THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI.
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
N^0. 2 – 2011, ISSN 1453 – 083X

THE INFLUENCE OF BOTH FUNCTIONING TIME AND THE SERVICE TEMPERATURE ON THE MECHANIC CHARACTERISTICS AND METALLOGRAPHIC STRUCTURE OF SOME STEELS

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ABSTRACT

The paper determines the influence of both functioning time and the service temperature on mechanic characteristics of 12H1MF steel. In this purpose, the results of mechanical tests, performed at temperatures ranging from 510 to 590^{0}C, have been correlated with those of the optical microscopy analysis.

Due to the prolonged exposure to high temperatures, a slight degradation of the mechanical behaviour has been noticed that has been ascribed to the structural changes produced during functioning. The microstructural study of the steel has emphasized that after prolonged functioning several irreversible changes have occurred such as the increase of the ferrite grains, the dispersion of pearlite areas as well as the precipitation and coalescence of carbides. Yet, since neither decarburation nor network formation tendencies for the precipitated carbides have been observed, it has been concluded the 12H1MF steel can be kept in service even after more than 71000 functioning hours in live steam, at temperatures of 570^{0}C and pressures of 155 atmospheres.

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

1. Introduction

It is well known that, with increasing the temperature and the functioning time at elevated temperatures, structural changes occur within the metallic materials that alter their mechanic and elastic characteristics [1]. The present paper aims to derive the influence of both the functioning time and the service temperature on the mechanic and elastic characteristics of 12H1MF steel. In this purpose, the structural changes will be analyzed in the above steel when used in the steam pipes of the kettles from thermal power stations. In addition, the functioning time of the piping will be predicted under safe service conditions.

2. Experimental part

The specimens were taken from longitudinal and transversal sections of 12H1MF steel pipes that initially had the following dimensions: 865-mm length, 273-mm diameter and 36 mm wall thickness. The service temperature and pressure of the piping from which samples have been taken were: T = 540^{0}C and p = 155 atmospheres, respectively. The specimens have been analyzed after three different functioning periods: 0 functioning hours, 29867 functioning hours and 71409 functioning hours. The experiments consisted in mechanical tests and metallographic analyses.

The mechanical tests comprised tensile tests, dynamic shock tests and Brinell hardness tests.

Tensile tests were performed on a VEB 500KN tensile testing machine, at the following temperatures: 20^{0}C, 510^{0}C, 540^{0}C, 560^{0}C, 565^{0}C, 570^{0}C, 580^{0}C. The main tensile mechanical characteristics are: the yield stress ($R_{p0.2}$) and ultimate stress (R_m)

Dynamic shock tests were performed on MK30 Amsler pendulum, in order to determine the toughness designated by KCU30/2/10, at the following test temperatures: 20^{0}C, 510^{0}C, 540^{0}C, 560^{0}C, 565^{0}C, 570^{0}C, 580^{0}C.

These tests allowed observing the macroscopic structural aspect of the material.

The results are merely qualitative since they did not reveal any quantitative information related to the purpose of the paper.

Brinell hardness, designated by HB 300/10/15, has been determined at the same test temperatures as above, by means of a universal hardness tester type AB-1.

All the three testing apparatus were equipped with heating chamber able to automatically adjust the temperature.

3. Results and discussion

The experimental results of the mechanical tests are listed in Tables 1, 2 and 3 that contain the values of ultimate stress (R_m), yield stress ($R_{p0.2}$) and Brinell hardness (HB), respectively [2]. In the tables the symbols specify whether the values are taken from standards (S) or are experimentally determined (E) and whether the specimens were taken from longitudinal (L) or transversal (T) sections.

Table 1. *The standard and experimental values of the ultimate stress*

Functioning hours	Source of data	Position	R_m [MPa]						
			Test temperature [ºC]						
			20	510	540	560	565	570	580
	S	T	min 450	190 at 500ºC	110 at 550ºC				85 at 575ºC
		L	min 450						
0	E	T	594	403.6	357.9	347.5	350.8	335.4	321.1
		L	600.1	387.9	365.4	355.8	341.4	338.9	325
29867	E	T	501.3	285.6	275.8	254.6	248.9	230.6	225.1
		L	515.6	301.2	295.6	275.8	265.6	245.9	215.8
71409	E	T	465.9	255.6	245.8	238.9	225.6	215.6	201.9
		L	470.2	260.2	258.9	239.2	235.6	231.2	226.4

Table 2. *The standard and experimental values of the yield stress*

Functioning hours	Source of data	Position	$R_{p0.2}$ [MPa]						
			Test temperature (ºC)						
			20	510	540	560	565	570	580
	S	T	min 250	110				65 at 575ºC	
		L	min 260						
0	E	T	380.6	323.6	312.2	312.8	299.9	284.5	273.2
		L	399.4	316	313.6	309.7	303.3	295.7	268.4
29867	E	T	345.8	248.5	235.2	225.8	216.9	195.3	187.2
		L	355.6	250.6	240.6	238.3	225.6	224.8	206.9
71409	E	T	301.4	175.6	165.3	161.2	159.6	143.4	131.2
		L	315.8	180.1	170.2	169.3	161.5	148.9	135.6

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

Functioning hours	Source of data	Position	HB [MPa]						
			Test temperature (ºC)						
			20	510	540	560	565	570	580
0	E	T	1584	1462	1409	1405	1329	1318	1200
		L	1612	1514	1461	1385	1313	1301	1205
29867	E	T	1426	1170	1145	1101	995	896	805
		L	1461	1191	1160	1109	997	875	853
71409	E	T	1368	1045	1001	976	896	848	746
		L	1376	1099	1036	1021	946	935	902

The metallographic analysis revealed that 12H1MF steel has a ferrite-pearlite structure [3]. The ferrite grains have uniform sizes and pearlite is mostly located on the boundaries of ferrite grains. Along the wall thickness, no variations of the grain size have been noticed. Both in longitudinal and transversal sections the grain size has been determined as N3-4 according to the standard GOST-10801-64. The decarburation process is not metallographically noticeable either in the interior or at the exterior of the wall thickness. On the micrographs recorded at the magnifications 500:1 and 1000:1 a slight precipitation of carbidic islets has been observed both inside the grains and along the grain boundaries. The carbides show a very reduced tendency to form a network. The results of the mechanical tests are summarized in Fig. 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. 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 a behaviour that agrees well with the general tendencies of high temperature low alloy steels.

