

Remaining Life Analysis Of A Steam Boiler Tube

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ABSTRACT:- Remaining life analysis of a failed in service steam boiler was conducted using Neubauer's classification of creep damage. In the course of the study, metallographic analysis and scanning electron microscopy were carried out with the resultant micrographs subjected to Neubauer's classification of creep damage as contained in ECCC Recommendations, Issue 1. The residual life of the steam boiler was then determined to be 6.75 years. Thorough thickness survey was therefore recommended for the steam boiler tubes to identify portions with severe wall loss for eventual replacement.

KEY WORDS: *remaining, life, steam boiler creep, micrographs*

I. INTRODUCTION

A refinery steam boiler that has had a history of good performance with few leakages and damages that were successfully repaired was observed to have developed several perforations/punctures on numerous furnace chamber tubes, twenty two years after commissioning. Given the risks inherent with these failures, a study of the remaining life became imperative to prepare the owners for scheduled replacements. According to Okpala et al (2014), several methods are available for predicting the remaining life of high temperature steel piping. This study however aims at determining the remaining life of a steam boiler tube using metallography and applying the creep life consumption ratio.

Remaining Life Evaluation

Computing estimates of remaining life requires a model of the material damage mechanism. More accurate damage models and knowledge of operating conditions will yield more accurate calculations of remaining life. For an in-service component, the current condition of a component must be determined before remaining life can be estimated. This can be done by using offcuts of undamaged tubes as samples or by in-situ metallography

High-temperature equipment is subject to creep damage during long-term service. As with fatigue, remaining creep life can be evaluated in terms of failure life or in terms of crack-growth life. The former approach is most often employed because creep damage is typically associated with the formation of multiple voids and micro-cracks, rather than a single dominant crack that can be analyzed using fracture mechanics.

Life assessment

According to Jaske (2002), Life assessment methodology can broadly be classified into three levels. Level 1 methodology is generally employed when service life of the components is less than 80% of their design lives. In level 1, assessments are performed using plant records, design stress and temperatures, and minimum values of material properties from literature. When service life exceeds 80% of the design life, level 2 methodology is employed. It involves actual measurements of dimensions and temperatures, stress calculations and inspections coupled with the use of the minimum material properties from literature. However, when life extension begins after attaining design life, level 3 methodologies is employed. It involves in-depth inspection, stress analysis, plant monitoring and generation of actual material data from samples removed from the component. The details and accuracy of the results increase from level 1 to level 3 but at the same time the cost of life assessment increases. Depending on the extent of information available and the results obtained, the analysis may stop at any level or proceed to the next level as necessary. This study could therefore be classified as level 1 assessment since the boiler tubes have utilized 73% of their design life (that is 22 year out of 30 years design life).

Microstructure-based approach:

According to Coade (1985), semi quantitative and qualitative approaches involving database on changes in microstructure as a function of service history have been widely used for predicting residual life.

II. MATERIAL AND METHOD

Sample:

The sample used for this work was drawn from the steam boiler tube in a refinery that experienced a failure after about 22 years of service life. Records showed that the tube is made up of SA 210 Gr. A1 seamless steel boiler pipe. The operating temperature is 557°C and operating pressure is 52Kg/Cm² g. Two samples were taken from the tube, labeled A and B. The sample A was taken from the internal of the tube while B was taken from the tube external.

Spectrometric Analysis

The Chemical analysis of the tube was carried out using an optical emission spectrometer which gave the composition presented in Table 1.

Table 1: Chemical composition of steam boiler tube samples

	C (%)	S (%)	P (%)	Mn (%)	Si (%)	Cr (%)	Ni (%)	Mo (%)	Al (%)	Cu (%)
Sample A	0.15	0.010	0.022	0.68	0.21	0.10	0.098	0.025	0.014	0.20
Sample B	0.16	0.009	0.022	0.69	0.23	0.10	0.10	0.025	0.010	0.20
Required	0.27max	0.035max	0.035max	0.93max	0.10min					

This conformstoASTMSA 210 Gr. A1

Metallographic Analysis

The perforated tube samples were prepared for metallography in accordance with ASTM E3, methods of preparation of metallographic specimen. The samples were then observed under metallurgical microscope and the resulting micrographs are presented in plates 1 and 2.

Scanning Electron Microscopy

SEM was conducted on samples A and B to reveal more details about the microstructure. The micrographs presented in plates 3 and 4 were obtained.

Creep Level Investigation for The ASTM A 210 Gr.A1 Tubes

The tubes were subjected to metallography and the resultant micrographs were evaluated for creep level.

