MICROSTRUCTURE AND MECHANICAL PROPERTIES OF MULTILAYER SUBMERGED ARC C - Mn WELDED METAL

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Twenty millimeters thick HSLA steel plates, symmetrical X groove prepared were welded in flat position with 4 layers using C - Mn wire and basic flux, at atmosphere conditions. Some of welded joints were stress relieved at 560 ^{0}C/2h. Transverse weld sections were machined and prepared for metallographic examination and microstructure of top bead and heated regions was examined. Microhardness measurement was carried out on metalographic specimens too. Charpy V-notch specimens were machined with notch near the weld center line and near coarse heated regions. Strength and ductility were examined using microspecimens machined from as welded regions parallel to welding direction and standard specimens from weld deposit at room temperature. Our examinations showed that there is difference in properties between as welded and stress relieved conditions of welded joints.

INTRODUCTION

Increased requirement of materials with improved characteristics (strength, fracture toughness) for different structures lead to a wide use of HSLA steels. But, in some cases it happens that welded joints from HSLA are the most critical parts of welded structures.

The main problem in welding of HSLA steels is behavior of microalloying elements into the base and weld metal (1). The basic conclusion about the role of microalloying elements is that their precipitated particles (carbides, nitrides or carbo-nitrides) suppress coarsening of austenite grains which enables high values of strength and toughness. Solved atoms of microalloying elements lower transformation temperature which contribute to the formation of transformation products in microstructure with a pretty low impact mechanical characteristics.

During arc welding, because of high temperature in HAZ, there is solving of microaloying elements which means coarsening of austenite grains and formation of low temperature transformation products which means worsening of fracture toughness.

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It is obvious too, that in arc welding, because of intensive mixing between base and weld metal atoms of microalloying elements into the weld. Solvent microalloying elements or reprecipitated particles during PWHT can worsen toughness of weld metal too.

Many investigators showed that lowering of delayed strength is very important to structure reliability of HSLA steels. Because of that many regulations anticipate PWHT of welded joints. But as PWHT can lead to the metallurgical changes and lowering of weld metal and HAZ toughness.

EXPERIMENTAL RESULTS

Experimental work is carried out to HSLA steel, NIOVAL 47. The plates of investigated steel, 20 mm thick were submerged arc welded in flat position with four passes. Welding was done with welding wire EPP3 and basic flux OP 121-TT. Shape and dimensions of groove are given in Fig.1. Welding was done without preheating because of two reasons, one because of steel producers recommendation and another because of the fact that successful welding without preheating means great facilitation for structure producers, especially in production of larger structures. Welding parameters are given in T.1. Complete chemical analyzses of the base metal, weld metal, and welding wire are given in T.2.

TABLE 1 - Welding parameters for four passes

	I	II	III	IV
U, (V)	26	26	28	28
I, (A)	640	670	550	550
v, (sm/min)	66	62	58	58

TABLE 2- Chemical analysis of base metal, (BM), weld metal, (WM), and welding wire, (a) - our analysis, (p) - producer analysis

	C	Si	Mn	P	S	Al	Mo	Ni	Nb	V
BM(p)	0.2	0.4	1.45	0.02	0.02	0.02				
BM(a)	0.19	0.39	1.5	0.02	0.01	0.03	0.03	0.2	0.06	0.06
EPP3(p)	0.11	0.2	1.5							
EPP3(a)	0.13	0.15	1.35	0.03	0.01					
WM(a)	0.14	0.35	1.49	0.01	0.01	0.02	0.05	0.2	0.03	0.04

Some welded plates were PWHT at temperature of 560^{0}C for 2h. Experimental welded plates were used to prepare probes for following investigations of the base metal, weld metal and HAZ in the AS weld and PWHT condition.

Metalography

Metalographic investigations were carried out in order to identify different regions of welded joint. Its macrostructure is shown in Fig.2. Fig.3 shows microstructure of a base metal and a partially transformed base metal. Fig.4 shows fine and coarse grained HAZ and weld metal. We can see a microstructure change from lamellar ferite-perlite (base metal), ferite-perlite-bainite (fine grained HAZ), bainite-martensite (coarse grained HAZ) and ferite-bainite (WM), all in AW condition.

Mechanical properties

Mechanical properties, strength and ductility, were investigated by standard specimens and microspecimens machined from base metal and different layers of weld metal. Average values of base metal and weld metal are given in T.3.

