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Effect of the precipitation after improvement treatment on corrosion behavior L485Q grade steel

D. Berdjane[1], O. Ghelloudj[1], B. Maalem[1], L. Tairi[1], Y. Faci[1], S. Djemili[1], H. Amara Korba[2]

[1]*Research Center in Industrial Technologies CRTI, P.O. Box 64, Cheraga16014 Algiers Algeria*
d.berdjamel@yahoo.fr, *d.berdjane@crti.dz*
[2]*Ecole Nationale Supérieure Des Mines et Métallurgie ENSMM Annaba, Algérie–*

Abstract

High yield strength steels (HSLA) are microalloyed niobium, vanadium and titanium steels. They are known as dispersoidal steels with respect to elements forming stable insertion phases. The main structural constituents of these steels are: ferrite, perlite and secondary phases (carbides, nitrides). These steels are used in the as-rolled state or in the improved state for welded constructions and pipelines. Their intrinsic properties after thermomechanical rolling are obtained by hardening of precipitation and by refining. These compounds prevent any growth of grains during heating giving rise to fine grain structure. However, thermal and/or thermomechanical treatments applied to maximize the mechanical properties of these alloys can sensitize them to various modes of structural corrosion.

For this reason, we will follow the evolution of the metallurgical and electrochemical behavior of L485Q grade steel (Quenched and tempered) in relation to the effect of precipitation after thermal improvement treatments. We will do a final comparative study with the same grade of L485M Thermomechanical rolled steel according to the ISO3183 standard.

Thus, knowledge of the mixed influence of precipitation hardening and microstructural modifications resulting from heat treatments on the corrosion resistance is necessary to allow the desensitization of these alloys to this mode of damage, by introducing in particular a normative notion. imitates elasticity /corrosion resistance "among the many requirements.

Key words: HSLA grade steel L485, corrosion, precipitation, structure, thermomechanical treatment.

1. Introduction

The transport of gas and oil over long distances by pipeline requires the use of reliable materials that offer better mechanical strength, resilience and corrosion resistance. The basic material is microalloyed steel with Nb-V-Ti. The purpose of this work is to study the influence of precipitates on the corrosion behaviour of API5L grade L485Q dispercoid steels. The pipes are buried underground in places and are therefore exposed to corrosion to varying degrees depending on the nature of the environment. In this study, both the mechanical properties and corrosion behaviour of these steels were investigated in order to determine the optimal properties. Emphasis was placed on the effect of the precipitation of carbides, which play an essential role in the hardening of the material. Their influence on corrosion behaviour should be studied. To make a precipitation of different sizes of tempering at 550°C with maintenance times of 30, 60, 90 minutes were achieved.

The results obtained reveal a maximum hardness (resistance) for a treatment of 60 min at 550°C, On the other hand the best corrosion behaviour is obtained for a treatment of 90 min. The choice is made for the treatment that gives a better mechanical resistance with a relatively acceptable corrosion resistance. Many means of investigation and characterization have been used in this work. I quote metallographic analysis, mechanical tests for tensile strength, hardness, bending and electrochemical tests.

2. Material and methods

2.1. Choice of material

The studied material is high yield strength HSLA steel (grade API 5L grade L485M used for pipeline construction. The chemical analyzes of the samples of the "FRX-Ray Fluorescence Oxygen Cooling System" gave the results shown in Table 1.

Table. 1: Chemical composition and mechanical properties L485M raw rolled

	Content in chemical element in% by mass									
Sample code	**C**	**Mn**	**Si**	**P**	**S**	**V**	**Nb**	**Ti**	**Cu**	**Mo**
L485Q	0.07	1.58	0.35	0.014	0.003	0.08	0.057	0.004	0.022	0.009

2.2. Heat treatment cycle

In this work we made a quenching treatment at 1100°C (dissolution) to put the sample in the same structural state. Tracking of an tempering at 550 ° C for different holding times 30, 60 and 90 mn.

2.3. Mechanical characteristics of the raw state

Table 2 summarizes the results of the characterization tests (tensile, bend, thoughness and hardness) of hot-rolled grade L485M grade steel.

Table 2: Mechanical Properties of Rolled Raw L485 Steel.

Re (MPa)	Rm (MPa)	A (%)	Re/Rm	Hv Hardness
529	644	37	0.8	221

2.4. Micro hardness tests

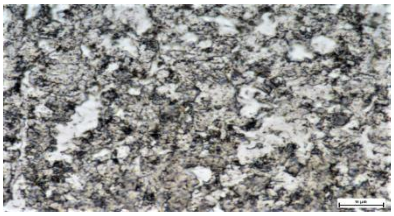
Micro hardness tests were carried out on samples taken from the tube. The results of Hv microhardness in different parts under a load of 5 Kgf are shown in Table 3.

