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Life Management Technique of Thermal Fatigue for SMST Boiler Tube at Different Heating Zone Using Smithy Furnace

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Abstract
This paper highlights on the evaluation of thermal fatigue failure for SMST (Salzgitter Mannesmann strain less boiler tube) DMV 304 HCu boiler tube using life management technique by using of smithy furnace. Boiler tubes are highly affected by operating conditions like, high temperature and high pressure. So it needs periodic checking for the purpose of safety and health assessment of the plant. So using this technique we can identify the degradation of tubes at microstructure level, So that one create the current situation of the component and give respective result.
Keywords—SMST boiler tube, Smithy furnace, quenching process, Metallurgical Microscope, Vickers Hardness tester, Thermocouple.

I. INTRODUCTION

In water tube boiler, water is passing from tube and convert into the pressurize steam due to heating of tube at outer peripheral side with fuel gasses. In water tubes boiler there are many different types of failure mechanisms has been occurred. These can be divided into six categories like, Erosion, Water side corrosion, Lack of quality control of water, Fire-side corrosion, Stress rupture, Fatigue. [1]

This paper we are focused on thermal Fatigue failure of the boiler tube. When cyclic temperature is applied to a component, restriction in thermal expansion and contraction causes thermal stresses which may eventually initiate and propagate fatigue cracks. Thermal fatigue is classified in two categories, corrosion fatigue and thermal fatigue.
Thermal fatigue, ―at the time of the boiler shut down, temperature of water tube decrease up to atmosphere temperature, and when started of boiler temperature rise up to set up temperature due to this fluctuation of temperature, due to this fluctuation failure occurs in boiler tubes is called thermal fatigue failure. [2] SMST DAV 304 HCu tubes are widely used in conventional thermal power plants, because of its increased high temperature strength and enhanced creep rapture strength,embrittlement high-temperature corrosion and oxidation [3]when compared to other ferrite steels and it shows good resistance to thermal fatigue better to pearlite carbon steels[4].

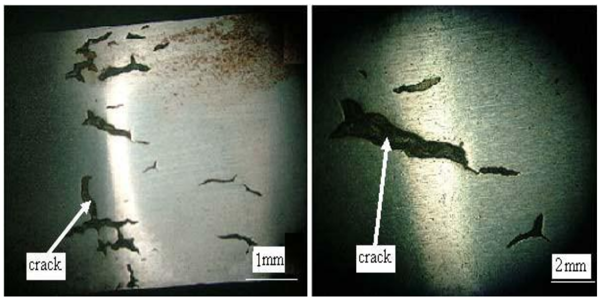


Fig.1 Magnified view of the surface crack obtained in the failed base tube

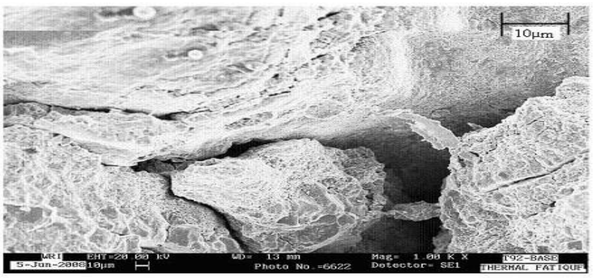


Fig.2 cracking along the grain boundaries

A. Boiler operation

Boilers apply the produce high pressure steam for the different kind of application at different type of steam as per application of industry. Production of steam in coal fired boiler coal converted big size to micron size with the help of the conveyor belt and grinder bled. Which injecting in combustion chamber in micron size and high temperature maintain pressurized air supply with help of blower due to striking of pressurized air and coal mixture the external surface of the tube randomly damage, scaling of the material at peripheral surface.