Principle: The creep level investigation was carried out in consonance with the specifications of Neubauer's classification of creep damage as contained in ECCC Recommendations, Issue 1. This practice classifies creep damage into single cavities/voids, coherent cavities, micro cracks and macro cracks which are superimposed on the creep curve to identify life consumption ratio. This is further depicted by the figures presented in Figures 1, 2 and 3.

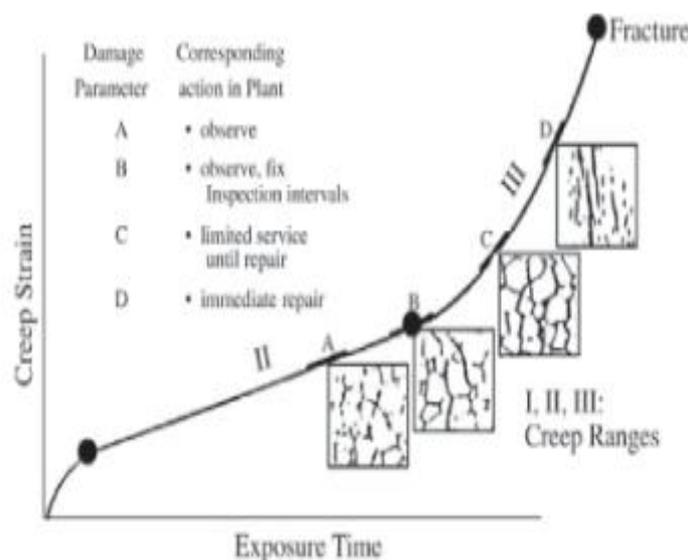


Figure 1 : Neubauer's classification of creep damage from observation of replica and consequent action to be taken

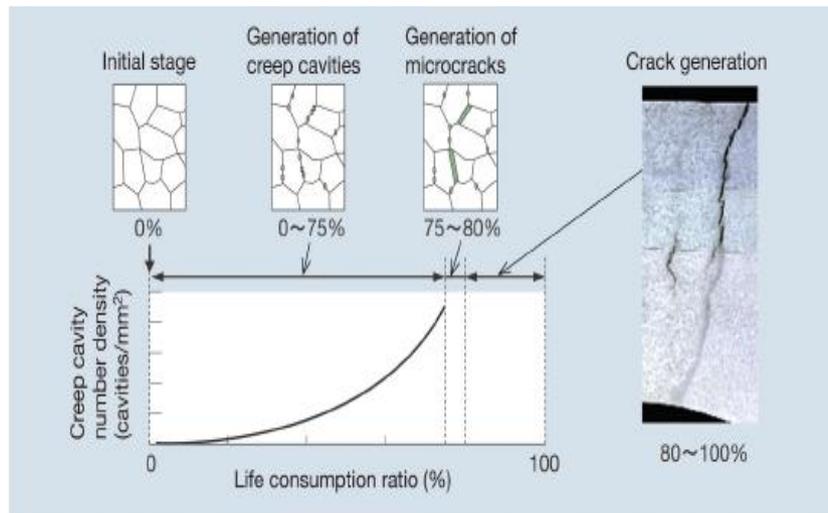


Figure 2: Creep Life Consumption ratio depiction

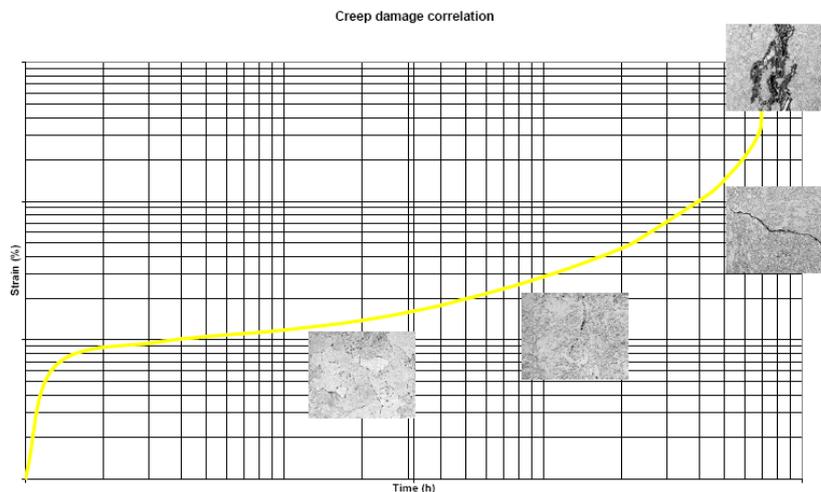


Figure 3: Creep Life Damage Correlation [Source: *Mitsubishi Heavy Industries Technical Review Vol. No. 2 (June 2009)*]