As compared to the data found in standards it is obvious that the material has a large reserve regarding the ultimate stress R_m. For all the tests, the spreading of the partial values is very low for the same test conditions.

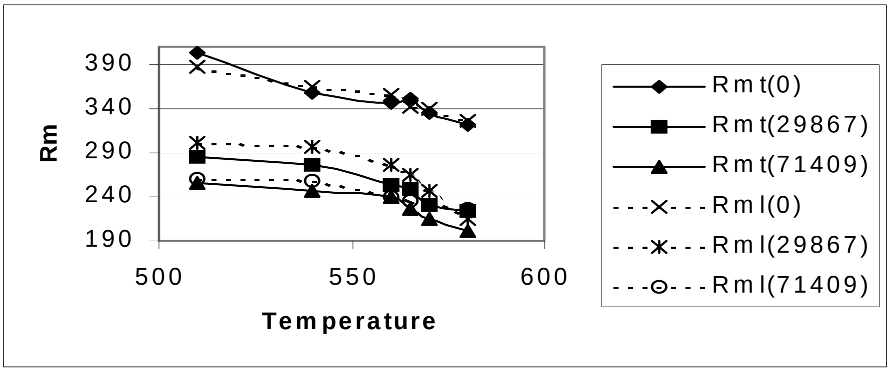

Fig.1. *Evolution tendency of the ultimate stress with test temperature and functioning period.*

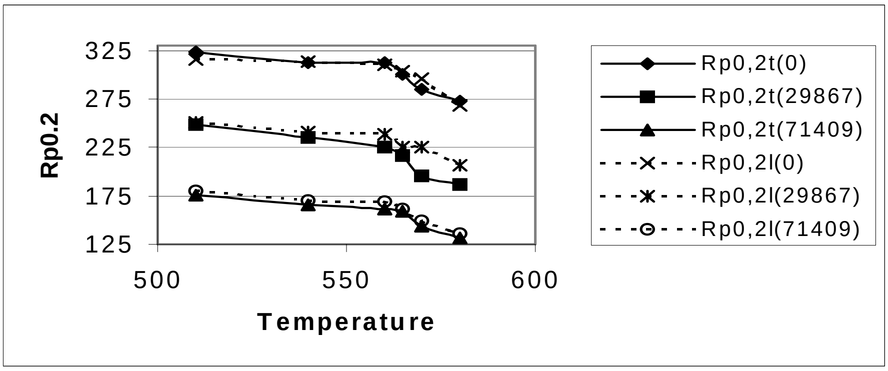

Fig.2. *Evolution tendency of the yield stress with test temperature and functioning period.*

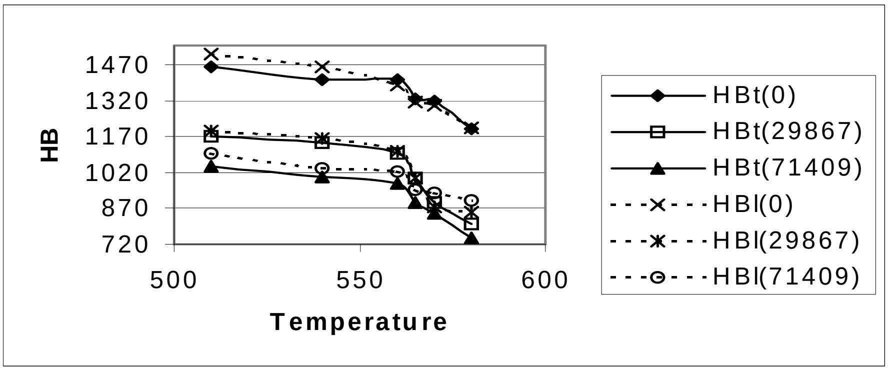

Fig.3. *Evolution tendency of the Brinell hardness with test temperature and functioning period.*

4. Conclusions

1. Based on the values determined for the mechanical characteristics in the case of the pipe under study, it may be 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. Based on the interpolated variation tendencies of the mechanical characteristics R_m, $R_{p0,2}$ and HB as a function of temperature, the functioning time under safe service conditions, of the piping from thermal power plants, can be predicted with high enough accuracy.

3. The structural changes that have been produced during functioning represent the cause for the alteration of mechanical characteristics. The microstructural study of the steel has emphasized that after prolonged functioning at high temperatures, metallurgical degradation has occurred comprising the increase of the ferrite grains, the dispersion of pearlite areas as well as the precipitation and coalescence of carbides.

References

[1]. Ailincai, G. and Mihai, D. – *Studies on the structural transformation stage of the steam piping materials of the kettles from thermal power stations* (in Romanian), Research contract no. 821-84. Beneficiary: CIPEET Bucuresti

[2]. Baciu.C. and Mihai, D. – *Studies on the structural transformation stage of the steam piping materials of the kettles from thermal power stations* (in Romanian), Research contract no. 49/2206-89. Beneficiary: ICEMENERG Bucuresti

[3]. *** Romanian standard STAS 2883/3-88 – Steels for high temperature pipes. Grades and technical quality conditions.