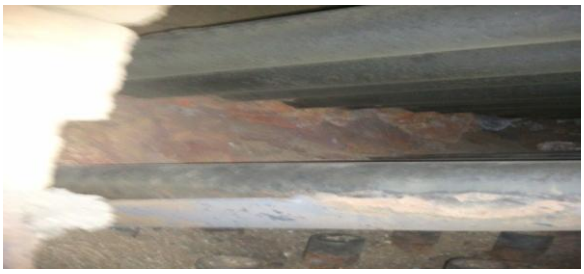


Fig.3 combustion chamber of boiler

B. Boiler Tube specifications

Boiler tube SMST DMV 304 HCu which chemical composition is given below in table-1 and table-2material properties are also show below.

1. Chemical composition Here chemical composition of boiler tube of given.

Table I Chemical composition of DMV 304 HCu material.

Mat.	%C	Cr%	% Mn	N	%S	Ni%	%P	%cr	%Si	Nb
DMV 304 HCu	0.07	17.0	-	0.05	-	7.5	-	17.0	-	0.30
	0.13	19.0	0.1	0.12	0.01	10.5	0.04	19.0	0.3	0.60

II. Mechanical properties of DMV 304 HCu material.

Table 2.mechanical property requirement in solution –annealed condition according to ASME code case 2328-1

Sr. no.	Content	Result
1	O.D. (mm)	63.52
2	Thickness (mm)	3.63
3	Area (mm2)	683
5	Max. Yield load (MPa)	235
6	Yield Stress (MPa)	34
7	Ultimate Tensile Stress (MPa)	590
8	% of Elongation	35%

Table 3. Tensile strength of boiler tube at 20˚ C and 700˚c as per value given below

Temperature˚C	0.2 % proof strength (MPa)	1% proof strength (MPa)	Tensile strength (MPa)	Elongation at facture %
20	235	270	590-850	35
700	135	160	370	

C. Experimental procedure

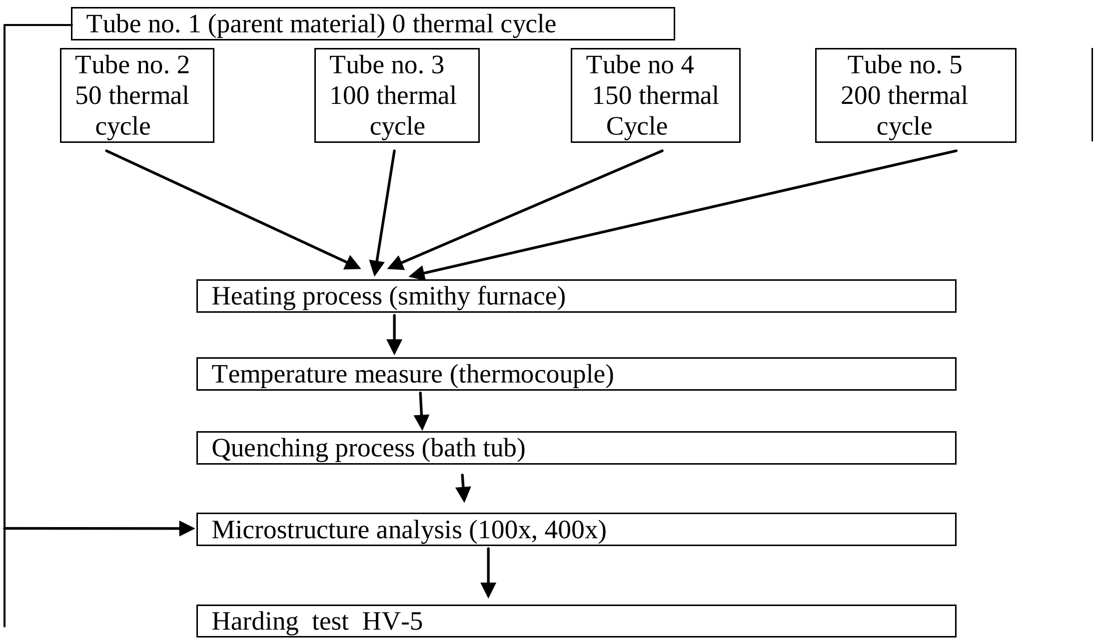


Table III flow diagram of the experimental work

The same effect achieve at the tube peripheral surface we can use smithy furnace, in this procedure tube specimen prepare and close both ends with the help of arc welding because to prevent elongation of the tube. After that all process completed tube ready to use in smithy furnace.