Class Damage Recommendations precautions

- 1) Single cavities: Re-Examine after approximate 20000 hours of operation
- 2) Coherent cavities: Re-Examine after approximate 15000 hours of operation
- 3) Creep cracks (Micro): Re-Examine after approximate 10000 hours of operation
- 4) Creep cracks (Macro): the plant is contacted immediately

The generally observed creep level in the microstructure in plate 1 and the SEM micrograph of plate 3 for the tube from which sample A is drawn is between few coherent cavities and more of micro cracks. Obviously the creep level is within the secondary creep stage which has a span of 75-80% (averaging 77.5%) life consumption ratio as illustrated in Figure 2. The residual life of the tube from which sample A is drawn is thus estimated as 59,130 hours of operation out of a designed life of 262,800 hours. Using the Neubauer's criteria, a re-examination was recommended after 10,000 hours of operation. Conversely, no significance presences of creep cracks are present in the microstructure of sample B presented in plate 2 and 4. The creep level when interpolated from the Neubauer's life consumption ratio graph illustrated in Figure 2, gives a value of 62.5%(between 50-75%). The residual life of the tubes is estimated as 98,550 hours of operation out of a designed life of 262,800 hours.

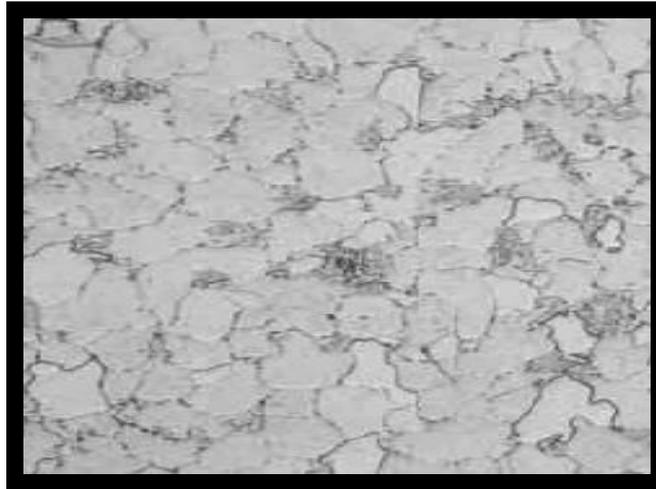


Plate 1: Micrographs of Sample A Showing Creep Cavity/Micro-cracks500x

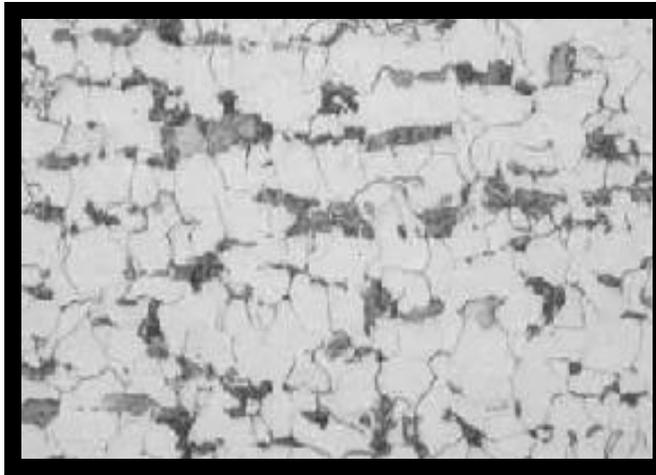


Plate 2:Micrographs of Sample B Showing Few Creep Cavities500x

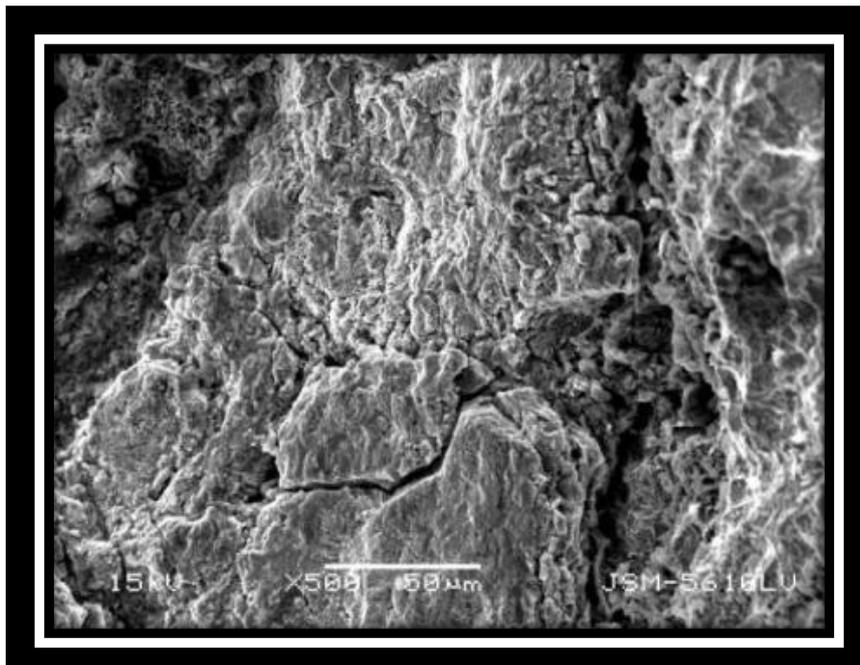


Plate 3: SEM Micrograph of sample A

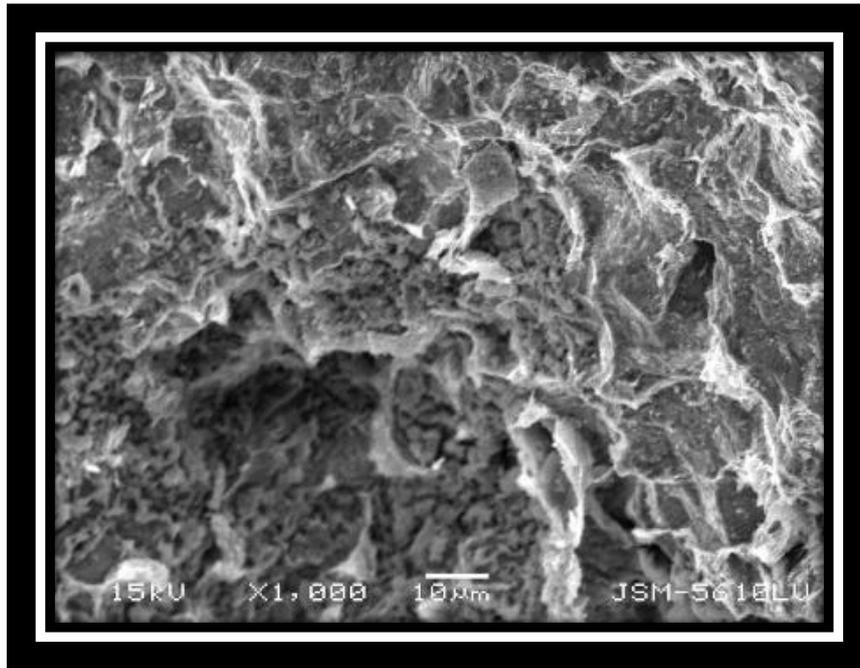


Plate 4: SEM Micrograph of sample B

III. CONCLUSION

