Research Paper

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High Temperature ultra sound testing for in Situ condition monitoring of super heated steam to improve creep life of platen super heater tubes in ultra super critical power plants

Engineering

KEYWORDS : Long range ultra sonic testing, in situ condition monitoring, catastrophic damage, aging, and reliability centered maintenance, ultra super critical power plants, and power plant economics.

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ABSTRACT

The Present paper gives an overview of high temperature ultra sound testing of super heater steam zone in platen super heater tubes in ultra super critical power plants modern power plants are based on ultra super critical technology require higher temperature and pressure of steam. Due to material degradation during aging of power plants boiler outage may take place. Creep phenomenon may be a dominant cause of tube failure results in boiler outage. If critical features at high temperature operation in platen super heater tubes are not detected in advance, they may cause catastrophic damage and failure which may result in environmental pollution and negative impact on power plant economics. During planned outage of power plants various non-destructive techniques can be used to assess the integrity of platen super heater tube. In this paper the hypothesis is based on condition monitoring of aging power plants in between outage as preventive measure to minimize boiler outage during plant operation. To extent life of power plant components with safe operation reliability centered maintenance may be a mile stone. In situ condition monitoring techniques may play vital role in reduction of boiler outage. NDE ultra sound transducers may provide a path towards reliability centered in situ condition monitoring the major challenge is safe and reliable operation of transducer with basic concept of long range ultra sonic testing during plant operation. To improve efficiency of power plants and to minimize waste heat, steam temperature and pressure must be upgraded to improve quality of steam. Due to material restriction and lack of continuous condition monitoring of platen super heater tubes during plant operation these areas require proper attention in research. This paper may be an indicative document for key areas with possible solutions of in situ condition monitoring through long range ultra sonic testing in ultra super critical power plants.

Introduction

Catastrophic failure in thermal power plants may cause considerable financial losses as well as chances of accidents. Structural health control of thermal power plant components is a key element for safe, reliable and efficient operation of power plants. Transportation of high pressure, high temperature super heater steam from boiler to turbine inlet is a critical issue and can lead to deformation of flaws and defeats due to material degradation mechanism. Creep, fatigue over time and corrosion are major problems may arise due to continuous high temperature operation. Creep and fatigue over time can cause catastrophic damage and failure. During plant outage various inspections and tests are performed for analysis of structural health of power plant. Inspections are performed during plant outage so that inspection techniques and technologies are used at room temperatures. For an aging power plant the condition of platen super heater tubes is to be monitored during plant operation between outages. In situ condition monitoring are to be utilized to retain reliability and to extend life time of power plant component. Long range ultra sonic testing (LRUT) can be used for inspection of platen super heater tubes at higher temperature. Ultra sonic guided waves can be used to detect defeats and large areas in high temperature zone can be screened from a

single location. Long range ultra sonic testing can be performed at lower frequencies. LRUT is useful technique can be used for in situ monitoring for platen super heater tubes. For this purpose an arrays of transducers are mounted around the tube to excite an axially symmetric wave mode and to capture interaction of the wave mode with defects. LRUT system for continuous in service inspection and structural health monitoring of high temperature super heated steam tubes at platen super heater section require sensitive and effective efforts during. In situ condition monitoring the system has to work at temperatures in the range of 610º C while the power plant is in operational state. Development of transducers that can operate at elevated temperature is the key challenge for in situ monitoring in high temperature zone of platen super heater tubes. Contact type transducers have their own limitations and cannot be used effectively and efficiently at high temperatures. Non contact transducers for ultra sonic inspection at high temperatures can be used for condition monitoring during plant operating situations. Electromagnetic acoustic transducers (EMAT) and laser ultra sound transducers can be used for continuous monitoring of power plant components subjected to elevated temperatures. In EMAT a magnet generated magnetic field and a coil generates eddy currents when alternating current passes through it. During transmission mode of EMAT an alternating current is passed through the coil to generate alternating eddy currents near the surface of structure which interact with the magnetic field and generates an alternating force in the material resulting in generation of ultra sound. In reception mode when the travelling ultra sound passes through EMAT it will cause interference in the magnetic field which inducer an ac voltage into coil of EMAT and a signal may be detected. In EMAT no need for couplant as it works without making contact to specimen. It is advantageous at higher temperatures. EMAT used permanent magnet as they provide high magnetic field. And have compact size. The magnets having low Curie point are not suitable at higher temperatures. Laser ultra sonic testing can be employed on non-contact techniques. It has higher band width and can interrogate cracks in presence of local surface corrosion. Engineering parameters and material parameters play important role to enable high temperature ultra sonic inspection of boiler tubes during operation. Piezo electric effect can be used in ultra sonic transducers to operate at high temperatures to generate ultra sound by using piezo electric effect high temperature acoustically active piezo electric material which can with stand high temperature are utilized. Piezo electric materials posses high curie temperatures are to be used in ultra sound transducers. $LINbo_3$ (lithium niobate) has the curie temperature of 1210º C and thickness coupling coefficient k_f = 0.30. Safe operating temperature for piezo electric materials is half of their curie temperature. $LINbo_3$ can operate at temperature up to 605º C. Another material based on lithium niobate is fabricated using only sol-gel based technology. $LINbo_3$ starts to lose oxygen at 600º C sodium substituted LINbo3 ceramics Li_1-x Na_x Nbo_3 has working temperature up to 650º C. It is higher sensitive and has good quality pulse shape at higher temperatures. Modified bismuth titanate (kezite k15) is a new option having high piezo

