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Research on the quality of welded joints of P265GH heat-resistant steel pipes at electron beam mechanized welding

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This paper analyzes the quality of welded joints of high temperature resistant steel pipe at electron beam welding, knowing that the mechanical properties of these types of steels are influenced by the interaction of different processes specific to physical and mechanical metallurgy. Analyzing the values of the local hardening estimator ΔHV10 calculated between the characteristic areas of welded joints, it is observed that it has a decreasing tendency at thermally de-stressed joints, in all areas of the welded joints, especially in the welded seam.

Keywords: *pipes, heat-resistant steel, quality, creeping strength.*

1. Introduction

These steels must ensure high temperature resistance characteristics (creep), respectively ductility, especially elongation and necking, at high values, stable during the use of the metal structure [1]. In this sense, it is necessary to optimize the relationship between microstructure, microscopic deformation and macroscopic creep behaviour [2], [3].

An important mechanical characteristic is the strength of the steel, considered to be the property of the structure to oppose certain displacements of dislocations due to the applied stresses. Thus, the strength of the steel depends on the type and number of obstacles that hinder the displacement of the dislocations through the matrix [4].

These obstacles can consist of dislocation networks, loops of marginal dislocations, individual atoms and agglomerations of atoms, precipitates, cavities etc.

Under specific conditions, the strength of steel can be controlled or at least influenced by some of these obstacles, depending on the chemical composition and microstructure of the steel [5], [6], [7].

2. Experimental program

In the experimental program on mechanized electron beam welding of P265GH non-alloy heat-resistant steel pipes, the samples F1 and F1T were made of P265GH heat-resistant steel pipes, Φ 60.3 x 6.0 mm, 75 mm in length.

Following the preliminary experiments (U_a = 60 kV, I_s = 25...30 mA, D_t = 130...150 mm, F_o = 700...750 mA, v_s = 40 cm/min), the optimal parameters were established for the electron beam welding process (511), namely: welding current I_s = 28 mA, arc voltage U_a = 60 KV, firing distance D_t = 150 mm, focusing F_o = 740 mA, welding speed v_s = 40 cm / min.

After cooling, each electron beam welded butt sample was examined visually (with the naked eye and a 5X magnifying glass), the welded joints being of a suitable quality and without external defects [8], [9].

2.1. Post-welding heat treatment

The butt welded sample made of non-alloy heat-resistant steel type P265GH, Φ 60.3 x 6.0 mm (F1T) was subjected to a strain relief treatment according to Table 1. Figure 1 and Figure 2, show the visual aspects of the mechanized electron beam butt welded samples F1 and F1T. The joints did not show welding defects on the outer surfaces.

Figure 1. F1 butt welded sample, not heat treated.

Figure 2. F1T butt welded sample, heat treated.

Table 1. Stress relief treatment regimes parameters

Local stress-relief heat-treatment	Stress relief treatment regimes parameters							Steel type
	Temp min, [^{0}C]	Temp max, [^{0}C]	Rate of heating, [^{0}C/h]	Rate of cooling, [^{0}C/h]	Heating-up time, [h]	Holding time, [h]	Cooling time, [h]	
Welded sample heat treated	20	600	150	200	3,86	0,50	2,90	P265GH

2.2. Results of mechanical laboratory tests

a. The results of tensile tests on flat test pieces with calibrated area no. 1 and 2 taken from the mechanized welded buttocks with the F1 and F1T electron beam are centralized in Table 2. Figure 3 and Figure 4 show the specimens after the tensile tests.

Table 2. Results of tensile tests on flat specimens with the calibrated portion

Nr. sample	Nr. test	Test dimens. (S_0 x B_0), mm	F_{max}, N	R_m, N/mm^2	The place of rupture
F1	F1.1	5,9 x 12,1	34150	478	BM
	F1.2	5,9 x 12,0	32900	465	WELD
F1T	F1.1T	5,8 x 12,0	28600	411	WELD
	F1.2T	5,8 x 12,1	32300	460	WELD

