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THE EXPERIMENTAL ANALYSIS REGARDING THE EVOLUTION OF SOME MECHANICAL CHARACTERISTICS FOR A STEEL USED IN CONSTRUCTIONS OF CONDUITS FOR STEAM TRANSFER

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ABSTRACT

The metallographic analysis [4], revealed that the initial ferrite-pearlite structure of the steel under study shows slight tendencies for coalescence, decarburation and carbide precipitation. The precipitating carbides maintained their globular shape being located on the grain boundaries. Due to the metallurgical degradation, the mechanical degradation occurs as a consequence of both cavities and microcracks formation processes. Based on the values determined for the mechanical characteristics of the pipe under study it has been concluded that the material is suitable for continuing the service and has marked resistance reserves. These reserves have been explained by the absence of the marked processes of grain boundary decarburation and the carbide network formation.

KEYWORDS: low alloy steel, metallurgical degradation, irreversible structural phenomena

1. Introduction

The present paper aims to derive the influence of both the functioning time and the service temperature on the mechanic and elastic characteristics of 15123-CSN steel. Likewise, the structural changes are analyzed in the above steel when used in the steam pipes of the kettles from thermal power stations.

Based on the test results, it will be found out if whether the structural changes as well as those produced in the mechanic and elastic characteristics still allow or not for the piping to be kept in service.

2. Experimental part

The specimens were taken from longitudinal and transversal sections of 15123-CSN steel pipes that initially had the same dimensions and served under the same service temperatures and pressures as already reported [1].

The specimens have been analysed in initial state and after two different functioning periods namely 35789 and 58371 functioning hours, respectively. The experiments consisted in mechanical tests and metallographic analyses.

The mechanical tests comprised tensile, toughness and hardness tests and were performed in accordance with the Romanian norms for special equipment ISCIR C29-67. Both the entire procedure and the test temperature have been mentioned in the previous study [1].

The metallographic analysis has been performed by means of an optical microscope at magnifications ranging from 100:1 to 1000:1. The specimens have been carefully prepared, without damaging the inner and outer edges of the wall thickness and etched with a solution of 2 % HNO_3 in alcohol.

3. Results and discussion

The standard and the experimental values of the ultimate stress are listed in Table 1.

Table 1. *The standard and experimental values of the ultimate stress, Rm, [MPa]*

Functioning hours	Source of data	Posi-tion	Test temperature, (ºC)						
			20	510	540	560	565	570	
	S	T	450-460	180 at 500ºC		150 at 550ºC		82 at 575ºC	580
		L	450-460						
0	E	T	671.9	485	438.8	425.6	418.2	411.2	410.3
		L	704	533.9	496.7	481.2	469.2	460.1	459.5
35789	E	T	451.8	221.2	195.6	190.8	175.3	174.4	155.4
		L	461.3	235.8	201.5	195.6	183.2	178.2	168.7
58371	E	T	541.2	325.8	219.3	201.6	199.3	190.5	155.6
		L	560.8	356.4	301.7	241.2	236.2	201.6	196.8

The standard and the experimental values of the yield stress, under the same conditions regarding the functioning periods and the test temperatures are listed in Table 2. Finally the standard and experimental values of Brinell hardness are shown in Table 3.

Table 2. *The standard and experimental values of the yield stress Rp0.2, [MPa]*

Functioning hours	Source of data	Posi-tion	Test temperature, (ºC)						
			20	510	540	560	565	570	580
	S	T	min 300	95 la 500ºC		80 la 550ºC			75
		L	min 300						
0	E	T	526.2	392.1	362.5	335.6	320.7	318.3	315.8
		L	575.3	419.9	392.5	390.2	391.9	385.3	369.2
35789	E	T	311.3	210.6	209.8	183.2	180.6	179.2	169.5
		L	315.7	217.8	218.9	191.5	190.5	181.4	175.3
58371	E	T	361.3	268.9	231.2	214.5	211.3	209.5	201.4
		L	381.4	305.6	248.3	235.9	226.4	218.3	215.6

Table 3. *The experimental values of the Brinell hardness, HB*

Functioning hours	Source of data	Posi-tion	Test temperature, (ºC)						
			20	510	540	560	565	570	580
	S	T	1350-1830						
		L	1350-1830						
0	E	T	2107	1997	1901	1895	1826	1799	1631
		L	2127	1997	1905	1898	1826	1805	1683
35789	E	T	1385	1187	1113	1106	997	905	889
		L	1397	1200	1117	1115	1095	985	908.7
58371	E	T	1365	1201	1195	996.8	991.5	875.4	796.2
		L	1385	1209	1201	1110	999.8	998.5	865.9

