RESIDUAL LIFE ASSESSMENT IN HIGH TEMPERATURE ZONES OF POWER PLANT COMPONENTS

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Abstract: The present paper gives an overview of the high temperature assessment procedures with recent developments in procedures of residual life assessment. A failure in any power plant will ultimately affects the shutdown of the plant and affects the Power supply by the plant that leads to the heavy losses. The Failure of the power plant is mostly due to failure in the Boiler tubes of different zones. Failure of tubes in boiler of the power plants may occur due to various reasons. These include failures due to creep, corrosion, erosion, overheating, fatigue, welding defects etc. It needs to be addressed by a methodology that will be developed and incorporated into design codes such as ASME, as well as in Fitness-for-Service assessment procedures. This is due to the complex microstructures of weldments that include base metal, heat-affected zone and weld metal. The reliability of the structural assessments following the codes depends strongly on availability of reliable data required as input data. Micro cracks during production either at the parent metal or at the weld metal can affect the service condition of the component which affects the life of the component, so there is a need to qualitative and reliable check of the various components of the boiler and its pressure parts by various non-destructive testing methods for the successful and cost effective operation of the plant.

Keywords:- NDT, Life extension, Ultrasonic test, oxides scale, microstructure.

I. INTRODUCTION

Thermal power plant boiler is one of the critical equipment for the power generation industries. In the present situation of power generation, pulverized coal fired power stations are the backbones of industrial development in the country, thus necessitating their maximum availability in terms of plant load factor (PLF). At the same time reliability and safety aspect is also to be considered. The major percentage of the forced shutdown of the power stations is from boiler side. So it is necessary to predict the probable root cause/ causes of the forced outages and also the remedial action to prevent the recurrence of similar failure in future. A boiler for thermal power generation typically consists of different pressure parts tubes like Bed coils water wall, economizer, superheater and reheater [3]. Different damage mechanism like creep, fatigue, erosion and corrosion are responsible of the different pressure parts tube failure.

The average all India plant load factor of thermal power plants is around 65%. There is a wide gap between the supply and demand of electric power and it is increasing day by day.

To overcome, this, there are two possibilities; first one is to by setting up new projects and second one is to renovate & modernize the old plants which are operating at very low PLF and derated capacities. The former one is highly capital intensive and takes long gestation period. The later one is cost effective and most useful for improving plant load factor and availability factor [3].

This paper highlights the life extension in high temperature zones of power plant components.

Aim of Life Assessment or Extension of Old Power plants

The main objectives of this systematic approach of inspection on old power plants are to:

- Enhance the operating life.
- Increase safe operational reliability for extended life.
- Improved boiler availability.
- Quality assurance and improved life of boilers.
- Prevent the catastrophic failures of pressure components.
- Prevent forced outages & repairs. .
- Improved boiler efficiency.

The inspection involves a detailed qualitative and quantitative examination and tests and interpretation of test results for every critical component. Various latest technologies available in Non-destructive and destructive tests will be used to assess the present status of each component.

II. PROCEDURE OF INSPECTION

Procedure of inspection starts with maintenance, history and failure analysis data, reviewing relevant design, operating, outage, and as well as records available at the station for the boiler components.

Interaction with boiler maintenance division including information and about overall boiler performance, operational and maintenance history of the system and individual components modification/ deletion made if any, additional boiler operational data etc.

Quantitative condition assessment and identification of critical inspection zones are carried out on the history-base. The service information provided by the concerned authorities is assessed and scrutinised.

Inspection techniques are used in different stages like hot condition (Pre-shutdown), clod condition (Shutdown) and again hot condition (post-shutdown) to assess the present performance & life of the components.

Making a detailed inspection plan, including NDE procedure and necessary preparation of all components for which NDE testing is to be performed.

The pre-shutdown inspection covers hot walk down survey, flue gas leakage testing, boiler expansion checking, hanger checking etc. of the complete boiler.