Fig.4 boiler tube heating in smithy furnace

The boiler tube of which is prepare for experimental procedure that is put in the furnace. Before the heating of the tube the furnace prepare with the wooden peaces and kerosene spraying in the furnace after that starting of the firing. After proper firing of the furnace blower start to supply of the air with proper velocity and supply more and more coal for firing.

The boiler tube heating temperature up to 600˚C and to check the temperature with the help of thermocouple at every cycle of heating. For reaching this temperature 20 to 25 minutes taken.

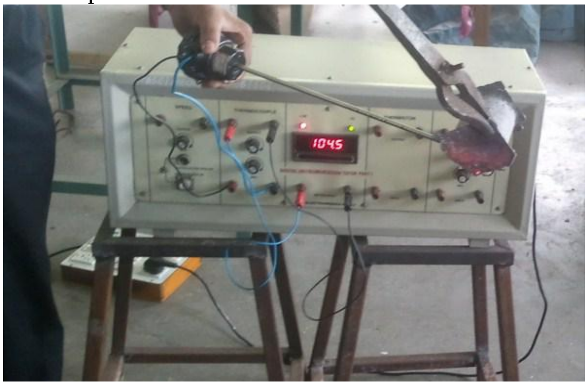


Fig.5 Thermocouple

There are three tubes use to performing thermal fatigue failure at the different range of the cycle and comparing the thermal fatigue at microstructure, hardness. Above two parameter use and conclude results.

Fig.6 Quenching process

For the cooling of the tubes water tub used in which water filling up to ¾ portion of the tub. After the heating of the tubes and temperature reach at 600˚ C, tubes quenching in the water tub and the drop the temperature up to the room temperature.

To reduce the temperature 7 to 10 minutes required. After every cycle water change in the tub.

III. RESULTS AND DISCUSSION

This is the parent material tube DMV 304 HCu. Which microstructure see below.

Fig.7 parent material tube

The boiler tube distribute in the parent material (0)-50-100-150-200 cycle. Results of the boiler tube in the form of the microstructure, hardness of the tube. As describe below and obtain the results in the form of graph of the hardness **v/s** no. of thermal cycle.

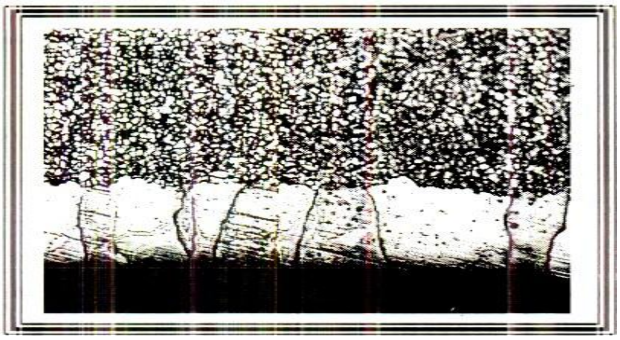


Fig.9 Parent material of tube at internal side magnification of 100 X

This is the microstructure of the parent material tube from the internal side of the tube magnification at the 100 X. Microstructure shows decarburized layer of ferrite grains at ID of tube as shown in this figure.

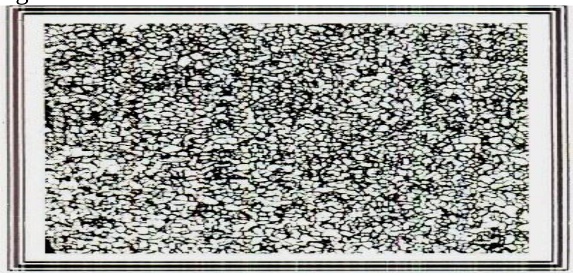


Fig.10 Parent material of tube at external side magnification of 100 X

This is the microstructure of the parent material tube from the external side of the tube magnification at the 100 X. Microstructure shows fine ferrite grains and partially pearlite as shown in figure.