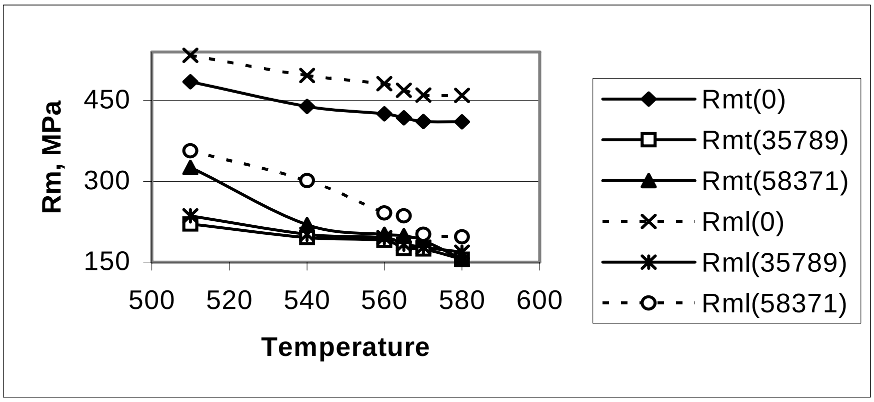

Fig.1. *Evolution tendency of the ultimate stress with test temperature and functioning period*

As noticeable, no standard hardness values have been found for elevated temperatures [2]. In the tables the symbols specify if the values are taken from standards (S) or are experimentally determined (E) and if the specimens were taken from longitudinal (L) or transversal (T) sections.

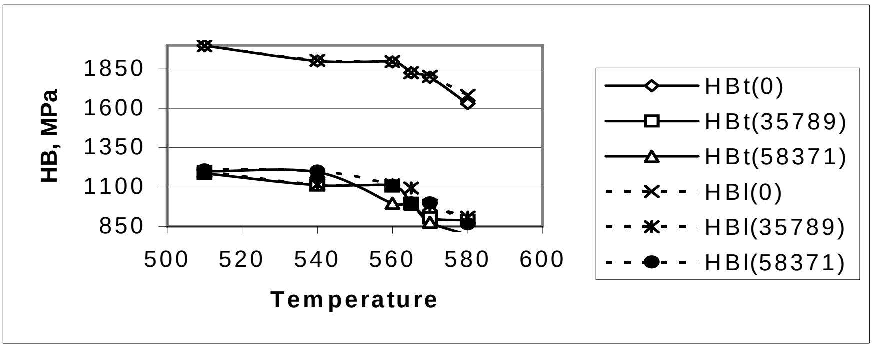

Fig.2. *Evolution tendency of the yield stress with test temperature and functioning period*

The metallographic analysis revealed that 15123-CSN steel had a prevalent ferrite structure that includes up to 10 % pearlite [3]. The ferrite grains have rather uniform shapes and sizes along the wall thickness section. The grain sizes have been determined as 6-7, 7-8 and 8-9 according to the Romanian standard STAS 5490-80. In the area located at the interior of the wall thickness a coalescence process is noticed at the ferrite grains that reach a grain size of 5. At the magnification of 100:1 no carbide precipitation has been noticed.

The decarburation process is metallographically noticeable on both sides of the wall thickness reaching a 0.3-mm depth in certain areas. No corrosion has been observed since the pipe shows an inner oxide layer with variable thickness that obviously differentiates from the rest of the structure. On the micrographs recorded at the magnifications 500:1 the same uniform structure has been observed that shows however some coalescence areas.

The carbides have mostly globular shape and are located on the grain boundaries. Yet in some areas the tendency to form a carbide pellicle has been observed. In the coalescence zones the carbide formation process is intensified but the carbides maintain their globular form and their intergranular preferred distribution. The same aspects have been observed at the magnification of 1000:1 regarding both the globular carbide distribution along the ferrite grain boundaries and the intensification of the carbide formation process in the coalescence zones.

The results of the mechanical tests are summarized in Figures 1, 2 and 3 that show the evolution of ultimate stress (R_m), yield stress ($R_{p0.2}$) and Brinell hardness (HB), respectively with the test temperature and the functioning period. The curves have been plotted by the interpolation of the data found in the above three tables [4]. Here again the symbols t and l designate transversal and longitudinal sections, respectively.

The study of the variations of the mechanical properties with temperature emphasizes that, as compared to the data found in standards, the material has a large reserve regarding the ultimate stress R_m.

4. Conclusions

1. In the case of the pipe under study it has been concluded that the material is suitable for continuing the service and has marked resistance reserves. These reserves are explained by the absence of both the grain boundary decarburation process and the carbide network.

2. The interpolated variation tendencies of the mechanical characteristics R_m, $R_{p0,2}$ and HB as a function of temperature, allowed to predict the functioning time under safe service conditions, of the pipe under study. A fair precision level has been attained for the functioning time prediction, due to the low values of maximum deviation of the interpolated curves as compared to the experimental ones.

3. The metallurgical degradation has been caused generally by the structural degradation and particularly by the fluctuations of the precipitates and the alloying elements within the metal matrix. These degradation processes lead to intergranular erosion by cavitation that causes the fragile failure of the steels at elevated temperatures. The mechanical degradation occurs as a consequence of both cavities and microcracks formation processes.

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