IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X
PP 06-10
www.iosrjournals.org

Root Cause Analysis and Economic Implication of Boiler Tube Failures in 210 MW Thermal Power Plant

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***ABSTRACT*:** *Boiler tube failure is the prime reason of forced Outages at coal fired thermal power plants. With ever increasing demand for electricity, it is very necessary for the power plants to generate electricity without forced outages. This paper illustrates cause & effect analysis of boiler tube failures. The data pertaining to boiler tube failures for one of Thermal Power Plant in Maharashtra State of last ten years is referred. Out of total 144 failures, 43 failures are observed in Economiser zone. Economizer is the main part of the boiler in the furnace second pass. It is the medium for transportation of the feed water to boiler drum. It helps to increase the boiler efficiency. Economizer is placed in the flue gas path, to absorb the heat from the flue gas and increase the temperature of the feed water. Factors contributing for Economizer tube failure includes stress rupture, fatigue, erosion, water side corrosion, fire side corrosion and lack of material quality. Out of these factors Erosion is the prime factor contributing for tube failure as referred from literature review. Erosion is a process in which material is removed from the surface layers of an object impacted by a stream of abrasive particles. Factor influencing the Erosion is the velocity of flue gas, the temperature of flue gas, the mineral content in coal, the arrangement of pressure parts and deviation from design condition. Amongst these factors velocity of flue gas ash particle has the predominant effect on erosion of economizer tubes. Boiler tube failures results in loss of 465 Million Of Units (MU's) in power generation. Moreover the severe service condition in coal fired thermal power plants causes failures such as the effects of high temperature, erosion, stress, vibration and corrosion combined resulting in failure of the boiler tubes thus it is extremely important to determine and correct the root cause to get your boiler back on line and reduce or eliminate future forced outages.*

***Keywords**: Boiler tube failure, forced outage, flue gas ash erosion, root causes.*

INTRODUCTION

In the modern increasing competitive environment, an efficient operating criterion for pulverised coal fired furnace is vital for the future of thermal power station. Thermal power plants contribute about 75% to all India installed capacity of electric power generating stations. In worldwide energy sector, total 37% of electricity is produced by combusting coal. [1-2] In the thermal power station, the boiler performance is a backbone for power production. With ever increasing demand for electricity, it is very necessary for the power plants to generate electricity without forced outages. The power plants are facing the problem of boiler tube leakage and it is more critical when they are running on full load. It becomes one of the critical reasons among numerous reasons of the energy crisis. Utilities have been fighting boiler tube failure since long. The tube failure cost crores of rupees lost, as it causes loss in generation. Boiler tubes have limited life and can fail due to various failure mechanisms. Tube failures are classified as in-service failure in boilers. These failures can be grouped under six major causes. stress rupture, fatigue, corrosion, erosion, material failure and welding defects.[3]

II. BOILER TUBE FAILURE MECHANISM

2.1 Types of Failure

1) Stress Rupture	2) Water side corrosion	3) Fatigue
Short term overheating	Caustic corrosion	Vibration
High temperature creep	Hydrogen damage	Thermal
Dissimilar metal welds	Pitting	Corrosion
	Stress corrosion cracking	
4) Erosion	5) Fire side corrosion	6) Lack of Quality Control
Fly ash erosion	Low temperature corrosion	Maintenance cleaning damage
Falling slag erosion	Water wall corrosion	Chemical damage
Soot blower erosion	Coal ash corrosion	Material defects

Erosion due to coal particle Oil ash corrosion Welding defects

2.2 Details of Tube Failure With Their Root Causes.

1) Short Term Overheating

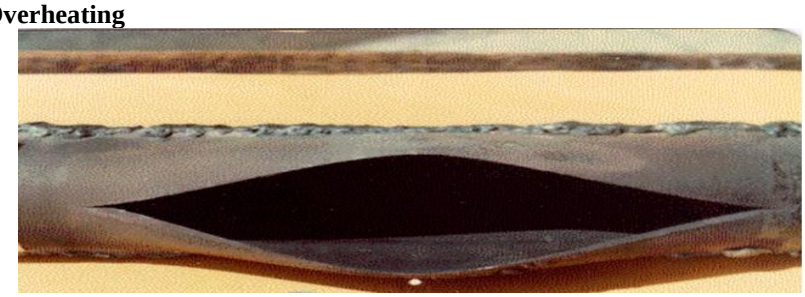

Fig: 1 Tube failed due to short term overheating

Causes: The short term overheating leads to stress rupture of the tube as shown in Fig: 1. Causes of short term overheating are Formation of debris and scale on the steam / water tube, high heat transfer rate or improper firing and Low water / steam level due to poor circulation.