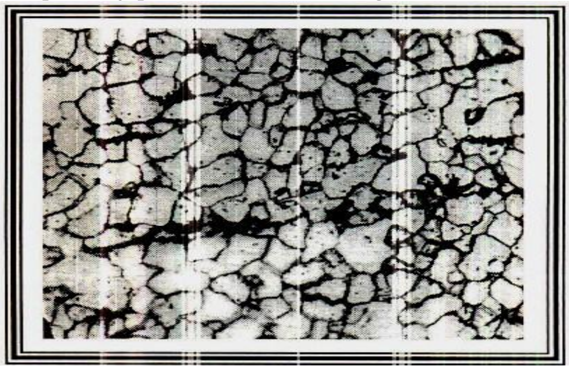


Fig.11 Parent material of tube at external side magnification of 400 X

This is the microstructure of the parent material tube from the external side of the tube magnification at the 400 X. Microstructure shows fine ferrite grains and partially pearlite as shown in figure. Ferrite gain size at centre of tube wall thickness is ASTM NO: 10.0 and observing this microstructure 2% nital used.

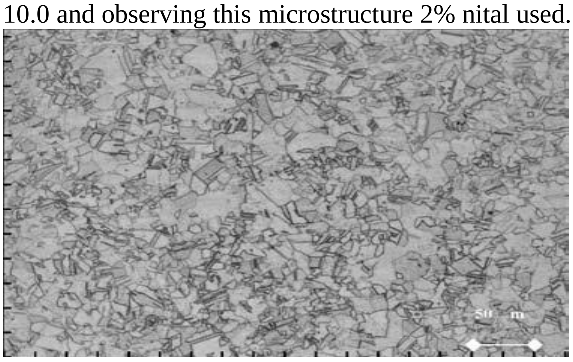


Fig .12 Microstructure of DMV 304 HCu in solution annealed condition.

In the solution-annealed condition the dissolved nitrogen increases the tensile strength at room temperature and elevated temperatures by the solid solution-strengthening effect.

Visual examine of tube after 50 thermal cycle

Fig.13 Tube after 50 thermal cycles

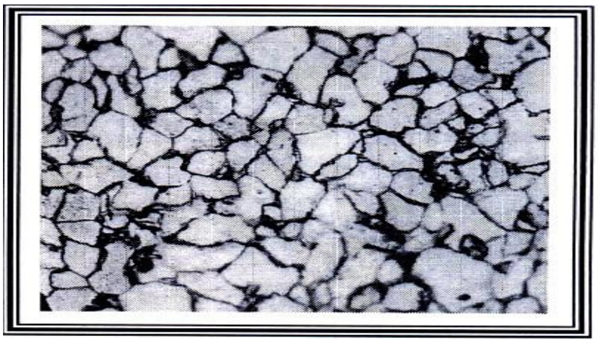


Fig.14 50 thermal cycles performed material of tube at internal side magnification of 100 X

This is the microstructure of the 50 thermal cycles performed material tube from the internal side of the tube magnification at the 100 X. Microstructure shows coarsening of ferrite grains at ID of tube as shown in this figure.

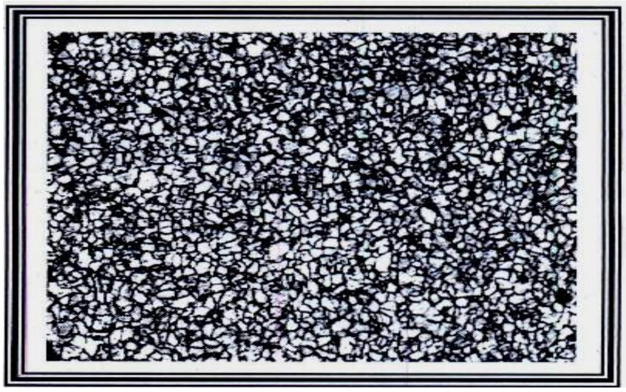


Fig.15 50 thermal cycles performed material of tube at external side magnification of 100 X

This is the microstructure of the 50 thermal cycles performed material tube from the external side of the tube magnification at the 100 X. Microstructure shows fine ferrite grains and pearlite as shown in this figure.

