Remaining life assessment of radiant super heater in creep regime

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Abstract- *Assessment of remaining life of power plant components is necessary for awareness of its health. This is beneficial in preventing failure and force shutdown while life is expended. It also helps to avoid to capital investment on premature replacement of tubes. This study investigates the condition of platen superheater of pulverized fuel fired boiler. Visual inspection and various testing like dye penetrant testing, magnetic particle testing and ultrasonic testing carried out for checking structural integrity of header and tubes. Metallographic replication carried out for both inlet and outlet header of platen superheater. Oxide scale measurement carried out for superheater tubes and remaining life of tubes calculated.*

Keywords—Super heater tubes; Oxide scale measurements; microstructure; creep

1. Introduction

The high temperature headers include the superheater and reheater outlets which operate at temperatures in excess of 900°F. These headers experience the effects of creep under normal conditions. In addition to the material degradation resulting from creep, high temperature headers can also experience thermal and mechanical fatigue. Creep stresses combined with thermal fatigue stresses can lead to a failure much sooner than creep acting alone. [1]. As the strength reduced due to decarburization the creep mechanism transformed from long term intragranular creep to short term transgranular rupture [2]. Increased inlet temperature coupled with higher turbine rotational speeds, exposure the hot end components to faster rate of creep damage [3]. Due to combination of internal pressure loading and exposure to high temperature steam pipe experience creep damage. Seam welded steam pipes are prone to creep cracking [4]. measuring high temperature corrosion depth of boiler tubes extracted from heating surface allows assessment of the integrated impact of local operating condition metal corrosion resistance, gas environment, deposit condition and assessment of remaining life [5]. The process of creep damage leading up to crack initiation in boiler and turbine needs to be quantatively characterized in terms of material and operational parameters. The effect of environment stress state and cyclic operation on creep damage needs to be considered. The validity of life fraction rule for life assessment needs to be verified [6]. Tube forms an internal oxide layer that exhibits heat transfer through the wall and causes the tube metal temperature to rise. The thickness of this oxide can be used with unit operating data and wall thickness measurements to estimate the remaining life of a tube .At the high temperature oxide growth and diameter reduction both having simultaneous effect on tube life.[7}

2- Estimation of Remaining Life

The norms developed by Neubauer and Wedel, have now become the industry standard as given in the following table:

2.1 U. Neubauer and B. Wedel Classification

Table1. Class of assessment

Class of assessment	Damage definitio	Expended life fraction $(t_{exp} / \boldsymbol{t_r})$
Class I	Undamaged	.27
Class II	Isolated cavities	.46
Class III	Oriented cavities	.74
Class IV	Linked cavities / micro cracks	.88
Class V	Macro cracks	1

t_{rem} = t_{exp} [t_r/ t_{exp} – 1]
Where,
t_{rem} = Remaining Life
t_{exp} = Expended Life
t_r = Rupture Life

Theoretical calculations were also performed to estimate creep type damage of critical components operating in creep zone.

2.2 Larson miller parameter approach

LMP = Tx10^{-3} x [log (t_r) +20]
T = Temperature in ºRankine = [ºF+460]
t_r = rupture life in hours
LMP = Larsen Miller Parameter
Nominal stress (Ksi) = (WPxDx14.22)/ (2tx1000)
LMP can be obtained from nominal stress vs LMP creep curves of materials
Remaining Life = t_r – operating time
Assessment of structural integrity of tubes has been assessed from IBR 338 Eqn. 87

3- Microstructure analysis

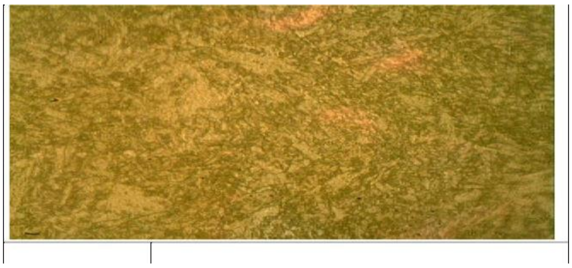


Fig 1. Microstructure of inlet header parent metal

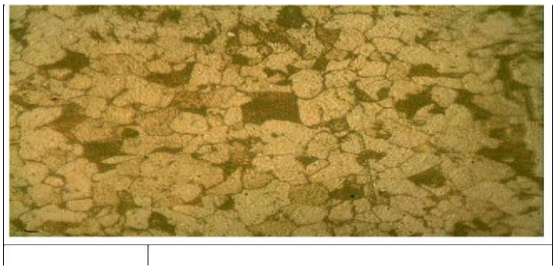


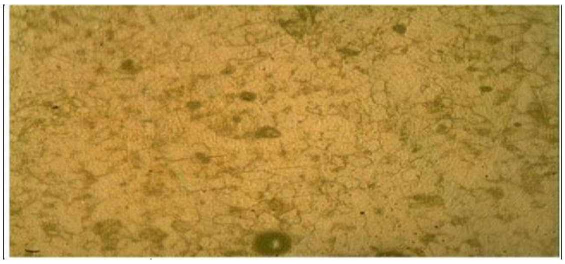
Fig. 2. Microstructure inlet header (WELD+HAZ)

