. | • [15] Kevin J. Stein, Brian S. Schorr, Arnold R. Marder, "Erosion of thermal spray MCr-Cr C cermet coatings", Wear, Vol. 224, 1999, pp 153-159. | • [16] V. Higuera Hidalgo, J. Belzunce Verela, A. Carriles Menendez, S. Poveda Martinez, "High temperature erosion wear of flame and plasma sprayed nickel-chromium coatings under similated coal-fired boiler atmospheres", Wear, VOl.247, 2001, pp 214-222 | • [17]S.B. Mishra, K. Chandra, S. Prakash, B. Venkataraman, "Characterization and erosion behaviour of a plasma sprayed Ni3Al coating on a Fe-based superalloy", Materials Letters, Vol.59, 2005, pp. 3694-3698. | • [18] H. Singh , S. Prakash , D. Puri, "Some observations on the high temperature oxidation behaviour of plasma sprayed Ni3Al coating",Materials Science & Engineering, Vol 2006, | • [19]Study material of Power Engineering Training Society, New Delhi | • [20] Power Engineering Journals | • [21] "Boiler Tube Failure Root Cause Analysis Advisory System" by Heriberto Gonzlez and Peter S. Chang of Tennesse Valley Authority | • [22] I... Klevtsov, H .Tallermo and R. A. Crane. In proceedings of International Conference on Plant Conditon & Life Measurement, Vol I, Helsinki, Finland (6-8 June 1995): Pub- Technical Research Centre of Finland.