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STRESS CORROSION CRACKING OF STAINLESS STEEL SUPER HEATER TUBES IN 200 MW BOILER

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Abstract

A few cases of super heater tube failures by corrosion were noticed in a boiler of 210 MW units of NTPC stations. The failure investigation was carried out at the Research and Development centre of NTPC. The failed tubes were examined by using Optical, scanning Electron Microscope and conventional methods. The material of the tube was stabilised grade austenitic stainless steel. The microscopic examination indicated the presence of a large number of transgranular cracks with branches. The surface analysis by EDAX revealed the presence of chloride in the corrosion products. The reason of failure has been attributed to chloride induced stress corrosion cracking. Chloride ions had generated supposedly due to leaching of residual contaminants carried over from manufacturing stage. It was suggested to check the cracks already generated by NDT methods and wash the tube panels which were already installed. After implementation of the recommendations, no such case of tube failure was reported. The present paper describes the investigations carried out and the remedial measures to prevent chloride induced stress corrosion cracking in supper heater tubes.

Introduction

One of the 200 MW boiler at NTPC station had faced a series of super heater tube failure which was detected at different stages of commissning activities. These failures were mainly at or near the welding joints. Fig. 1-2 and Table no.1 show the locations and failure histories of tube failures. This paper presents details of the failure investigation of stainless steel spool pieces of exit super heater coil no. 4, tube no. 3 and coil no. 22, tube no. 3 respectively. The pieces were sectioned into two halves along the axis and further examined by optical microscope, scanning electron microscope, EDAX, Auger electron microscope and secondary ion mass spectroscopy. The discussions on failure mechanisms, conclusion and recommendations are given in the following sections.

Experimental Procedure

Visual Observation

The tube were cut in longitudinal direction with hand hacksaw without any use of lubricant and coolant to avoid the possibilities of ingress of impurities on the sample. The spool pieces were found to have circumferentail cracks near the MIG welding alongwith the red iron oxide deposits and organic films. The cracks were 10 mm away from welding point. A few pits were also observed under stereo microscope near the MIG welds as shown in Fig. 2.

A small portion was cut from the spool pieces for surface analysis. The remaining pieces were cleaned in carbon tetra chloride to remove and collect the oil film deposits. The container was found to have a significant oil deposit when the solvent was evaporated. The incidence of deposits was discussed with the IOC which indicates the all types of oil film may not evaporate in presence of steam at high temperature.

Identification of Tube Materials

The materials of the stainless steel spool piece joined with other materials were analysed by alloy analyser and carbon sulphur analyser. The results are given in Table 1. The materials are as per specifications supplied by the manufacturer. The joining tubes are conforming the AISI 347 stabilised Austenitic stainless steel.

Metallographic Examination

Both the samples were cut to take out the pieces for metallographic examination. The samples were mounted and polished in usual way and etched to reveal the mode of cracking. The etched and unetched samples viewed under optical microscope revealed the transgranular cracks with branches originating from inside as shown in Fig. no. 3 and 4. The cracks were blunt and wide and few were sharp. The pits viewed under microscope at edges of sample were not always initiation points. One carck was found originating from the pits.

Scanning Electron Microscope (SEM) and EDAX Examination

The morphology of the cracks and deposits were examined by SEM and analysed under Energy Dispersive X-ray analyser. The morphology could not reveal much except the large number of machine markings on the internal surface of the tube. The cracks were mainly around the circumference about 10 mm away from the weld as shown in micrographs no. 5, 6 and 7. The fracture surface was found to contain black surface deposit. The surface analysis at different spots are given in Table 3. First sample was found to contain chloride and sulphur ions on the fracture surface. The second sample was containing the dye penetrant inside crack showed large number of elements on the surface as shown in Table 3.

SAM and SIMS Examination

The presence of sulphur detected by EDAX made the investigation examine its compound in detail. This was done by scanning Auger Microprobe (SAM) andSecondary Ion Mass Spectroscopic (SIMS) techniques. The results indicate the presence of organic compounds containing carbon bonds with chloride and sulphur on the fracture surface.

Visit To Manufacturer Site

The manufacturing site was visited and discussed with the concerning engineers to examine possibilities of ingress of residual contaminants found inside the spool pieces. The spool pieces are made by sub vendors. The heat treatment requirements of coil are based on the radius of bending and availability of time before despatching to commission the boiler in time.

Discussion

The transgranular cracks with branching observed under the optical microscope and chloride presence detected by surface analytical techniques confirmed the evidence of SCC of austenitic stainless steel type 347 H. It was important to know at which stage crack initiation and propagation had taken place in order to take suitable measures to prevent the forced outages. We therefore, examined all the stages i.e., manufacturing, transit, storage, erection, alkali boil out, acid cleaning, hydraulic test, preservation and operation. Based on the authors experience, knowledge and results of the findings and discussion with engineer at operation and manufacturing site, it is believed that the stress corrosion had taken place in presence of hydrolysible chloride generated by residual contaminants carried over from manufacturing site when the metal temp. was more than 100°C. It is not possible to establish the stage of operation or commissioning where stress, (residual plus operating tensile stress) had exceeded the threshold stress which led to SCC. The other possible causes i.e., caustic accumulation has already been ruled out because the pH of the deposits on surface was neutral. The chloride evidence and the mode of failure i.e., transgranular with branching made us to conclude that chloride and excessive residual tensile stress present in the spool piece caused this type of failure. It was believed that no further crack initiation and propagation would not take place after several operating hours and hydraulic test had already taken place.