4. Oxide scale measurement and remaining life calculation

One parameter used is the Larson-Miller Parameter. This is derived by taking natural logs of the Arrhenius equation ε= Aexp$-\left(\frac{Q}{KT}\right)$, Note that being used here instead of R so that Q is quoted in joules per atom. Also, if logs to the base 10 are used, the Larson-Miller Constant values given below are multiplied by log10e = 0.43429 in $\varepsilon = lnA - \frac{Q}{KT}$

$$\therefore\ lnA - ln\varepsilon = \frac{Q}{kT}$$

If we assume that the creep strain to rupture r ε is a constant over the temperature range of interest, and the major part of the creep strain is steady state creep, then the average creep rate



Fig,3. Microstructure of outlet header parent metal

Fig .4 Microstructure of outlet header (WELD+HAZ)

over the life to rupture of the specimen is t_r,

$$\varepsilon = \frac{\varepsilon_r}{t_r} \qquad \ln A - \ln\left(\frac{\varepsilon_r}{t_r}\right) = \frac{Q}{kT}$$

$$\therefore \ln A - \ln\varepsilon_r + \ln t_r = \frac{Q}{kT}$$

$$\therefore T(C1 + \ln t_r) = \frac{Q}{k} = P$$

Where $C1 = \ln(A) - \ln(t_r)$

Is the Larson-miller Constant and P is the Larson-Miller Parameter for a particular stress, since $Q = Q_0 - v\sigma$. Plotting experimental data of $\ln t_r$ versus $\frac{1}{T}$ gives a straight line with slope P and intercept at $\frac{1}{T} = 0\ of$ -C1 . The values of C1 range from 35 to 60, but are typically 46, and Figure 26 shows that it is independent of stress. Figure 26: Stress rupture data plotted as ln (rupture time) versus reciprocal of absolute temperature T.

Table no. 2. Remaining life of platen superheater tubes Component Name- Platen Superheater Material – T22
Tube OD- 50.8 mm /Thickness- 6.3/7.8/10.3 mm Pressure- 138 Kg/cm2

Panel N	Tube No	Outer dia (mm)	Thickness (mm)	Oxide sca (μ)	Hoop stre In (ksi)	Tube Met Temp. in (^{0}C)	LMP Valu	Remaining Li in Hours
1	1	50.8	7.8	<150	-	-	-	-
	4	50.7	6.3	<150	-	-	-	-
	8	50.8	10.3	<150	-	-	-	-
	12	50.7	7.7	<150	-	-	-	-
2	2	50.8	7.8	<150	-	-	-	-
	5	50.7	6.3	<150	-	-	-	-
	9	50.8	10.3	<150	-	-	-	-
	13	50.9	10.4	260	4.8	556.81	38200	211665
3	3	50.8	7.8	<150	-	-	-	-

	6	50.7	6.3	<150				
	10	50.8	10.3	<150				
	14	50.7	7.7	<150				
4	4	50.8	7.8	<150				
	7	50.7	6.3	<150				
	11	50.8	10.3	<150				
	15	50.7	7.7	<150				
5	5	50.8	7.8	<150	-	-	-	-
	8	50.7	6.3	<150		-	-	-
	12	50.8	10.3	<150	-	-	-	-
	16	50.7	7.7	<150	-	-	-	-
6	6	50.8	7.8	<150	-	-	-	-
	9	50.7	6.3	<150	-	-	-	-
	13	50.8	10.3	<150	-	-	-	-
	17	50.7	7.7	<150	-	-	-	-

Table no.3. Remaining life of platen superheater tubes Component Name- Platen Superheater Material – T22 Tube OD- 50.8 mm /Thickness- 6.3/7.8/10.3mm Pressure- 138 Kg/cm2