The inspection in shutdown covers various Non- Destructive Techniques viz. Ultrasonic testing, Magnetic particle inspection, Dye penetrant inspection, In-situ metallography (Replication), Hardness measurement, Remote video imagescopy, Dimensional measurement and visual examination methods to assess the present health condition of every component. A typical test procedure for health assessment is given in Annexure – 1.

When several activities/ testing are to be carried out on the same component, which is usually the case, the logistics are followed for testing sequence so that minimum time and material is spent. Findings requiring immediate attention of plant authorities to facilitate taking action are given then and there to plant authorities for the needful.

Observations are further augmented with laboratory investigations and a logical analysis of the results. The creep test results will be studied along with the presence of oxide scale & metallurgical status of these high temperature tubes for calculation of remaining life. Additionally, assessment of creep damage will be done on post-service samples of super heater tubes by subjecting these to uniaxial Stress Rupture tests.

The samples from various sections are subjected to mechanical tests to calculate the safe working pressure limit and provide recommendations thereof.

The post- shutdown inspection covers in the similar lines of Pre-shutdown inspection to confirm the improvement in specific areas after implementing the suitable modifications as identified & recommended.

The results from the field tests and post service accelerated laboratory tests would be analysed along with laboratory investigation like deposit analysis, Optical Microscopy, etc. to estimate the remaining life of the components like headers, drum, steam pipelines etc.

This study helps in giving recommendatory decisions like run/ repair/ replace for further safe usage of boiler and also for continuous monitoring of critical parts in regular intervals as preventive maintenance procedures to prevent forced outages.

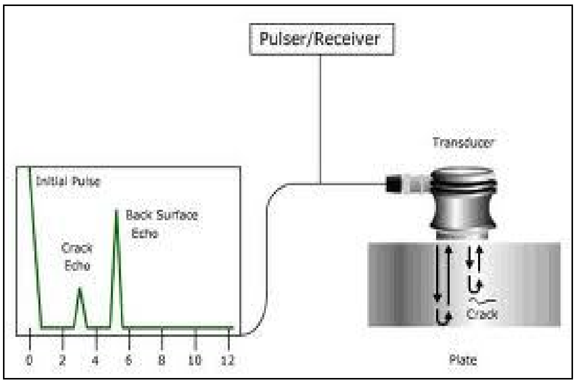
III. TESTING PROCESS

1) Visual Examination (VE)

During visual inspection the observations made with reference to discoloration of coils, misalignment is considered in deciding sample tubes removal for metallurgical examination. Prior evaluation of pressure part condition, based on experience and design knowledge from similar plants makes sample selection more rational. Visual examination is carried out to assess material wastage due to oxidation, erosion/corrosion problems, fouling conditions of heat transfer surfaces, integrity of attachments in coils. This includes inspection of drum internals to ensure proper steam/water separation.. Samples from the regions thus determined to be most susceptible to failures and samples depicting the general condition of each component are selected for an evaluation of the metallurgical condition.[3]

2) Ultrasonic Testing (UT)

By using high frequency sound waves, the surface and sub-surface flaws can be detected. Cracks, laminations, shrinkages, cavities, flakes, pores and binding faults that act as discontinuities in metal gas interfaces can also be easily detected. This technique also used for measuring oxide scale thickness of high temperature tubes[5].