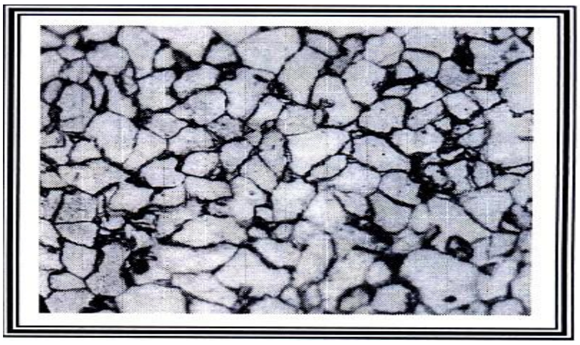


Fig.16 50 thermal cycles performed material of tube at external side magnification of 400 X

This is the microstructure of the 50 thermal cycles performed material tube from the external side of the tube magnification at the 400 X. Microstructure shows fine ferrite grains and pearlite as shown in this figure. Ferritic grain size at center of the tube wall thickness is ASTM No: 9.0 and fetrritic grain size has increased compared to parent material tube. For observing of microstructure of material 2% nital is use.

Visual examine of 100 thermal cycles.

Fig.17 Tube after 100 thermal fatigue cycles.

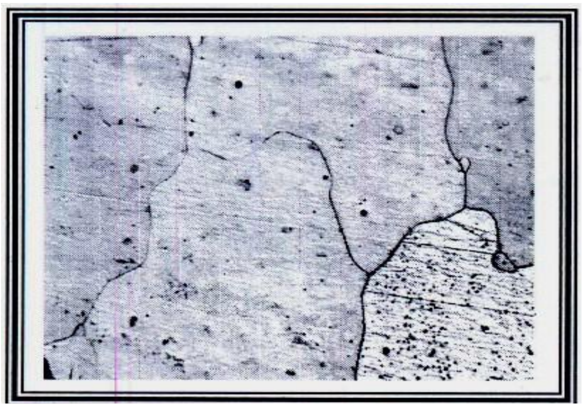


Fig.18 100 thermal cycles performed material of tube at internal side magnification of 100 X

This is the microstructure of the 100 thermal cycles performed material tube from the internal side of the tube magnification at the 100 X. Microstructure shows coarsening of ferrite grains at ID of tube as shown in this figure.

Fig.19 100 thermal cycles material of tube at external side magnification of 100 X

This is the microstructure of the parent material tube from the external side of the tube magnification at the 100 X. Microstructure shows fine ferrite grains and pearlite as shown in figure.

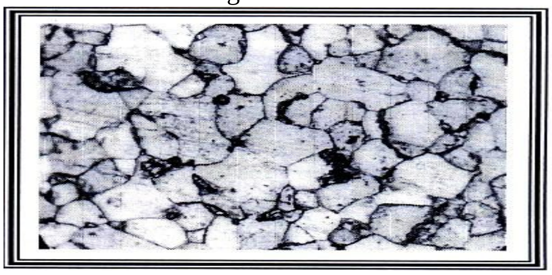


Fig.20 100 thermal cycles material of tube at external side magnification of 400 X

This is the microstructure of the parent material tube from the external side of the tube magnification at the 400 X. Microstructure shows fine ferrite grains and pearlite as shown in figure. Ferrite gain size at centre of tube wall thickness is ASTM NO: 8.5. Ferritic grain size has increased compared to 50 thermal cycles performing tube and observing this microstructure 2% nital used.

Fig.21 Tube after 150 thermal fatigue cycles.

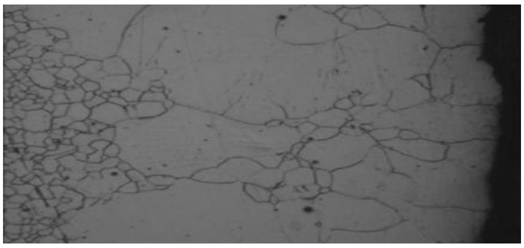


Fig.22 150 thermal cycles performed material of tube at internal side magnification of 100 X

Microstructure of the tube at internal side having essentially ferritic structure with relatively coarse gain at the Edge.