2) High Temperature Creep

Fig: 2 Tube failed due to high temperature creep.

Causes: High temperature creep leads to stress rupture of boiler tubes as shown in Fig: 2. Causes for such failures are partial chocking of tube, general blockage, incorrect material, material transition, and higher stress due to weld attachment.

3) Dissimilar Metal Welds

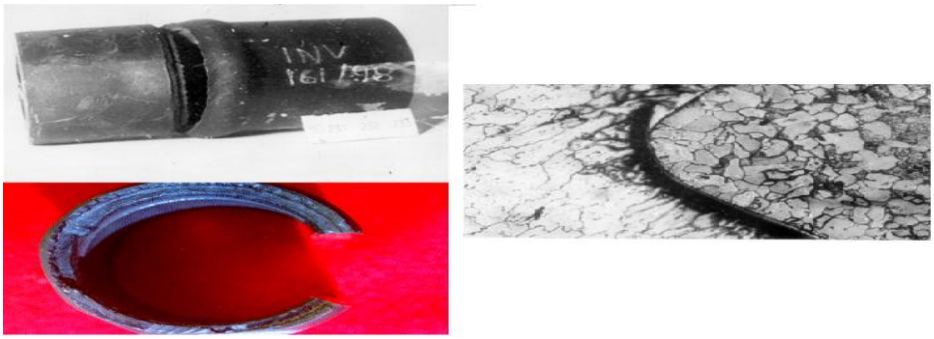

Fig: 3 Tube failures because of dissimilar welds.

Causes: Dissimilar metal welds causes rupture of Boiler tubes as shown in Fig: 3. This type of failure mainly occurs due to use of dissimilar metal rods for welding the tube. The prime location of dissimilar metal welds failures are super heater, Reheater dissimilar weld joints.

4) Long Term Overheating (LTOH)

Fig:4 Tube failures because of long term overheating.

Causes: Failed tube due to LTOH is as shown in Fig: 4. Long term overheating occurs due to Selection of incorrect material, Scale formation inside the tube, Water side deposits. [4-5]

5) Caustic Corrosion

Fig:5 Tube failures due to caustic corrosion.

Causes: As shown in Fig: 5, the boiler tube failed due to caustic corrosion, it arises due Feed water system corrosion deposits, condenser tube leakage, higher concentration of NaOH in Boiler water and temperature increase due to internal deposits.

6) Hydrogen Damage

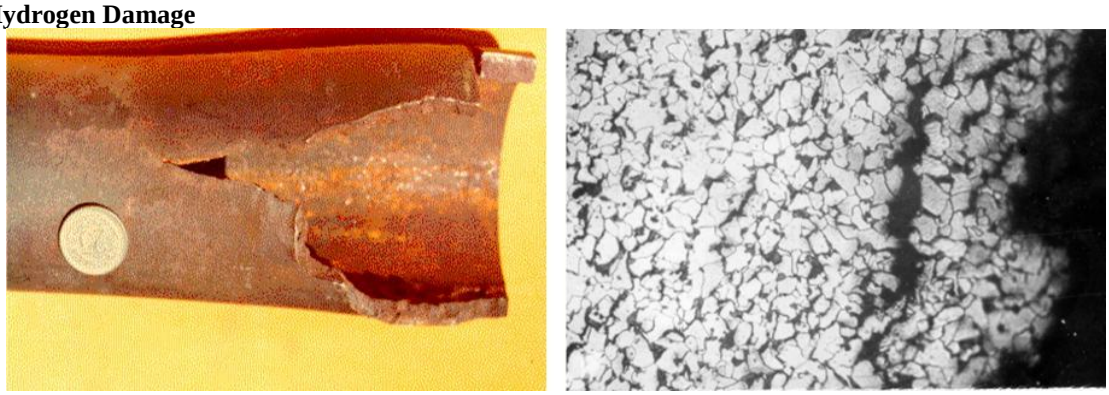

Fig: 6 Tube failures because of hydrogen damage.