COMPONENT: PLATEN SUPER HEATER HEADERS (I/L & O/L)
TEST: IN-SITU METALLOGRAPHY
Period of test: 13/09/2012 to 22/09/2012

Equipment Used Replica Kit Apollo Material used Cleaner, Polishing machine, Etchant, Metal foil, Microscope Location Platen super heater inlet headers

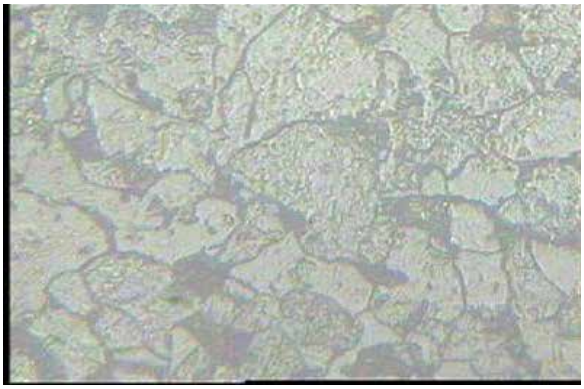

Fig.1-Microstructure of platen super heater

Spot Parent Metal
Hardness 105
Microstructure
Analysis
Micro-examination at weld shows structure of ferrite & bainite whereas at parent metal shows ferrite & bainite Structure. Initiation of decomposition of the bainite phases is Observed. Degradation level I-II L is observed

electric stability with T_c = 600° C and K_t = 0.15 lead meta niobate $PbNb_206$ has high curie temperature of 540° C. ceremics with a high density and high piezo electric effect can be fabricated by adding various elements as Mn and Ca to $PbNb_206$ with optimized sintering technique. $GaPo_4$ (Galluim Orthophosphate) is a quartz material having good piexo electric properties with properties with higher sensitivity and high thermal stability. It can be used 900° C temper. The $LiNbo_3$ can be bonded on to a stainless steel substrate and the transducer is heated to higher temperature in an electric furnace. It can work up to 1000° C. High temperature ultra sonic thickness gauge can also be used for measurements. An integrated ultra sonic sensor with an acoustic wave guide can be used up to 600° C temperature. At temperature 200 C and above ultra sonic testing is performed by electromagnetically generated ultra sound using EMAT transducers. For manufacturing of miniature high temperature ultra sonic transducers the lead – free thick bismuth titanate films have been successfully deposited on steel substrates of different shapes by sole-gel spray techniques.

LRUT transducers for in situ monitoring of power plant steam piping long range ultra sound testing
Etalon, panametrics, ultram, sigma, transducers are well known touse. Techniques and devices used for long range ultra sound transducers include piezo electric sensors, accelerometers, strain gauges, proximity sensors, fibers optics and buffer roads. High temperature transducers are used for high temperature acoustic coupling. Acoustic coupling may be dry, liquid or solid.