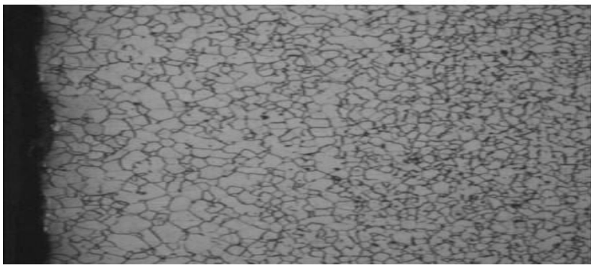


Fig.23 150 thermal cycles performed material of tube at external side magnification of 100 X

Microstructure of the tube at external side having essentially ferritic structure.

Fig.24 Tube after 200 thermal fatigue cycles.

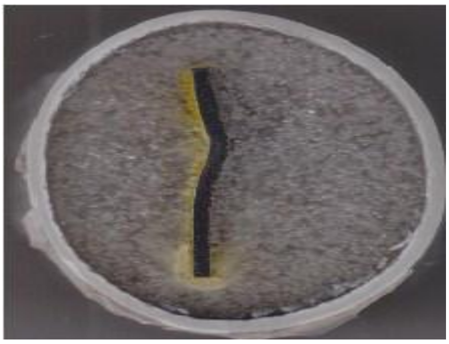


Fig. 25 200 thermal cycles performed material of tube at internal side magnification of 100 X

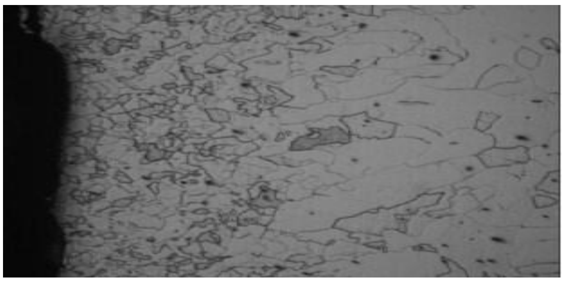


Fig.26 200 thermal cycles performed material of tube at internal side magnification of 100 X

Internal edge microstructure after 200 thermal fatigue cycles at portion away from damage having essentially coarse-grained Ferritic structure.

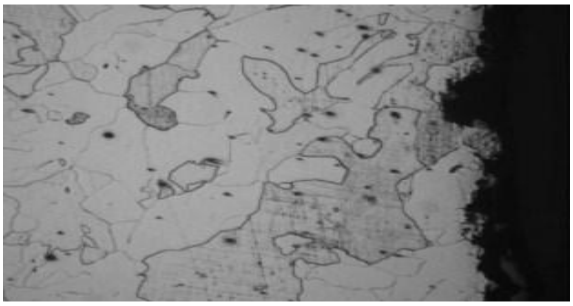


Fig.27 200 thermal cycles performed material of tube at external side magnification of 100 X.

External edge microstructure after 200 thermal fatigue cycle at portion away from damage having essentially fine & coarse-grained ferritic structure. Corrosion damage is observed at the edge.

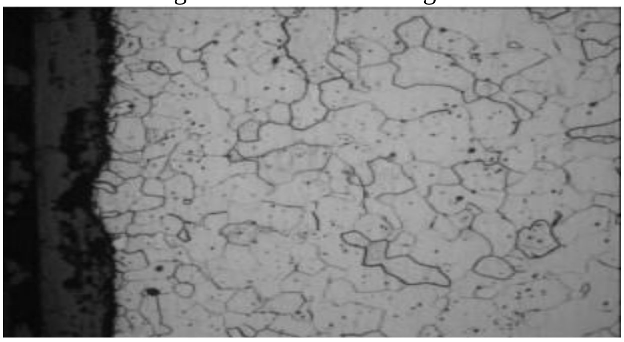


Fig. 28 200 thermal cycles material of tube at external side magnification of 400 X

External edge of tuwbe after 200 thermal fatigue cycle microstructure having essentially fine & coarse-grained Ferrite structure. Presence of oxide scale is observed at the edge.