TABLE 3- Mechanical properties

	normalized state	AW	PWHT
BM	R_{eH} = 540 (MPa) R_m = 570 (MPa)		R_{eH} = 580 (MPa) R_m = 720 (MPa)
WM		R_{eH} = 735 (MPa) R_m = 840 (MPa)	R_{eH} = 775 (MPa) R_m = 840 (MPa

Microhardness

Some of specimens were PWHT at different temperatures of 520, 560, 600 and 640 ^{0}C, for 2h, in order to analyze influence of PWHT temperatures to microhardness values. Those measurements were done along three measurements lines, Fig2. In all cases there are higher values of microhardness in PWHT than in AW conditions. But the smallest difference in microhardness between AW and PWHT is for temperature 560 ^{0}C. Results from those microhardness measurements along L1 in AW and PWHT (560 ^{0}C) are given in Fig.5, and along L2 in the same conditions in Fig.6.

Impact toughness investigations

These investigations were carried out on standard Charpy V notch specimens in temperature range from 20 to -50 ^{0}C in the AS welded and PWHT conditions at 560^{0}C. We investigated impact toughness of base metal, with notch location parallel and normal to the rolled direction, weld metal and coarse grained of HAZ.

General conclusion is that PWHT lower impact toughness in all investigated cases. The most significant case is for weld metal, where lowering of toughness is even 50%. Results of toughness investigations for different materials are given in Fig.7 for AW conditions and in Fig.8 for PWHT.

CONCLUSION

Presented results show the negative influence of PWHT to the impact toughness and microhardness. Those influences are noticed in all regions in the weld joints.

Lowering of impact tougness in the HAZ and weld metal is the most prominent in temperature range between +20 and 0 ^{0}C.

The weld metal chemical analysis shows that it contains some quantities of microalloying additions as a result of mixing between base and weld metal during the welding process. PWHT contributes for reprecipitacion of microalloying elements in the small coherent and fine disperged secondary particles. Those particles are very efficient barriers for moving dislocations. So they contribute for lowering of impact toughness but increase yield and tensile strength. In the same way we can explain increasing of base metal yield and tensile strength. This can be proved by the fact that normalised base metal can contain even 0.1%V,(3), which after PWHT reprecipitated into the base metal.

Microhardness values for all measuring lines have the same trend of increasing after PWHT. These results are in accordance with increased yield and tensile stre-ngth.

On the basis of the obtained results and their analyses the final conclusion is that PWHT does not always improves mechanical properties of welded joints. So the steel producers recommends to be attenttive about PWHT, for HSLA steel. So we can say that application of these steels for structure with obligatory PWHT is not justified.

The presented investigation and obtained results are part of a complex on going program which includes different materials and their welded joints, loaded in diffe-rent ways from the fracture resistance aspect. Probes with machined cracks have an important role in our investigations. In that sense special attention is devoted to the probes with the cracks located perpendicularly to the weld metal direction.

Besides comprehensive experimental investigations we are also treating the teoretical analysis using corresponding numerical estimation. In all of these investigations a multimaterial character of welded joints is included. So this paper presents the results of the investigation of different material components in HSLA. The obtained results can help us for more real inclusion of different weld joints regions into numerical estimations. So we hope that the comprehensive and very expensive experimental results could be diminished and reduced to the numerical analysis.

REFERENCES

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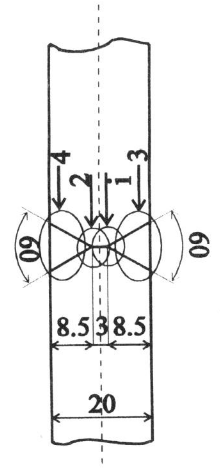