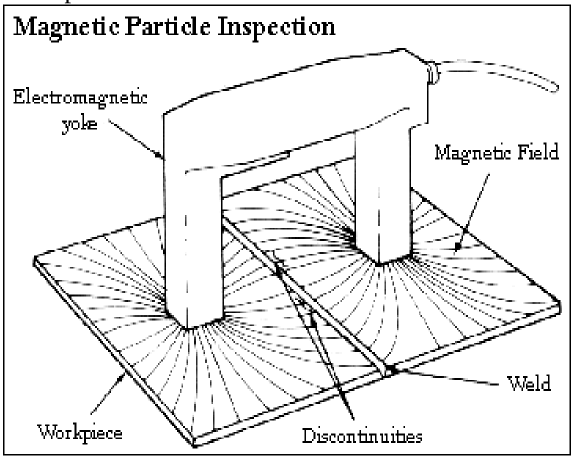


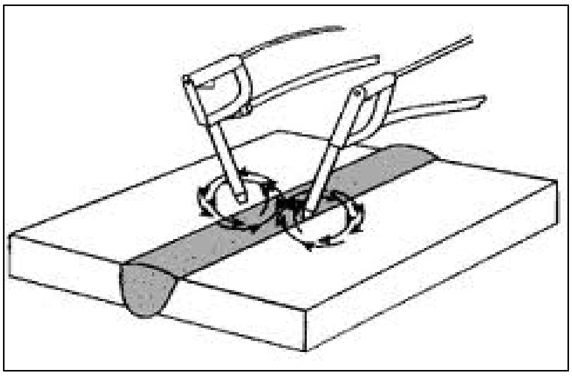
3)Magnetic Particle Inspection (MPI)

Magnetic particle inspection helps to detect cracks and discontinuities on or near the surface in ferromagnetic materials using dry magnetic particle testing equipment.

The technique is adopted for locating surface and sub-surface discontinuities like seams, laps, quenching and grinding cracks and surface rupture occurring on welds. This method is also used for detecting surface fatigue cracks developed during service [2].

Magnetizing at least two mutually perpendicular directions ensures detection of defects in all possible orientations.

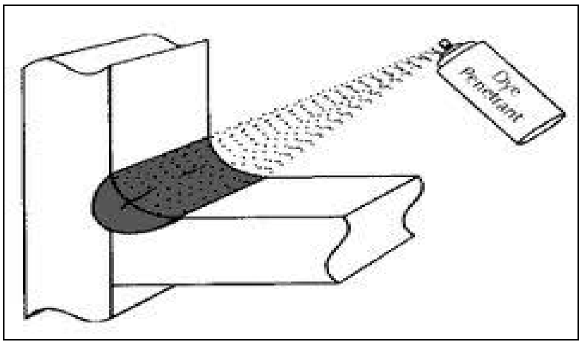


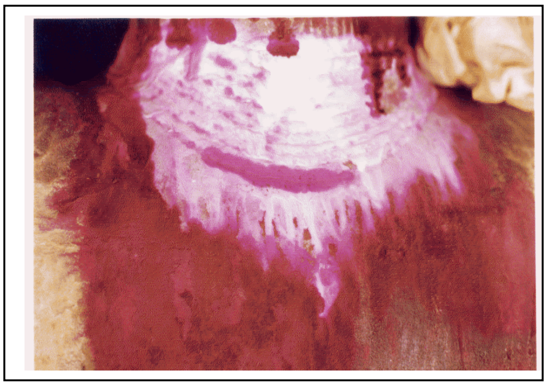


4)Dye Penetrant Inspection (DPI)

In principle the dye /liquid penetrant is applied to the surface to be examined and allowed to enter into the discontinuities. All excess penetrant is then removed, surface dried and the developer applied. The developer serves both as a blotter to absorb the penetrant coming out by capillary action and as contrasting background to enhance the visibility of the indication.

Method is adopted primarily for detection of cracks or crack like discontinuities that are open to the surface of a part, like surface porosity, pitting, pin holes and other weld defects.