Whereas sample A has a residual life of 59,130 hours, sample B has a residual life of 98,550 hours. It shows that sample B will live out the boiler life while sample A will not since the remaining life of the boiler is 70,080 hours. Since the boiler tube was designed for 30 years' service life, it is therefore imperative that the tube from which sample A was drawn has a residual life of 6.75 years $[59,130/(365 \times 24)]$ while the tube from which sample B was drawn has a residual life of 11.25 years $[98,550/(365 \times 24)]$. The remaining life of the steam boiler is therefore 6.75 years.

IV. RECOMMENDATIONS

Thorough thickness survey was therefore recommended for the steam boiler tubes to identify portions with severe wall loss for replacement. Since the creep level study presented indicates that sample B will live out the boiler life while sample A will not since the remaining life of the boiler is 70,080 hours it is recommended that extensive ultrasonic measurement be carried out on the tube from which sample A was drawn particularly those on the furnace internal walls with the aim of replacing those with appreciable wall loss.

REFERENCES

- [1] ASTM E3 – 01 Standard Guide for Preparation of Metallographic Specimens, ASTM International, West Conshohocken, PA, 2004.
- [2] A.N.Okpala, T.J.Tuaweri and E.E.Jumbo(2014), Comparative Study of Creep Life and Larson Miller Parameter as Tools for Determining Remaining Life of Steels used for Steam Boiler Tubes, International Research Journal In Engineering, Science and Technology, Vol.11, No.1, PP 40-46.
- [3] Jaske, C. E.,(2002) "Assuring the Safety of Ammonia Plant Vessels and Piping Using API RP 579," Paper 1C, Safety in Ammonia Plants and Related Facilities Symposium, Vol. 43, American Institute of Chemical Engineers, New York.
- [4] Mitsubishi Heavy Industries Technical Review Vol. No. 2 (June 2009).
- [5] R. Coade, Report No. SO/85/87, State Electricity Commission of Victoria, Australia, February 1985.