Causes: This type of damage as shown in Fig: 6 may results from low PH corrosion reaction which results in the production of atomic hydrogen. NaOH removes protective magnetic iron oxide layer Fe_3O_4. Iron reacts with water or NaOH liberating atomic hydrogen. Atomic hydrogen differs into iron oxide producing methane. Methane or Atomic hydrogen cannot disposes it, resulting in cracks of grain boundaries longitudinal bars occurs with thick tip.

7) Fatigue Failure

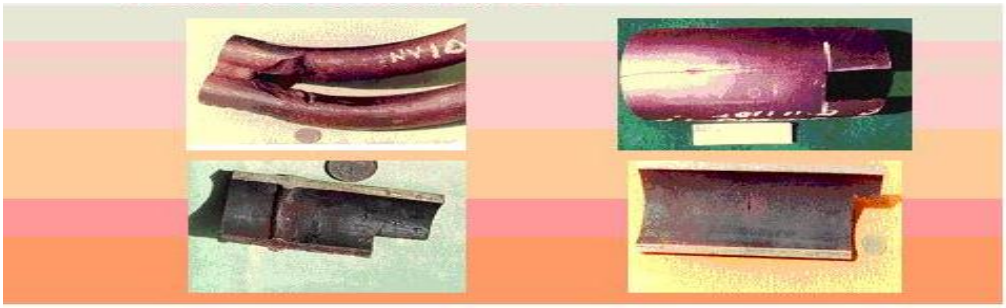

Fig: 7 Tube failures because of fatigue failure.

Causes: Tube failed due to fatigue is as shown in Fig: 7. Fatigue failure of tubes arises due to improper flexibility, attachment weld corrosion, cold bend restriction to the thermal expansion, improper heat treatment and contouring of welds.

8) Stress Corrosion Cracking

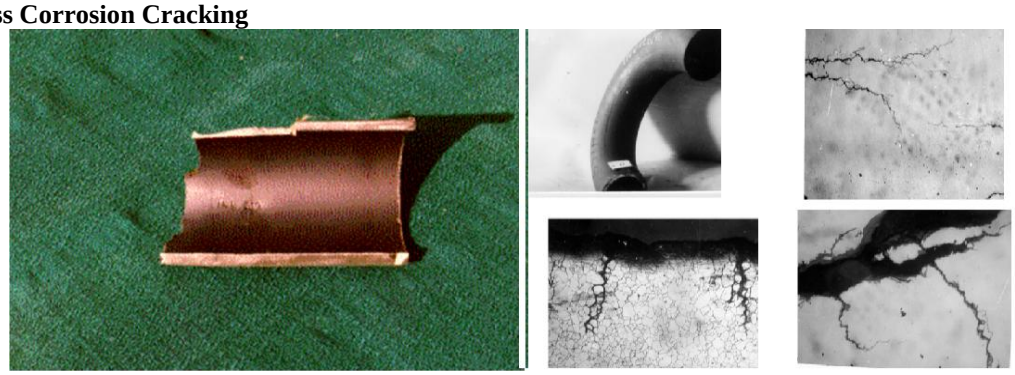

Fig: 8Tube failure due to stress corrosion cracking.

Causes: Above fig: 8 is of failed tube due stress corrosion, such cracks are generally observed in super-heater, Re-heater region having concentration of chlorides sulphates or hydroxide and stresses in fabrication service etc. like Bends, attachment weld.