Table 3: micro-hardness filaments on the pipes thermomechanical raw L485M steel and L485Q heat treatment steel

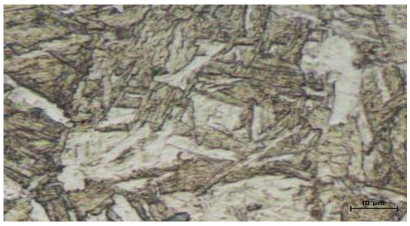
Sample code	Raw steel L485M	L485Q Tempering 30min	L485QTempering 60min	L485QTempering 90min
Hardness Hv	224	219	224	210

2.5 Metallographic examinations

Optical microscopic examinations of polished sections taken from tube samples at different magnifications revealed a fine ferrito-pearlitic structure with homogeneity of grain size and shape (fig.1).

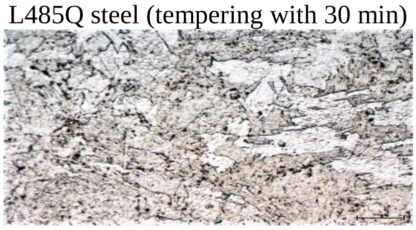


raw L485M steel



L485Q steel (tempering with 30 min)

L485Q steel X500 (tempering with 60 min)



L485Q steel X500 (tempering with 90 min)

Fig.1 : Microstructures of the thermomechanical raw L485M steel and L485Q heat treatment steel (X500)

The table 4 gaves the phase distribution (% Ferrite F, % Pearlite P) with an average grain size index (according to ASTM E1382-97, ISO643 and ASTM E112).

Table 4: Phases distribution and average grain size on the thermomechanical raw L485M steel and L485Q heat treatment steel

Designation	Structural Phases	Grain size (µm)
Raw steel L485M	F %77+P%23 (slow pearlitic transformation).	10.6
L485Q Tempering 30min	F%86+P%14 (pearlite in the form of troostite, faster transformation).	11.1
L485Q Tempering 60min	F %80+P%20 (pearlite (pearlite in the form of troostite, faster transformation).	10.7
L485Q Tempering 90min	F%91+09%P (pearlite in the form of troostite, faster transformation).	11.3

The observation of the structure by the optical microscope after the heat treatment means that more tempered at temperature T = 550 ° C proves that it type fine ferrite + pearlite (troostite).

2.6. Electrochemical study *and e*lectrochemical study and tests condition

The aim of this work is the evaluation of the kinetic parameters on a straight line of Tafel, during the corrosion of the raw microstructure of the raw L485M and L485Q steels observed by SEM and OM steel and after improvement treatment in a basic saline sodium chlorite (NaCl) medium. The latter is based on the plot of the polarization curves (logi = f(E)), taken from the main electrochemical equation of Buttler-Volmer. According to Tafel's hypotheses, anodic and cathodic polarization makes it possible to obtain curves with linear branches recognized under the straight name of Tafel. This linearity gives a proportionality between the potential and the current, which makes it possible to extrapolate the corrosion current, the corrosion potential, the corrosion rate, the anodic and cathodic Tafel coefficient and the polarization resistance. In our experiment, the electrochemical study was carried out by an Autolab, controlled by a microcomputer at the chemistry laboratory level at the research unit applied in the URASM / CRTI steel and metallurgy sector. Tthe conventional three-electrode assembly, a platinum electrode, a saturated calomel reference electrode, and the third working electrode, which represents L485 steel, were used. But before mounting three electrodes was immersed steel for one hour in a solution of NaCl 3.5%, to ensure the formation and stability of the electric double layer. Concerning the electrical impedance spectroscopy sweeping of the frequencies was carried out of the high frequencies (HF) (100 KHz) towards the low frequencies (BF) (10 mHz) with a sinusoidal perturbation of 1 mV of amplitude around the free potential. Polarization resistance measurements (Rp) were performed at scanning rate of 1 mVs-1. The measuring cell: the measuring cell used for the electrochemical tests is made of cylindrical pyrex glass with a volume of 250 ml with double thermostatic walls. The environment in which we tested the corrosion behavior of our L485 steel is a marine atmosphere characterized by a presence of chlorides. The evolution of the electrochemical behavior of L485 steel are realized by stationary and non-stationary.

