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LIFE TIME ESTIMATION FOR CSN 15128 STEEL USED IN THERMOELECTRIC STATION BY MEANS OF CREEP TESTING

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Abstract

Within the paper the experimental researches performed by the authors are introduced their purpose consisting in the life prediction of a CSN 15128 steel pipe which was employed during 184,000 hours at a pressure of 10 MPa and a temperature of 540 °C. Chemical and metallographic analyses, tensile mechanical tests and creep failure tests have been performed. The results of the creep test were extrapolated by means of both Larson - Miller and Manson - Hafered methods.

1. INTRODUCTION

Failure prevention, residual life assessment and life extension of material components operating high temperatures are becoming increasingly important problems in the modern power plant.

The progress registered in the energetic industry would not have been possible if the metallurgic specialist's had not offered the constructors complex steels and alloys and if the researches done on this subject had not obtained remarkable results concerning their behaviour at high temperature.

This paper presents the research the authors did to determine the current state of a steam pipe-line from CET-Săvineşti Romania after 184 000 hours in function at 540°C and 10 MPa. A ϕ219 x 20 section of the pipe-line was used to prevail all the necessary samples for the experiments.

2. EXPERIMENTAL PROCEDURE

Chemical analysis

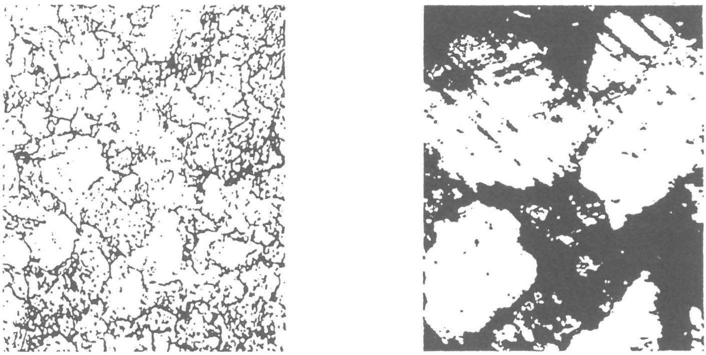
Using the spectral analysis method, by means of a spectrometer, type Quantovac, the chemical composition was determined for the alloy under study. The obtained results are listed in Table 1, as compared to the chemical composition prescribed in the norm for CSN 15 128 steel.

Table 1. **Chemical composition, weight %**

	C	Si	Mn	P	S	Cr	Mo	V	Al
specimen	0.1585	0.30	0.525	0.0085	0.0115	0.705	0.54	0.3135	0.0175
standard	0.10-0.18	0.15-0.40	0.45-0.70	max 0.04	max 0.04	0.50-0.75	0.40-0.60	0.22-0.35	0.025

Metallograpfic analysis

The microscopic test samples were prepared by grinding and finishing and then treated with a chemical reagent (Nital 3 %). The photos were taken with a metallographic microscope with a PMT-3 microhardnessmeter. The hardness of a ferrite grain was measured using the Wickers test and it resulted to be 180 HV_{01}.



a) **b)**

Figure 1. Microstructure of CSN 15 128 steel
a) x 100; b) x 500

Figure 1a presents a mostly ferric structure, with reduced perlitic separation that is characteristic for a low carbon content steel. The granulation is uniform and corresponds to a 0.035÷0.050 mm scale.

From the analysis in fig. 1b results that at the bondage of the ferrite grains there are precipitates specific to long period of working in hot condition of steel.

Even though from the structural analysis resulted a separation process of the precipitates from the edge of the grains, the steel does not present an advanced degree of structural degradation. The microseparation that appear at the interface of the grains consolidate the material in the process of creep strain, but it also reduces the resistance for mechanical and thermal shocks.

Tensile tests

The following characteristics were determined:

- proof stress Rp_{02} ; - percentage elongation A;
- tensile strength Rm ; - percentage reduction of area Z.

The tensile tests were performed at the temperatures: 20°C, 500°C, 525°C, 550°C, 575°C and. 600°C according to SR EN 10002-1:1994 and SR EN 10002-5:1995 standards. The variation of the proof stress Rp_{02} and of the tensile strength Rm as a function of temperature is illustrated in Figure 2.