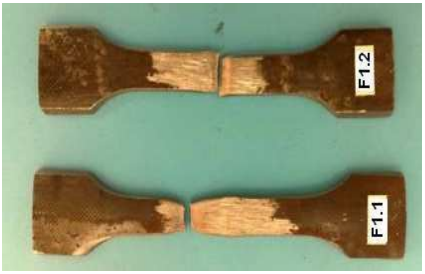

Figure 3. Broken test piece F1

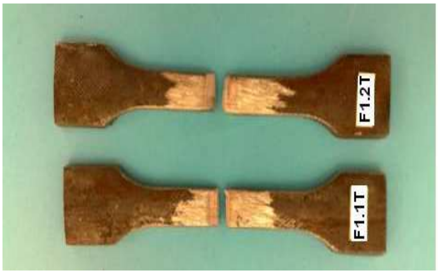

Figure 4. Broken test piece F1T

b. The macroscopic examination of the cross sections of the welded joints did not reveal macro cracks (Figure 5 and Figure 6) both on the welded samples without heat treatment and on those with heat treatment (TD1).

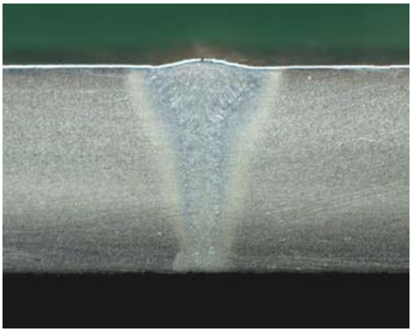

Figure 5. Sample F1, Nital 10%

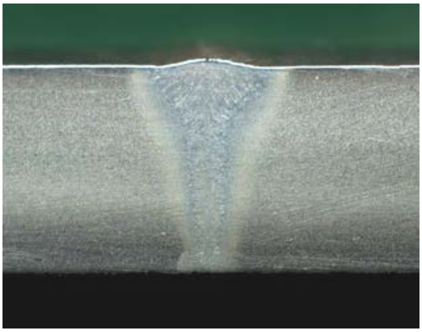

Figure 6. Sample F1T, Nital 10%

c. The microscopic examination revealed specific microstructures, namely: in the base material (BM_{right} and BM_{left}), ferrite-pearlite granular structures in rows, with alternating ferrite and pearlite bands, whose granulation is between scores 7-8, according to SR ISO 643: 2003 (Figure 7 and Figure 8).

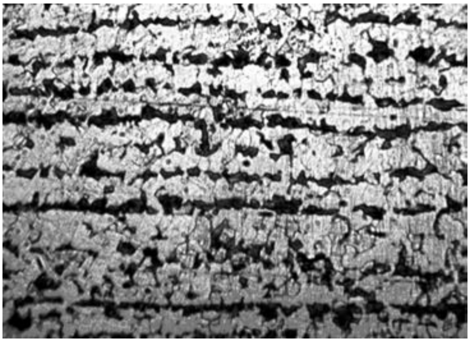

Figure 7. Sample F1, BM, Nital 2%, 100X

Figure 8. Sample F1T, BM, Nital 2%, 100X

In the WELD), pearlite-ferrite structures with inferior bainite and acicular ferrite, according to SR ISO 643: 2003 (Figure 9 and Figure 10).

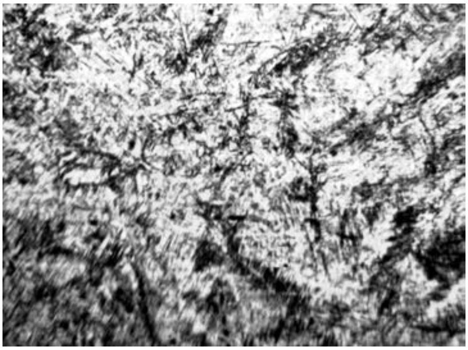

Figure 9. Sample F1, WELD, Nital 2%, 100X

Figure 10. Sample F1T, WELD, Nital 2%, 100X

In thermally influenced areas (TIZ_{right}, TIZ_{left}), pearlite-ferritie granular structures with granulations point 4-5 and areas with acicular ferrite, according to SR ISO 643: 2003 (Figure 11 and Figure 12).

The presence of acicular ferrite is greatly diminished in the heat-treated sample (Figure 12) attesting that the structural modification of the lower bainite is beneficial to the welding of non-alloy steel in reducing its hardness.