3. Results and Discussion

3.1. Identification of nuance

Based on the results of chemical and mechanical characterizations, the base material forming the section of the seamless pipe is similar to a low-carbon microalloyed steel grade L485M according to the respective standards API 5L / ISO3183. It is classified in the category of high yield strength steels easily weldable [1, 2].

3.2. Comportement to the corrosion of L485steel

The parameters deduced from these polarization curves are summarized in Table 4. The behavior of L485 steel has a low resistance to corrosion in interaction with the surrounding medium (Table 5, fig.2).

Table 5: Parmeters of polarization curves of L485 steel in marine atmosphere

Paramètre	Ecorr (V)	Icorr (A/cm^2)	Corrosion rate (mm/year)	Polarisation (Ω)
Raw steel L485M	-0.52946	$1.1027*10^{-7}$	0,0012813	65049
L485Q Tempering 30 min	-0.52555	$1.0018*10^{-7}$	0,0011641	65191
L485Q Tempering 60 min	-0.55477	$9.8624*10^{-8}$	0,001030	62537
L485Q Tempering 90 min	-0.52614	$8.5663*10^{-8}$	0,0009954	64970

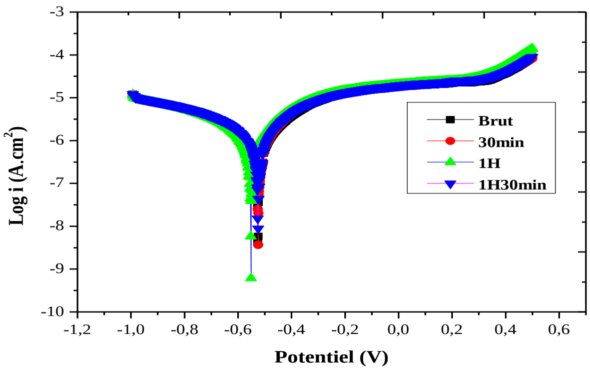


Fig. 2 : Polarisation curves of of the thermomechanical raw L485M steel and L485Q heat treatment steel

To study the mechanisms of corrosion and protection of metals [6]; the impedance spectroscopy method proved to be the most efficient tool. Figure 4 shows the Nyquist diagram Z of L485 steel at room temperature 25°C.

The shape of the curves shows us that with the size of the loop which decreases in parallel with the increase of holdins tempering time, we can deduce that the latter prevents the formation of film and thus blocks the adsorption of the oxides and the interface, the attack of chloride on the bare surface and thus the degradation of steel.

We note from this diagram that the size of the half circle increases with the increase in time holding of tempering, this phenomenon results from the protective layer (Table 6, fig.3) [3, 4].

Table 6: Parmeters of impedence curves of L485 steel in marine atmosphere

Nuance	CPE.YO (F)	Rp.R (Ω)	Rs.R (Ω)	CPE.N
Raw steel L485M	$9.1889.10^{-6}$	51238	12.315	0.99804
L485Q Tempering 30 min	$1.2593.10^{-5}$	38692	14.936	0.99778
L485Q Tempering 60 min	$1.3914.\ 10^{-5}$	35738	17.053	0.99797
L485Q Tempering 90 min	$1.5059.\ 10^{-5}$	34356	13.625	0.99782

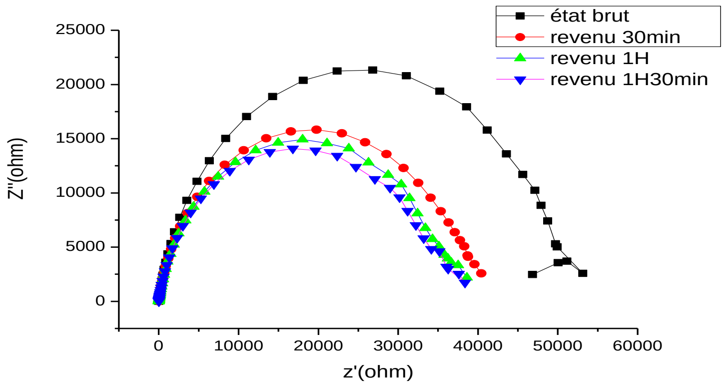


Fig.3 : Impedence curves of of the thermomechanical raw L485M steel and L485Q heat treatment steel

3.3 Precipitation examinations

At 600 ° C, a large number of precipitates of size of a few tens of nanometers is observed on lines of dislocations. Shows a detail of this microstructure: an alignment of precipitates along a dislocation. The image of figure 4 presented comes from an area close to an old primary precipitate, particularly rich in dislocations [5, 6, 7, 8].