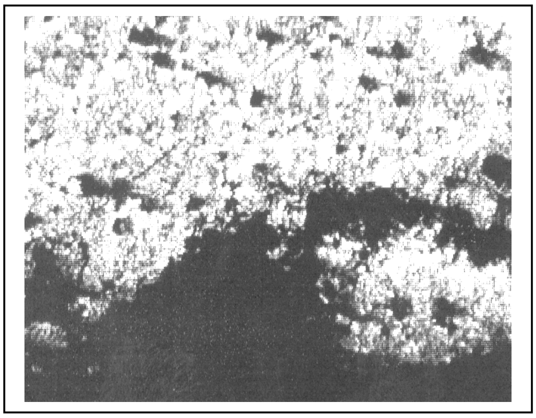
5)Replication (R) [In-situ Metallography]

The process involves preliminary preparation of the metal surface using polishing equipment. When the spot is ensured free from rust and polishing will be done using abrasive paper of varying grits from 120, 200, 400 and 600 in sequence. Subsequently diamond paste lapping is done followed by etching with 3% nital to reveal the structure.[3]

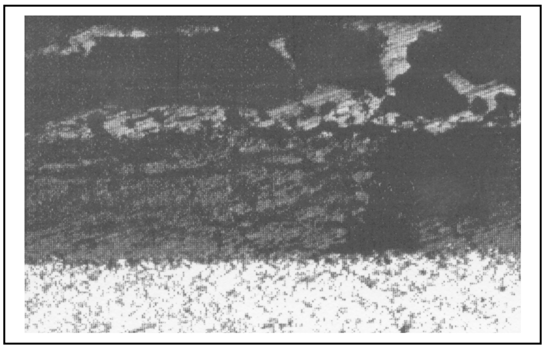
Adopting Electro-polishing can also do the surface preparation. After the preparation of the surface the microstructure of component is truly transferred to a film. Transparent film with green reflecting foil can be used which can be examined in laboratory with magnification up to 500X to assess the metallurgical damages like creep cavitation.

For examination at higher magnification, the microstructure of the component can be transferred to cellulose acetate replicating tape. A cellulose acetate film of 0.1 to 0.15mm thickness and 20 X 40 mm size is cut from roll or sheet. A few drops of acetone will be applied on one surface for about 5 seconds and this makes the acetate film soft on one side and retains hardness on the reverse side. The soft side is pressed uniformly over the etched surface using clean and plain rubber and exerting the force of the thumb for about 10 seconds. It will be protected against dust and left for some time for drying.

The dried film will be lifted up by using fine knife and will be kept between parallel glass slides. This helps in microstructural examination using light optical microscope. The following figures are the cross-sectional views of the boiler tubes at fire-side and steam side section of the tubes.



Microstructure at the fireside section - separation of metallic layer by oxidation and clear penetration of oxide through the grain boundaries



Microstructure at the steam side section - separation of metallic layer by oxidation and clear penetration of oxide through the grain boundaries

10) Hardness Measurement (HA)

A portable hardness tester is used for in-situ hardness measurement of various critical components like steam drum, high and low temperature headers, pipelines etc. Hardness measurement aids in assessment of metallurgical status/ condition of the component

6) Dimensional Measurement (DM)

Outside diameter measurements are generally employed to determine the swelling (bulging) due to creep. Diameter measurements are made using micrometers, digital vernier calipers and bow gauges.

7) Thickness Measurement (TM)

Thickness measurements at critical areas give a measure of thickness loss over the years due to erosion and corrosion. The thickness measurements are made using ultrasonic thickness gauge.

8)Fibroscopic Inspection(FI)

A flexible Fibroscope is used for internal inspection of components like headers, pipes, tubes etc. by illuminating and observing internal, otherwise inaccessible components. This inspection reveals the valuable information about the inside condition of the components.

9) Sampling (S)

Tube samples carefully selected after the visual inspection from super heaters/ re-heaters are analysed in laboratory for material degradation, extent of oxide scaling and corrosion/erosion and mechanical tests like flattening & tensile testing. Economiser tubes will be tested for weight loss calculation to assess the extent of material loss in addition to the above said tests.

Super heater tubes operating at higher temperatures (more than 450^{0}C) are subjected to a time dependent phenomenon known as creep. The sample tubes removed from boiler will be subjected to creep rupture tests at accelerated temperature and at service pressure. The data obtained through such accelerated stress rupture tests are used for assessing remaining life estimation.