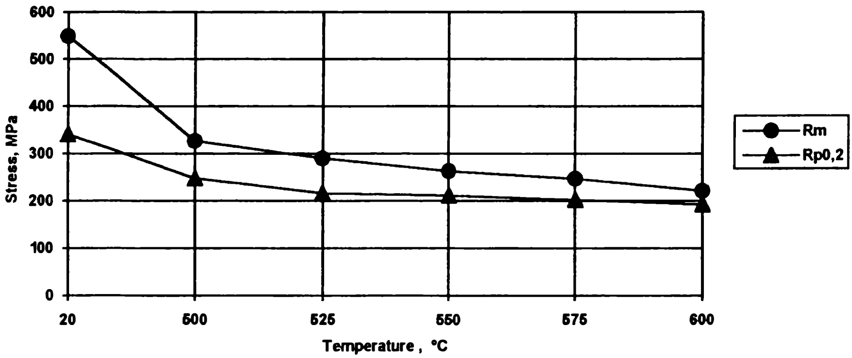


Figure 2. Tensile stress R_m and proof stress R_{p02} variations

Figure 3 presents the variations graphics of the percentage elongation A and the percentage reduction of area Z with the temperature.

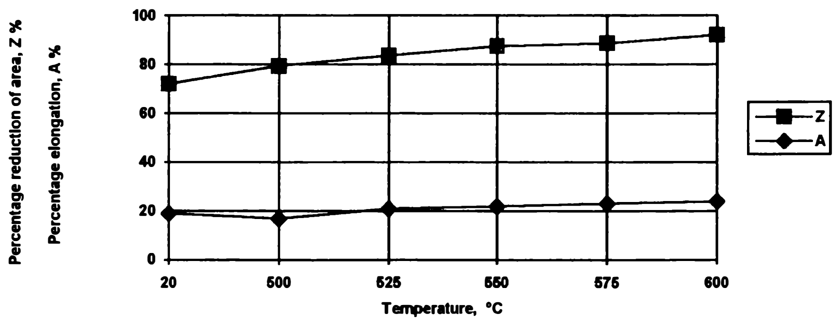


Figure 3. Percentage elongation A and of the percentage reduction of area Z variations

Creep testing

Creep fracture testing was done according to STAS 8894/1-80, the experimental results being interpreted using the Larson - Miller method and Manson - Hafered method, according to STAS 8894/2-81.

The Larson - Miller method used for the results' extrapolation is based on the fact that the isobars defined by the experimental creep fracture data traced in 1/T and log *t* co-ordinates are intersected in a certain point (T - testing temperature [K]; t - testing time until fracture).

The average absolute value of the isobars' family is equal to the C Larson - Miller extrapolation constant, specific to each material.

For this material the value of C constant results to be C = 20.04.

The Larson - Miller extrapolation parameter P, is calculated with:

$$\mathbf{P = T(\log t + C)} \tag{1}$$

Table 2. **Creep - rupture test results**

Crt.	σ_0	T	t	P_{LM}	P_{MH}
no.	[MPa]	[K]	[h]		
1	200	813	10	17 105	- 27.51
2	200	793	48	17 225	- 27.45
3	175	833	40	18 028	-32.86
4	175	813	165	18 095	-32.89
5	150	853	70	18 667	-37.00
6	150	833	245	18 683	-37.03

To estimate the strengths in case of long period of time functioning, the regression parabolic curve is traced, in P and log $R_{r/t}$ co-ordinates, for the points experimentally determined using the least squares method.

The following function is obtained:

$$\log R_{r/t} = - 6.42777 + 0.00104989 \cdot P_{LM} - 3.15491 \cdot 10^{-8} \cdot P_{LM}^2 \quad (2)$$

For a 20 000 hours functioning at 540°C temperature after these tests, the Larson - Miller parameter is:

P = T(log t +C) = 813(log 20 000 + 20.04) = 19 789

Replacing P in the above equation it results a strength in case of long period of time functioning $R_{r/20\ 000}$ = 98.6 MPa that is close to $R_{r/100\ 000}$ = 100 MPa value.

Figure 4 presents the variations of log $R_{r/t}$ with Larson - Miller parameter.

The use of Manson - Hafered method for results extrapolation consists in the fact that the isobars defined by the experimental creep data, and plotted in the coordinates T - logt, are intersecting in one point. The mean values of the coordinates of intersecting point are equal to the values of Manson - Hafered extrapolation constants, specific to each material in part.

For the analyzed material T_a =603 [K] and $\log t_a$ = 8.6.

The Manson - Hafered extrapolation parameter P_{MH}, is calculated with the relationship:

$$P_{MH} = \frac{T - T_a}{\log t - \log t_a} \quad (3)$$

In order to estimate the strength for a large functioning period, a parabolic regression curve is plotted, in P_{MH} - $R_{r/t}$ coordinates, where:

$R_{r/t}$ - long term fatigue limit;

t - time elapsed until failure.