Panel N	Tube No	Outer dia (mm)	Thickness (mm)	Oxide sca (μ)	Hoop stre In (ksi)	Tube Met Temp. in (^{0}C)	LMP Valu	Remaining Li in Hours
1	1	50.8	7.8	<150	-	-	-	-
	4	50.7	6.3	<150	-	-	-	-
	8	50.8	10.3	<150	-	-	-	-
	12	50.7	7.7	<150	-	-	-	-
2	2	50.8	7.8	<150	-	-	-	-
	5	50.7	6.3	<150	-	-	-	-
	9	50.8	10.3	<150	-	-	-	-
	13	50.9	10.4	260	4.8	556.81	38200	211665
3	3	50.8	7.8	<150	-	-	-	-
	6	50.7	6.3	<150				
	10	50.8	10.3	<150				
	14	50.7	7.7	<150				
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	7	50.7	6.3	<150				
	11	50.8	10.3	<150				
	15	50.7	7.7	<150				
5	5	50.8	7.8	<150	-	-	-	-

	8	50.7	6.3	<150		-	-	-
	12	50.8	10.3	<150	-	-	-	-
	16	50.7	7.7	<150	-	-	-	-
6	6	50.8	7.8	<150	-	-	-	-
	9	50.7	6.3	<150	-	-	-	-
	13	50.8	10.3	<150	-	-	-	-
	17	50.7	7.7	<150	-	-	-	-

Table no. 4. Remaining life of platen superheater tubes Component Name- Platen Superheater Material – T22 Tube OD- 50.8 mm /Thickness- 6.3/7.8/10.3 mm Pressure- 138 Kg/cm2

Panel No	Tube No	Outer dia (mm)	Thickness (mm)	Oxide scal (μ)	Hoop stre In (ksi)	Tube Meta Temp. in (^{0}C)	LMP Valu	Remaining Li in Hours
20	6	50.8	7.8	<150	-	-	-	-
	9	50.7	6.3	<150	-	-	-	-
	13	50.8	10.3	<150	-	-	-	-
	17	50.7	7.7	<150	-	-	-	-
21	7	50.8	7.8	<150	-	-	-	-
	10	50.7	6.3	<150	-	-	-	-
	14	50.8	10.3	<150	-	-	-	-
	18	50.7	7.7	<150	-	-	-	-

OXIDE SCALE (μ)

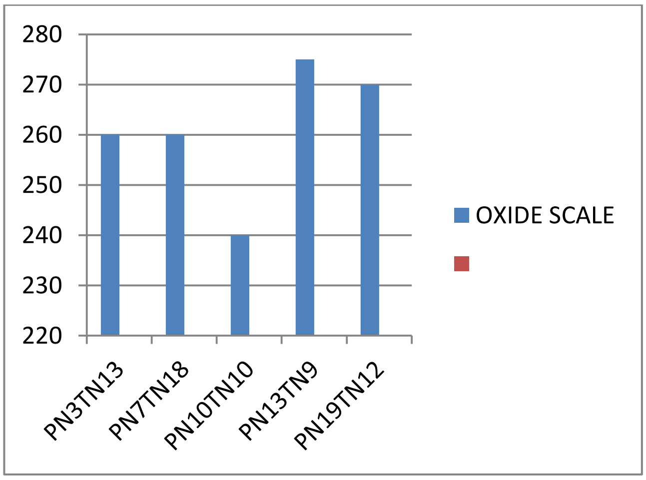

Fig. 5 comparison of oxide scale on different tubes

REMAINING LIFE (t_{rem})

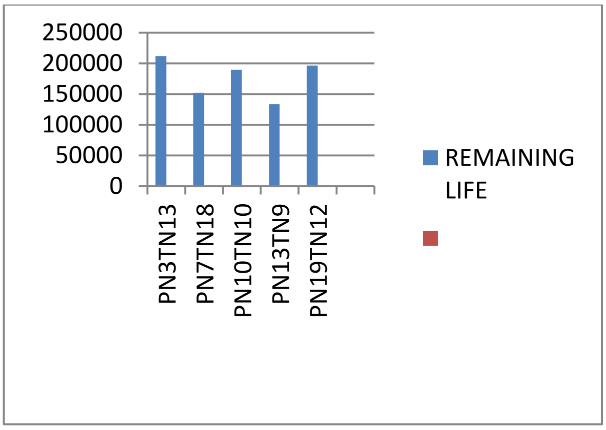

Fig. 7 Comparison of remaining life on different tubes

METAL TEMPERATURE (°C)