Conclusion

1. The failure is due to chloride induced stress corrosion cracking.
2. New cracks generation is not expected. However, it is believed that the cracks already existing may propagate due to mechanical stresses during operation.

References

1. Proceeding of Stress Corrosion Cracking and Hydrogen Embrittlement of Iron Base Alloys NACE, June 1973.
2. Proceeding of Americans Power Conference, 1976, Vol 38, pp.298-310.

Table - 1
Chemical Composition of the Austenitic Stainless Steel of Final Super Heater

Sample	(Element Analysis Wt%)					Material identified by AISI
	C	S	Cr	Ni	Mo	
Spool piece no. 1	0.063	0.0077	17.26	10.13	0.69	AISI347 hardness 75RB BHN 150
Spool piece no.2	0.059	0.0073	17.65	9.56	0.68	AISI347 hardness 75RB BHN 180

* Nb=(Nb+Ta)
(alloy analyser Model 9266 USA), (C.S.analyser LECO)

Table - 2
Elemental Analysis of Super Heater Tube of Unit No. 3 of FSTPS Collected on. 29.6.88 Analysed by EDAX at NPL Sample No. 1 at Different Points

Element	Weight %				
	Point I	Point II	Point III	Point IV	Point V
Fe	71.58	71.69	95.64	89.58	72.17
Cr	19.41	13.93	1.57	6.26	15.55
Ni	8.36	5.96	0.76	2.24	8.25
Mn	--	3.03	1.35	1.76	3.81
S	0.65	1.25	0.68	0.15	0.22
Cl	--	1.34	--	--	--
Na	--	2.02	--	--	--
K	--	0.45	--	--	--
Ca	--	0.45	--	--	--

Table - 3

Elemental Analysis of Super Heater Tube of Unit No. 3 of FSTPS Collected on. 6.7.88 Analysed by EDAX at NPL Sample No. 2 at Different Points

Element	Weight %					
	Point I	Point II	Point III	Point IV	Point V	Point VI
Fe	72.87	74.75	90.03	89.39	90.37	91.31
Cr	13.68	1.81	1.91	3.23	3.40	2.85
Ni	6.59	12.39	2.42	4.28	2.74	2.68
Mn	4.61	2.37	1.00	3.73	1.24	2.07
Cu	1.50	0.99	--	--	--	--
S	--	--	--	--	--	0.14
Cl	--	0.44	--	--	0.22	--
P	0.75	6.62	3.61	0.87	0.26	0.29
Ca	--	0.40	0.18	0.34	0.33	0.18
Al	--	--	--	--	0.71	--
Si	--	0.22	0.85	0.17	0.78	0.48

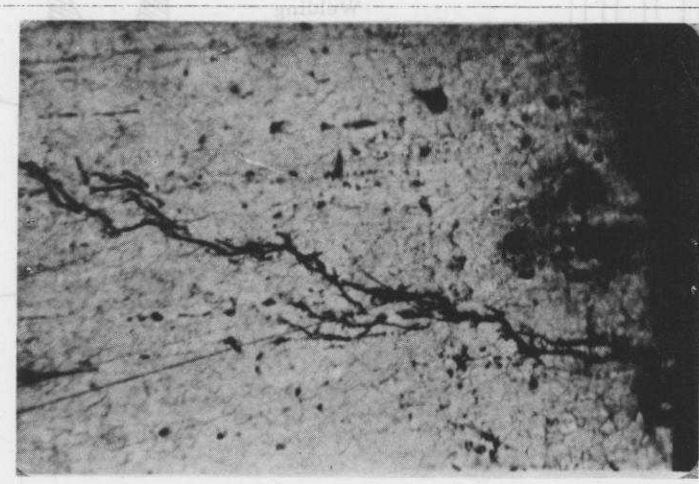

Fig. 3 : Optical micrographs showing transgranular cracks with branching. (mag. x 100)