COMPONENT: PLATEN SUPERHEATER
COIL (C-24)
TEST: LAB METALLOGRAPHY ANALYSIS
Period of test: 13/09/2012 to 22/09/2012
EQUIPMENT AND MATERIAL USED: 1)POLISH GRINDER 2) ETCHANT & REPLICA FILM 3)EMERY PAPER 4) MICROSCOPE
Location Identification Observation
Location PSH Header-O/L Header

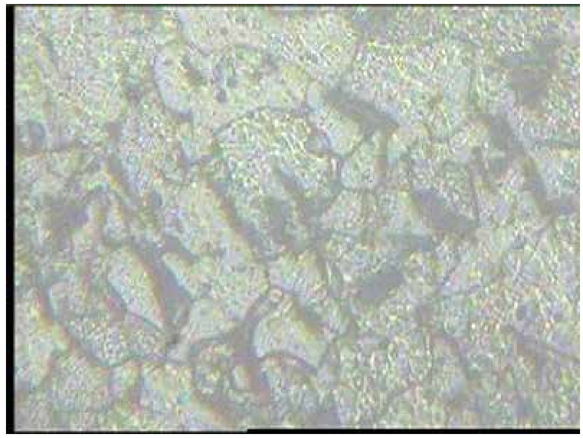

Fig. 2-microsture of platen super heater

Spot Parent metal
Hardness 111
Microstructure
analysis
Micro-examination at weld shows structure of ferrite & bainite whereas at parent metal shows ferrite & bainite structure.

Use of dry coupling is limited because with lower quality surface finish air gaps > 0.0/um between electric element and a front protective layer substantially reduces the acoustic energy and pressure up to 300 MPA are required to expel the air between highly polished surface. Liquid components can be divided in two groups – liquid at the room temperature and glass solders which are solid at the room temperature and melt prior to operation. During a lengthy operation of the transducers the liquid components can flow out of the interface due to vibrations of a piezo electric element. Thermal conductivity, expansion coefficient, oxidation and diffusion are critical parameters as operating temperatures increase. Diffusion bonding can be used in making piezo electric actuators. Fabrication of the actuators involves the stacking and diffusion bonding of multiple thin piezo electrodes. Stacked piezo electric layers were placed in a press for the diffusion process. The stack is pressed and heated at a specified curing temperature and pressure for a specified curing time. Wear plates are normally made of aluminum oxide which is high temperature resistance material. The wear plate is used to protect the piezoelectric element in ultra sonic probes where they are normally moved along the surface of specimens. In high temperature ultra sonic transducers high temperature cables are used to connect high temperature transducers with pulse system. Mineral insulated signal transmission cables may be used such as thermal coax. They can resist the temperature up to 1200° C and can carry relatively high currents & very low signals at high frequencies.

Non destructive evaluation of structural health of thermal power plant superheated steam section is an important aspect as in modern trend with future vision ultra critical power plants will be in operation & with higher temperature and pressure of steam during flow through steam tubes in situ condition monitoring during operation of plant between outages plays important role to improve creep life boiler tube material and may reduce failures due to creep in high temperature zone as continuous monitoring may help in safe and reliable operation of power plants.

Design of high temperature ultra sonic piezo electric transducers depend on piezo electric element and the bonding method selected.

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High temperature components and cables are required to with stand high temperature of steam flow. Existing material limitation, new material research and environmental conditions require proper consideration during design of long range ultra sonic transducers.

Conclusion

This paper reviews and eonphesizes on in situ condition monitoring of ultra super critical thermal power plants. Non contact techniques and remote sensors can be used for non destructive evaluation of structural health of super heated zones of power plants. In situ monitoring for continuous evaluation of structural health of components subjected to high temperatures with continuous flow of high temperature fluid at higher pressures plays vital role in reduction of boiler outage due to creep. Piezo electric transducers may provide an optimum solution for in situ condition monitoring EMAT and laser ultra sound techniques have their own limitations design of ultra sonic piezo electric transducers for sage and efficient in situ condition monitoring required good quality piezo electric element and proper bonding methods. Use of piezo electric transducers does not have commercial applications till date due to non available of good quality high temperature couplants and cables.

Long range ultra sonic testing transducers for in situ monitoring of high temperature components of power plant require new era in materials for improvement of micro structural properties. New materials being developed to with stand in specific environment. High temperature piezo electric ceramics are to be further investigated for high temperature ultra sonic transducers applications in Insitu condition monitoring of high temperature components to reduce outage due to creep.

Fig.3-Fibroscopic Image of Platen super heater

Fig.4-Microstructure of platen super heater

Fig.5-Microstructure of platen super heater

OBSERVATION: No Degradation level

Fig. 3Microscopic view of platen super heater images

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