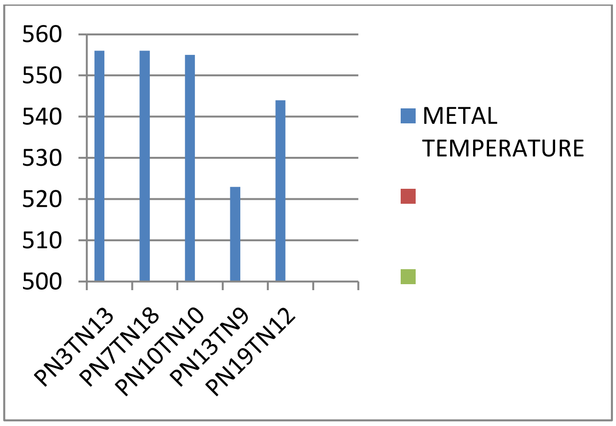

Fig. 6 comparison of metal temperature on different tubes

HOOP STRESS (σ)

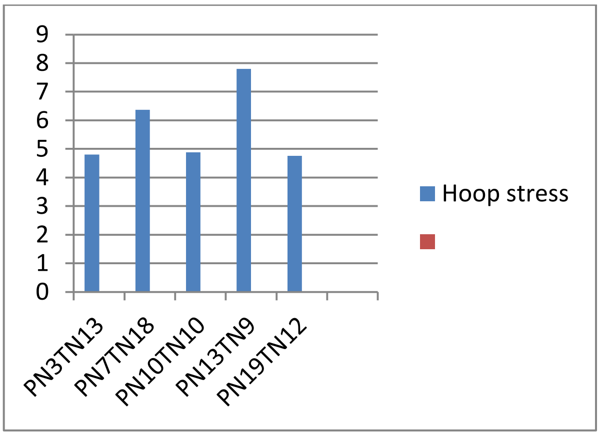

Fig. 8 comparison of hoop stress on different tubes

Results and discussions

1. Oxide scale thickness recorded in the high heat flux Platen superheater coils. The oxide scale thickness found within acceptable limits. In platen supheater coils, maximum oxide scale thickness was recorded as 275 microns which is acceptable. Oxide scale readings are furnished in the relevant chapter
2. Visual inspection during the cold walk down survey carried out for all the components like platen superheater inlet/outlet headers and tubing. No abnormality observed except minor bending of few tubes observed
3. Dye penetrant test (DPT) carried out for platen superheater inlet/outlet headers and
DMW joints. No significant surface defect observed
4. No significant abnormality observed during magnetic particle test of different weld joints.
5. Ultrasonic tests of circumferential weld joints of different components revealed no significant service induced discontinuity or deterioration.
6. Dimensional measurement (OD & Thickness) of headers/ coils recorded & found within acceptable range.
7. In – situ metallography of high temperature platen superheater headers, carried out. Analysis of the replicas of microstructure suggest that almost all the components are within mid life fraction between Stage II and III.
8. No abnormality like corrosion, scaling or crack found during video fibro- scopy inspection. of headers.

Conclusion

Based on all experimental results the fallowing conclusion has been drawn
1. In visual inspection bend tube no 3, 4, 8 should be replaced
2 .Microstructure of all headers found in stage 2 and .next inspection after five year necessary
3 .In dimensional measurement all dimension found within limit. So no maintenance is required on the basis of dimensional measurement.
4.On the basis of mechanical properties strength of material found in acceptable limit.
5. Oxide scale in five tubes found quite high, so in next shutdown emphasis should be given.

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References

1. P.K Liaw, A Saxena, J Schaefer, "Estimating remaining life of elevated-temperature steam pipes Part II. Fracture Mechanics analysis", Engineering Fracture Mechanics 32 (1989) 709-722
2. William Liu, " The dynamic creep rupture of a secondary superheater tube in a 43 MW coal-fired boiler by the decarburization and multilayer oxide scale buildup on both sides," Engineering Failure Analysis 53 (2015) 1-14
3. Vikas Kumar, "Remaining Life Related Issues Being Pursued at DRDO for Indian Air Force", Procedia Engineering 55 (2013) 428- 432

4 P.K Liaw, A Saxena,JSchaefer, "Estimating remaining life of elevated-temperature steam pipes Part II. Fracture Mechanics analysis", Engineering Fracture Mechanics 32 (1989) 709-722

5. Andrei Dedov, Ivan Klevtsov, Toomas Lausmaa, Aleksandr Hlebnikov, Tatjana Bojarinova "corrosion and life assessment of superheater tube in CFB oil shale boiler", Applied Thermal. Engineering 101 (2016) 468-478

6. R. Viswanathan "residual life technique for plant life extension"Material science and engineering 103(1988) 131-139

7. A. Al. Mazrouee and R.K. Singh Rahman "high temperature oxidation of Cr-Mo steels in context of accelerated rupture testing for creep life prediction." Journal of pressure vessel technology 129 (2006) 454-459