9) Fly Ash Erosion

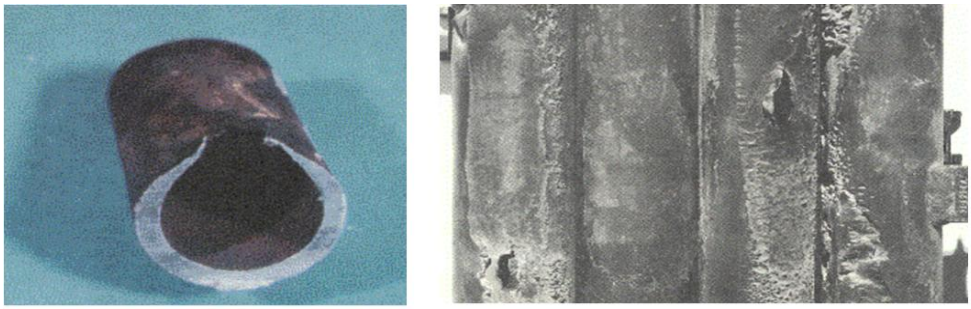

Fig: 9 Tube failures due to fly ash erosion

Causes: Failure of tube because of fly ash erosion is as shown in Fig: 9. As ash is having abrasive action it erodes the outer surface of tube in Economizer, LTSH, Reheater regions. Typical location of the fly ash erosions are, gaps between tubes, banks and duct walls, gas by pass channels production of ferrous area close to large ash accumulation the major causes of fly ash erosions are, Temperature of flue gas ,high ash content in coal high flue gas velocity and high impingement angle of ash particle.

III. CASE STUDY

The data shown in Table 1 pertaining to boiler tube failures for one of Thermal Power Plant in Maharashtra State of last ten years is referred. The plant is of 210 MW generation capacity with the prime fuel used as pulverised coal. Major four areas of boiler are identified i.e. Water wall, Economiser, Reheater, and Final superheater and the tube failure occurred in different zones with the loss in generation on account of tube failures were studied. Based on the data, it was found around 30% of failures occurred in Economiser zone. [6]

Table: 1 Failure history of Boiler tubes of past ten years.

Sr.No	Year	Total BTL	Zone					Loss of Gen. (MUS)
			Water wall	Economiser	Reheater	Final Superheater	Low Temp. Superheater	
1	2004-05	15	4	5	1	2	3	214.71
2	2005-06	12	8	2	0	1	1	191.98
3	2006-07	10	1	4	0	2	3	115.53
4	2007-08	7	3	2	0	1	1	61.63

5	2008-09	12	2	4	2	1	3	133.9
6	2009-10	28	7	13	5	2	1	279.94
7	2010-11	22	1	12	5	2	2	178.08
8	2011-12	13	3	0	9	1	0	147.78
9	2012-13	17	2	0	4	7	4	188.35
10	2013-14	8	0	1	0	5	2	67.088
Total No. of BTL		144	31	43	26	24	20	1578.988
Loss in Millions of Units			340.97	465.73	285.09	263.16	224.03	

IV. RESULTS AND DISCUSSIONS

Out of total 144 failures, 43 failures are observed in Economiser zone and accounts to about loss 465 MU's in past ten years. Economizer is the main part of the boiler in the furnace second pass. It is the medium for transportation of the feed water to boiler drum. It helps to increase the boiler efficiency. Economizer is placed in the flue gas path, to absorb the heat from the flue gas and increase the temperature of the feed water. Factors contributing for Economizer tube failure includes stress rupture, fatigue, erosion, water side corrosion, fire side corrosion and lack of material quality. Out of these factors Erosion is the prime factor contributing for tube failure as referred from literature review. Erosion is a process in which material is removed from the surface layers of an object impacted by a stream of abrasive particles. Factor influencing the Erosion is the velocity of flue gas, the temperature of flue gas, the mineral content in coal, the arrangement of pressure parts and deviation from design condition. Amongst these factors velocity of flue gas ash particle has the predominant effect on erosion of economizer tubes. [7-8]

V. CONCLUSION

Boiler tube failures might lead to more serious problem, if left uncorrected. Managing boiler tube failures can help reducing forced outages and thus improve plant availability and reliability. Plants which implement an effective tube failure prevention program can minimize the risk of failures. There are certainly many factors that need to be identified in order to implement a successful BTF prevention program. This paper provides a comprehensive review about the variours root causes of boiler tube failure therby generating the need for determining the requisite corrective action to miminimise such occurences in future. The case study presented identifies the zone where the failure are more and also emphasis on the factors which contribute for such type failure mechanism.

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