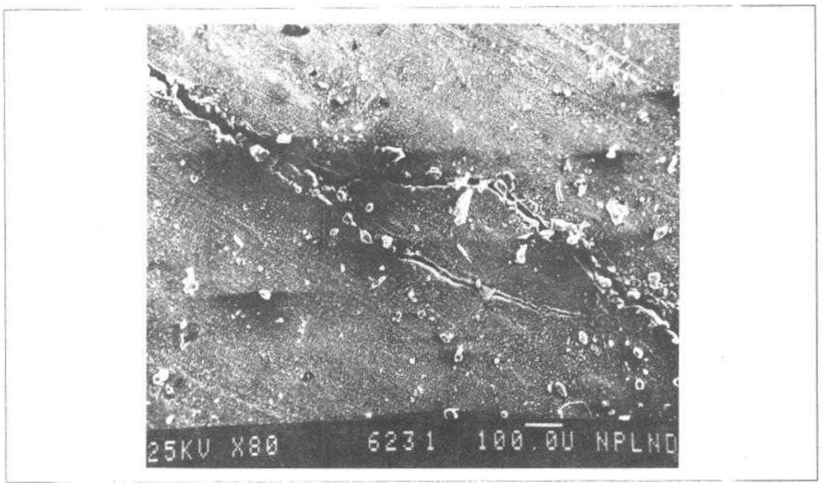

Fig. 7 : Eleectron micrograph showing wide cracks around the circumference

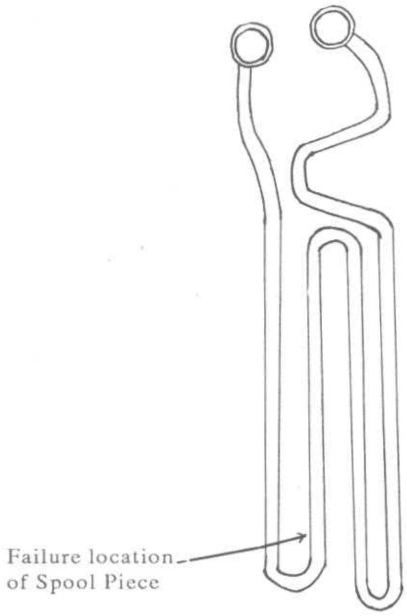

Fig. 1 : Final Super Heater Assy. (Coil) Showing Failure Location of Spool Piece

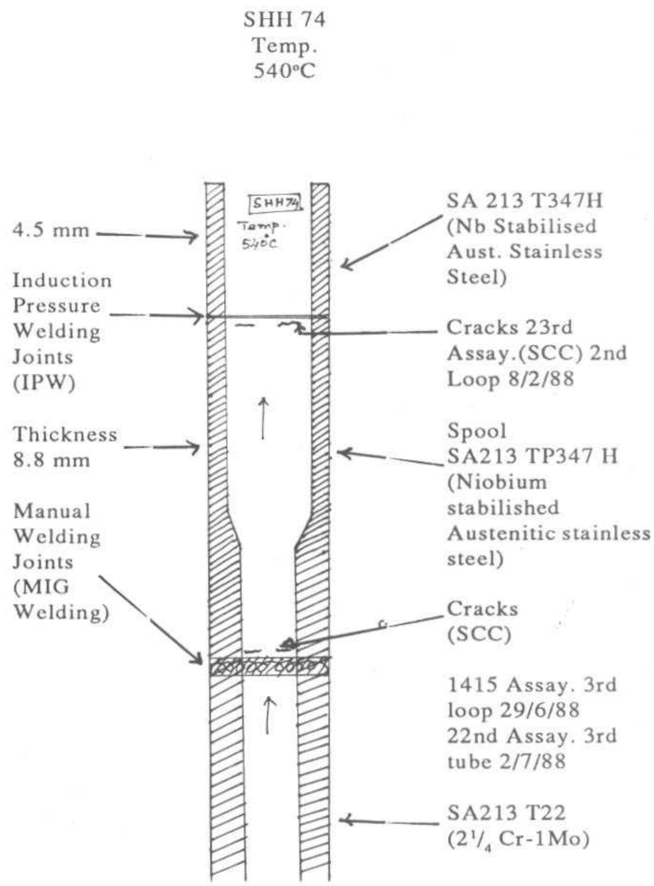

Fig. 2 : Spool Piece Joining Two Dissimilar Metal T22 and T347

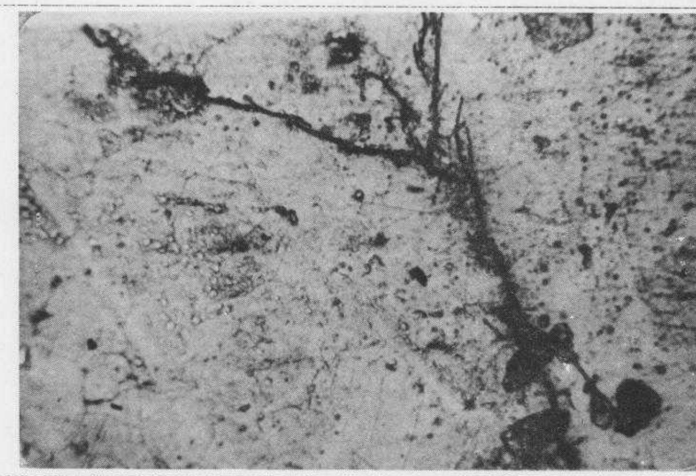

Fig. 4 : Optical micrograph showing transgranular cracks with branches (mag. x 200)

Fig. 5 : Electron micrograph showing cracks and thin layer of red oxide deposit inside the surface

Fig. 6 : Eleectron micrograph showing circumferential cracks inside the surface