The microscopically examined areas did not show micro cracks.

Figure 11. Sample F1, TIZ, Nital 2%, 100X

Figure 12. Sample F1T, TIZ, Nital 2%, 100X

d. The mechanical Vickers HV10 hardness tests on test specimens no. 3, taken from mechanized butt welded samples with electron beam F1 and F1T, were performed according to SR EN ISO 6507 - 1: 2006 and SR EN 1043 - 1: 1997 in the characteristic areas of the welded joints (BM_{left}, BM_{right}, TIZ_{left}, TIZ_{right}, WELD) respecting the location of the hardness fingerprints. The experimentally determined Vickers HV10 hardness values are centralized in Table 3.

Table 3. Results of Vickers HV10 mechanical hardness tests

Point	Tried area	Sample F1	Sample F1T
1	BM_{left}	160	143
2		145	138
3	BM_{right}	162	141
4		144	150
5	TIZ_{left}	239	201
6		247	214
7		240	202
8	TIZ_{right}	263	228
9		233	225
10		241	238
11	WELD	325	251
12		326	247

Table 4 shows the values of the estimator ΔHV10 calculated between the characteristic areas of the welded joints made by the welding procedure 511.

Table 4. Values of the ΔHV10 estimator calculated between the characteristic areas of welded joints made by the welding process 111

Weld sample mark	Local hardening estimator ΔHV10, %			
	WELD – TIZ_{left}	WELD – TIZ_{right}	TIZ_{rt} – BM_{lt}	TIZ_{lt} – BM_{rt}
F1	25,46	28,52	45,24	41,29
F1T	9,16	10,36	40,76	35,51

The variations of the maximum Vickers HV10 hardness on the characteristic areas of the welded joints made of non-alloy heat-resistant steel pipes type P265GH are shown in Figure 13.

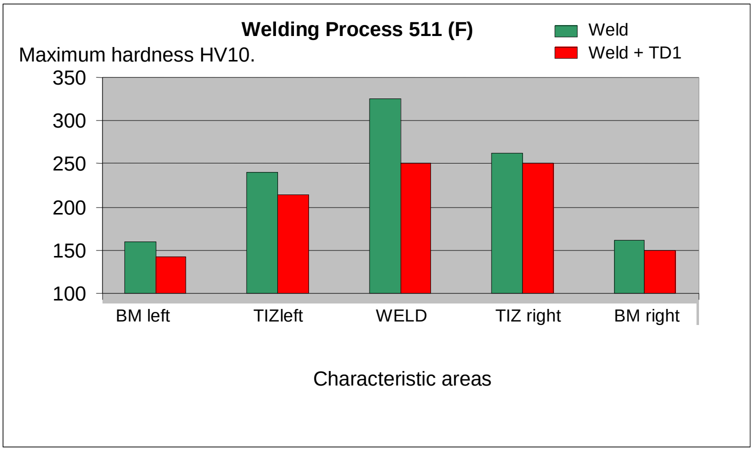

Figure 13. Variation $HV10_{max}$ = f (Characteristic areas)
at welded F1 şi F1T joints made by the process 511.

Conclusion

Following the tensile tests at 20° C, the macroscopic and microscopic analyzes and the Vickers HV10 hardness tests, the following conclusions can be drawn on the specimens taken from the F1 and F1T welded samples made of non-alloy heat-resistant steel P265GH:

The joints did not show welding defects on the outer surfaces.

Analyzing the variation of tensile strengths, we observe that they are higher than the value 410 N/mm^2 imposed by the norm EN 10216: 2 + A2 - 2007 for the analyzed steel.

In addition, even if three specimens broke in the weld, the determined tensile strengths are above the lower limit of the required tensile strength range (410… 570 N / mm^2) for the heat-resistant non-alloy steel.

The microscopically examined areas did not show micro cracks.

Maximum Vickers HV10 hardness's occur in the welds of welded joints (326 HV10 and 251 HV10), the application of thermal stress relief in the welded sample heat treated significantly reduces the hardness peaks of the characteristic areas and in the weld of the stressed area there is a decrease of Vickers HV10 hardness by 23.1% compared to undistensioned welding.

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