11) Deposit Analysis (DA)

Deposit samples carefully selected after the visual inspection from critical components like drum internal, external deposits on high and low temperature tubes etc. are analysed in laboratory for elemental analysis by conventional chemical methods/atomic absorption spectrometer.

12) Flue Gas Leakage Test

Flue gas leakage spots in the first & second pass of the boiler can be checked with the Infra-red Thermo graphic Equipment

IV. HEALTH ASSESSMENT OF VARIOUS COMPONENTS

All the filed observations recorded from various tests like visual examination, dye penetrant inspection, magnetic particle inspection, ultrasonic testing, dimensional measurement, in-situ metallography, in-situ hardness measurement, fibroscopic inspection will be used for the assessment of each component.

The recordable indications/observations of various tests will also be considered in final recommendations for further usage of boiler[3].

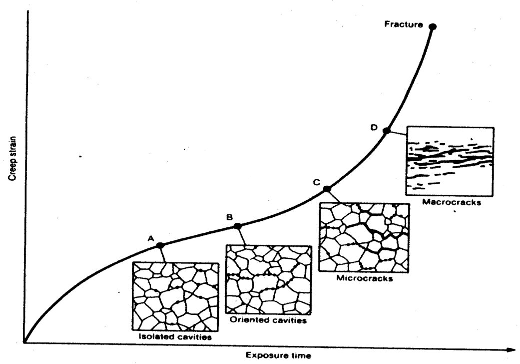
V. REMAINING LIFE CALCULATION

The remaining life assessment will be done based on various the following methods:

a) Metallographic analysis method

In high pressure and high temperature components, headers & steam pipes perse, the consequential damage mechanism is creep, which manifests itself in the form of cavities in the microstructure. The morphology (shape characteristics and orientation) of the cavities lends clue to the status of the component in terms of its remaining life. The conclusions drawn, however, are not deterministic. Nevertheless, the component susceptible to consequent failures could be identified and necessary action(s) could be initiated.

The phenomenon of creep is guided by the factors such as temperature, stress, time and material properties. Given a material that is subjected to constant temperature and stress (pressure), creep damage evident in the microstructure will be a function of time (expended life fraction). The Neubauer and Wedel was related the creep-life consumption of plant components to cavity



classification as given below:

Structural Classification	Microstructure features	Action needed	Expended life fraction
Undamaged	Ferrite & pearlite	None	0.12
A	Isolated cavities	None until next major scheduled maintenance outage.	0.46
B	Oriented cavities	Replica test at specified interval preferably within 1 ½ to 3 years	0.50
C	Linked cavities (micro-cracks)	Limited service until repair and better to inspect within 6 months	0.84
D	Macro-cracks	Immediate repair	1.00

b) Accelerated uniaxial creep test method

A very common way of estimating the remaining life under creep conditions the use of Uniaxial creep test on the service exposed material.

An approach commonly employed is to test a specimen from the service-exposed component to rupture under accelerated conditions in the laboratory. The iso-stress accelerated creep rupture test may be conducted at the chosen higher temperature for a duration of hours as per pre-calculation and if the test passes this duration without rupture the extension of life for the boiler can be recommended for calculated years (10 years).

c) Oxide scale thickness method

The Remaining Life is calculated based on the *oxide scale measured with the optical microscope and or* other non-destructive methods by using the following formulae:

$$\textbf{Log X = 0.00022 P – 7.25}$$

$$\textbf{P = T (20 + log t)}$$

X – Scale thickness in mils
P – T (20 + log t)
T – temperature in ^{0} R (^{0} F + 460)
t- time in hours