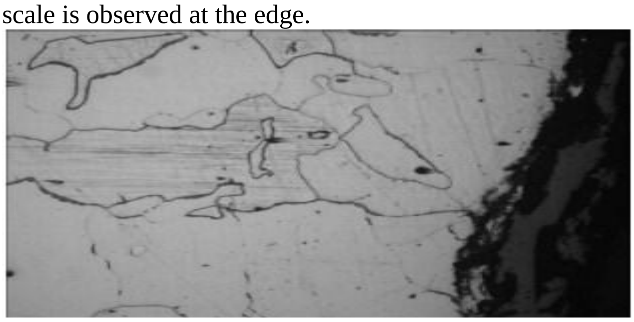


Fig.29 200 thermal cycles material of tube at internal side magnification of 400 X

Internal edge of tube after 200 thermal fatigue cycle microstructure having essentially coarse-grained ferrite structure.
Presence of oxide scale is observed at the edge.

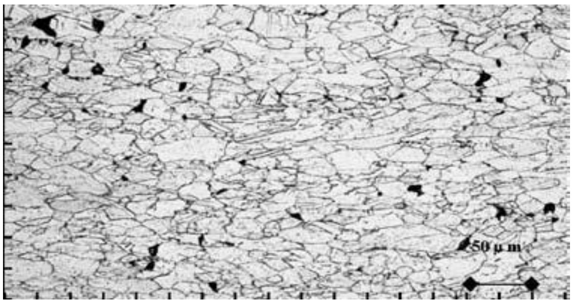
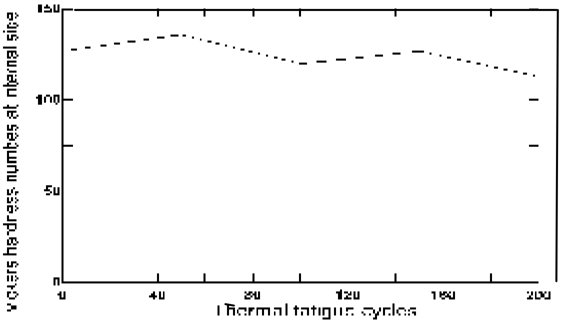


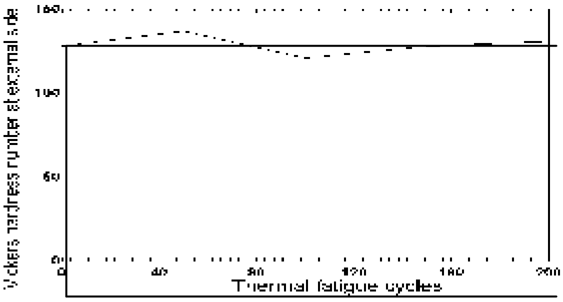
Fig. 30 Microstructure of DMV 304 HCu after failure in creep rupture test (600 °C, 303 MPa, 2009 h).

Vickers hardness results at different cycles at the internal side of the tube and external side of the tube.



Graph-I Thermal fatigue cycles v/s Vickers hardness numbers at Id

The Vickers hardness numbers are vary cycles to cycles from the 128 to 131.



Graph-II Thermal fatigue cycles v/s Vickers hardness numbers at OD

The Vickers hardness numbers are very cycles to cycles from the 128 to 131.

IV. CONCLUSION

All the results shows and its discussion culminate that the grain side of the parent tube is fine ferrite and pearlite, and it is gradually change fine to coarse and rough size. Failure of the thermal fatigue at the 200 cycles at the 600° C of the operating temperature of the tubes, during the thermal fatigue cycles it is distributes at 5 stages and at all stage there grain size and grain boundary change up to till failure should not faced. Same as the harness is drastically change and decrease at the internal side of the tube and the harness is drastically change at external side.

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