Figure 1 Shape and dimensions of weld joint

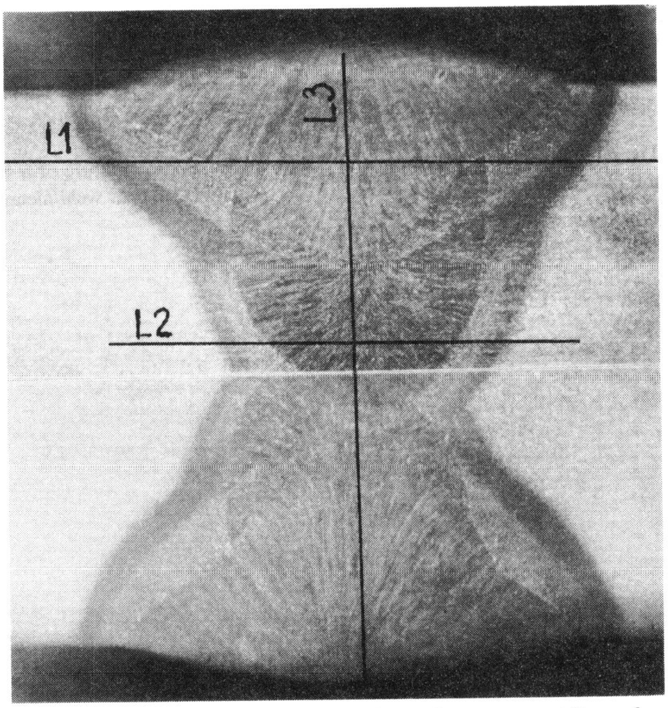

Figure 2 The macrostrukture of weld joint and measurement lines of microhardness, x5

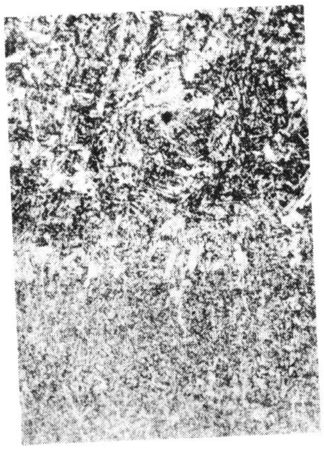

Figure 3 The microstrukture of a base metal and HAZ near base metal, x200

Figure 4 The microstrukture of a weld metall and HAZ near weld metal, x200

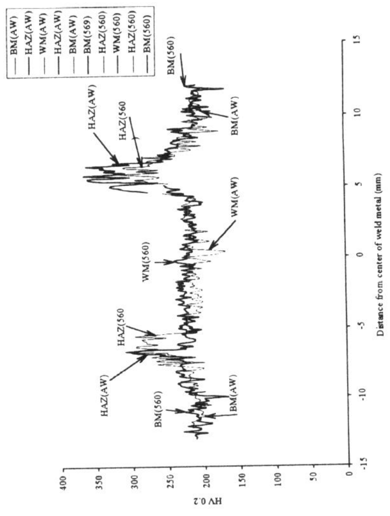

Figure 5 The microhardness along the line L1 (AW and PWHT)

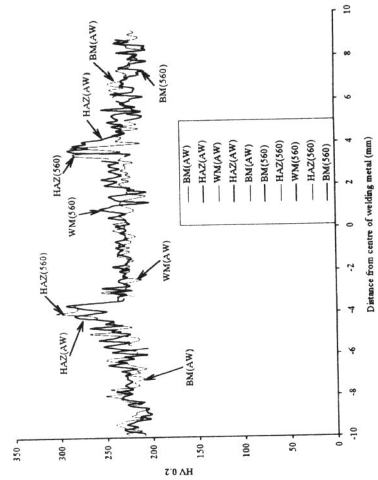

Figure 6 The microhardness along the line L2 (AW and PWHT)

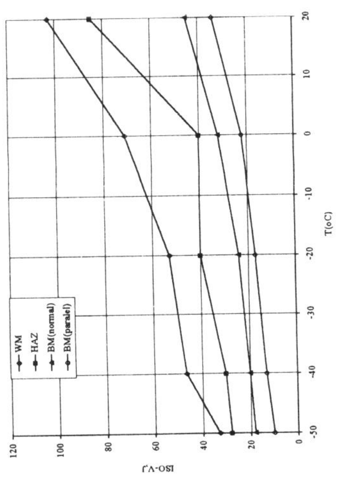

Figure 7 The impact toughness for (BM, WM,HAZ) in AW conditions

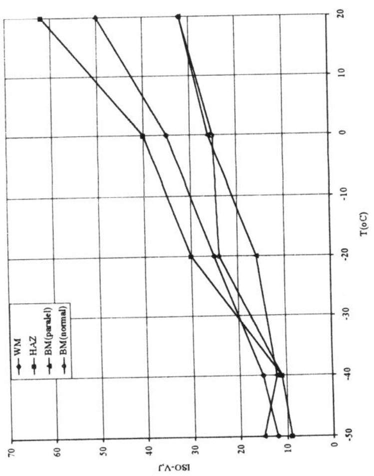

Figure 8 The impact toughness for (BM, WM,HAZ) in PWHT conditions