CONCULSION

Data collected from the site are compiled as per Indian Boiler Regulation Act-391,part A (I) & (II) and compare with the available plant history data. Based on the table below and the results available, it is compiled and compared with the above Neubauer and Wedel classification, metallurgical analysis and oxide scale measurement, the expected life of the plant component is thereby predicted, specific points/findings, which needs an immediate attention from the plant authorities is to be get noticed when required. Pressure calculations also is to be carried out on all the components of the boiler based on actual measurement of various parameters, mechanical tests like flattening test, tensile test, material properties etc. This safe working pressure for the boiler could increase safe operational reliability for extended life. The report contains the recommendations for the components, on one of the following decision namely Run, Repair, Refurbish, Replace/ Modification, etc. based on the thorough analysis of history data, operational & maintenance data, field investigation, information regarding health assessment of each component, laboratory evaluation, remaining life calculations, working pressure calculations etc.These results could be utilised for making suitable preventive & predictive plans for regular maintenance of critical components, which would drastically reduce the catastrophic failures of pressure parts. The adherence to these preventive & predictive maintenance plans for inspection and corrective actions will also reduce the forced outages of the boiler. Hence the boiler availability & efficiency could be increased to the large extent.

As more and more power plant equipments are reaching their designed life, utility owners are forced to take vital decisions on RUN, REPAIR, REPLACE for different components. Innovative NDE techniques are developed continuously and coupled with on-line monitoring and special computer programs, the decision making process has become more realistic and cost saving. Although the total generation capacity of our country has registered about 75 fold growth in generation since independence, It is well excepted that to meet the requirement, we need to install new power generating units. Moreover, augmentation of power generation capacity of the old power plants by renovation and modernization can significantly contribute to achieve the target. Renovation and modernization of existing power plants is economical as compared to setting up a greenfield project and is a more viable option. This involves less gestation period and low cost. Residual life assessment of the boiler further with suggested recommendations like regular inspection of critical components during overhauls, adherence to safe operational & maintenance tactics, etc. Hence this study would help to enhance the life extension and to predict the remaining life in high temperature zones of power plant components and also helps to prevent the catastrophic failures and helps to avoid forced outages and improve safety in operating the plant components effectively.

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Annexure – 1

SCOPE OF WORK FOR EFFICIENCY IMPROVEMENT TESTS ON BOILER COMPONENTS

S. No.	Name of the component	VE	DM	TM	UT	PT	MT	HT	RT	FI	DA	ME	DT
1	Steam Drum	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
2	Down Comers & Riser Tubes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	Yes	No
3	Water Wall Tubes	Yes	No	Yes	No	No	No	No	No	No	Yes	Yes	No
4	Water Wall Headers	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No
5	Economiser Tubes	Yes	Yes	Yes	No	No	No	No	No	No	Yes	Yes	No
6	Economiser headers	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No
7	Super Heater Coils	Yes	Yes	Yes	No	No	No	No	No	No	Yes	Yes *	No
8	Super Heater Headers	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
9	Connecting tubes	Yes	Yes	Yes	No	No	No	Yes	No	No	No	No	No
10	Re-heater Coils	Yes	Yes	Yes	No	No	No	No	No	No	Yes	Yes *	No
11	Re-heater Headers	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
12	Feed Water line	Yes	No	Yes	Yes	No	No	Yes	No	No	No	No	No
13	Main Steam line	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No
14	Critical Steam Piping	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No
15	Hangers & Supports	Yes	No	No	No	No	No	No	No	No	No	No	Yes

VE - VISUAL EXAMINATION
TM - THICKNESS MEASUREMENT
UT - ULTRASONIC TEST
PT - DYE PENETRANT TEST
MT - MAGNETIC PARTICLE TEST
DM - DIMENSIONAL MEASUREMENT
HT - HARDNESS TEST
RT - REPLICA TEST
ME - MECHANICAL TEST
DT - DEFLECTION MEASUREMENT
DA - DEPOSIT ANALAYASIS
FI - FIBROSCOPIC INSPECTION

ME * - CREEP RUPTURE TEST & METALLURGICAL TEST

YES - TEST TO BE DONE
NO - TEST NOT TO BE DONE