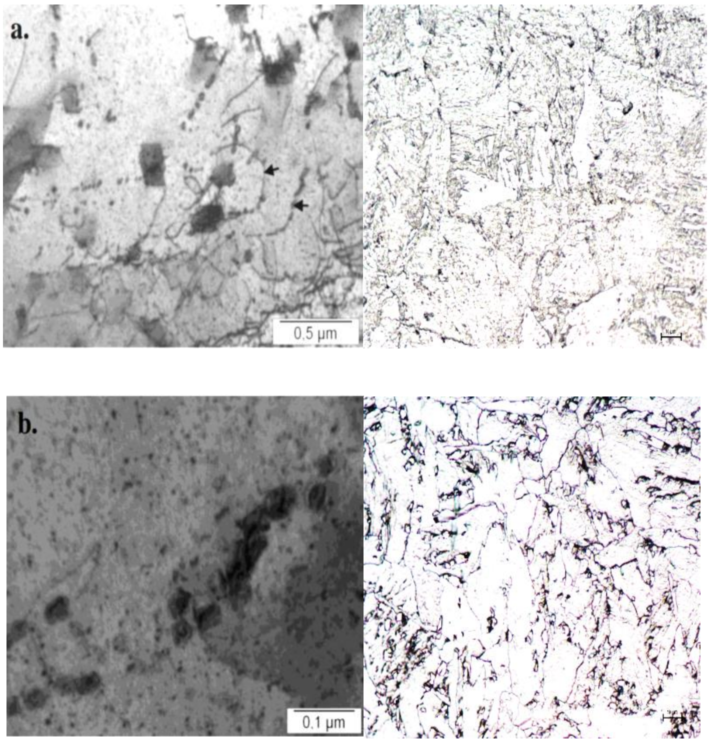


Fig. 4 : Large zone with two populations of precipitates, b. precipitation of NbC and VC on the dislocation lines for raw L485M and treated L485Q [9]

From the curve of variation of the hardness according to the treatment carried out, one interprets this variation as follows:

At first the temperature is softened, which results in the diffusion of carbon, it reacts with the Nb and begins to form niobium carbides. This is the case of a treatment of tempering for 30 minutes. Secondly, we have the growth and dispersion of these precipitated throughout the crystal lattice resulting in significant hardness, this is the case of a 60 minute tempering treatment. For the treatment of tempering having a holding time of 90 minutes, at this stage one reaches the phenomenon of coalescence which coalesces the precipitates to minimize the surface energy, for this purpose the movement of the dislocations becomes easy, which results in a hardness less [6, 7].

The table 4 shows that the shade that underwent a 60 minute tempering treatment with the highest pearlite phase (troostite) percentage, in addition to the lowest grain size results in the most severe hardness. The shading factor that has undergone an tempering of 60 min represents the most significant hardness that the other two grades that have gone through 30 min and 90 min tempering [2, 8].

It is to be considered that the troostite is a particular form of the perlite phase during the transformation of the austenite towards the perlite under cooling faster after martensitic transformation [8].

From the results obtained by comparing the values of the hardness and the rates of corrosion, it is found that the shade which has undergone at an tempering for an hour presents the most important value of the hardness. While its effect on the rate of corrosion is less. On the other hand we find the grade that has submitted to an tempering of 90 minutes shows the lowest corrosion rate that is to say the most resistant to corrosion but it has a low hardness.So we can see that the percentage of the precipitates plays an important role on the resistance to corrosion that means when one reaches the coalescence of the precipitates, that results a good resistance to the corrosion but a value of low hardness [1, 2, 4, 5].

4. Conclusion

The work has focused on the influence of precipitates on the mechanical properties and corrosion behavior of dispersoid steels. Raw rolling samples, quenched, quenched and returned at 550 ° C for 30.60 and 90 min showed maximum hardness for the sample returned at 550 ° C for 60 min. For a prolonged time the hardness decreases due to the coalescence phenomenon of the precipitates.

The corrosion tests reveal better behavior for the sample treated at 550 ° C. for 90 minutes.

A common treatment range to obtain both good mechanical strength and good corrosion resistance was not found. Mechanical strength is required in terms of choice for safety reasons. The corrosion that occurs very slowly affects the life of the tube, so it can be considered of relatively less importance

The results of the polarization curves of steel L485in marine atmosphere show that the electrochemical properties in this case potential, speed, polarization resistance are higher at raw thermomechaniacl L485M steel compared to heat treatment L485Q.

This deduction is supported by electrochemical impedance spectroscopy, which reveals that the size of the semicircle increases respectively to L485M, L485Q30, 60 and 90 min which reflects the behavior in resistance.

5. References

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