For the experimentally - determined points, by means of the least squares method, the following equation is obtained

$$\log R_{r/t} = 2.08163 - 0.0236415 \cdot P_{MH} - 0.000569825 \cdot P_{MH}^2 \quad (4)$$

For 20,000 functioning hours at 540 °C, after these tests, the Manson - Hafered parameter be comes:

$$P_{MH} = \frac{813-603}{\log 20000 - 8.6} = -48.84$$

Corresponding to the above value of the Manson - Hafered parameter, it follow that $R_{r/20000} \approx 80$ MPa.

This value is close to that obtained by the Larson - Miller extrapolation.

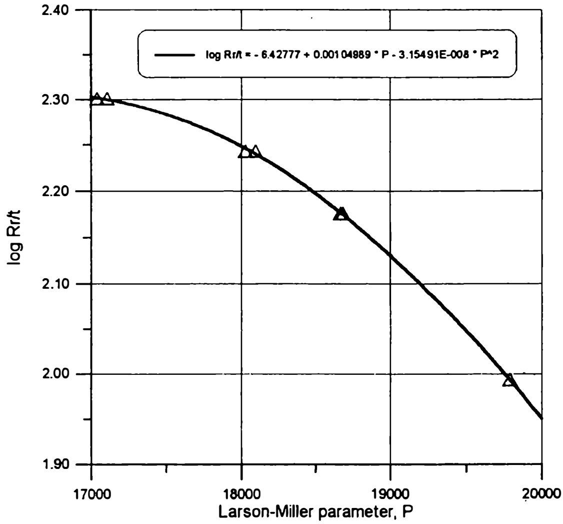


Figure 4. Variations of log $R_{r/t}$ with Larson - Miller parameter.

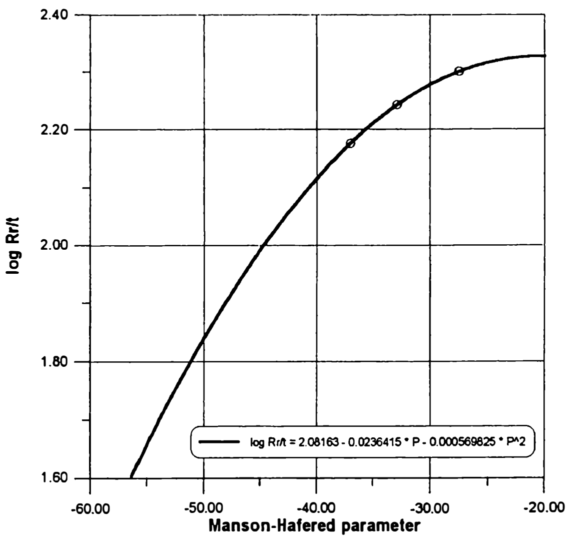


Figure 5. Variations of log $R_{r/t}$ with Manson - Hafered parameter

Figure 5 presents the logarithm of long term tensile strength as a function of Manson - Hafered parameter.

Manson - Hafered extrapolation, employed for estimating the long term tensile strength, leads to a lower but close enough value to that obtained by the Larson - Miller method.

3. Conclusions

On the basis of the analyses and tests done on the samples taken from a steam pipe - line ∅ 219 x 20, the following conclusions can be drown:

- the matallographic analyses shows at the grains boundary the presence of some precipitates formed as a consequence of long working period at high temperatures of the steel; still, the material doesn't present an advanced degree of structural degradation, the precipitates consolidating the steel used in creep conditions, even though the mechanical and thermal impacts strengths are diminished;
- the results of tensile tests, Charpy notch impact tests and the hardness tests at different temperatures indicate no significant steel degradation;
- the Larson - Miller extrapolation of the results obtained from the creep tensile rupture tests allow the evaluation of tensile strength at for 20 000 hours and working temperature 540°C, $R_{r/20\ 000} = 98.6$ MPa ≈ $R_{r/100\ 000} = 100$ MPa;
- the Manson - Hafered extrapolation of the results obtained from the creep tensile rupture tests allow the evaluation of tensile strength at for 20 000 hours and working temperature 540°C, $R_{r/20\ 000} = 80$ MPa < $R_{r/100\ 000} = 100$ MPa;
- the use for another 20 000 hour of the studied pipe - line requires the avoidance of all mechanical and thermal impacts and it also imposes new testing at the end of this working period.

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