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Hardness and Microstructural Changes During Repaired Welding of the Pipes of Power Plant Kosova

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Abstract: In recent years, the demand for welded steel pipes of large diameter for oil and gas transmission (pipelines) over long distance was increased rapidly. One of the most economical ways of producing these steel line pipes is Double side Submerged Arc Welding process (DSAW) of previously hot rolled steel coils formed into a round shape by uniformly plastic deformation, having a double side single pass spiral weld entire length of the pipe. In order to continuously production, the tail end of the previous coils and lead of the incoming coils are sheared and welded together on one side single pass in the transverse direction of the coils length and this welded joint is called transverse or scalp end weld. In the absence of the outside weld pass of this weld joint must be completely repaired by Manual Arc Welding process (MAW) and controlled on the purpose to increase the reliability and quality of the welded pipes. The objective of this study is to determine hardness distribution within repaired transverse welded joint in vanadium micro alloyed X65 steel pipes. This is achieved by careful hardness measurements (HV30/15 and metallographic examination of selected specimens, extracted from the repaired transverse welded joints in vanadium micro alloyed X65 steel pipes Ø 812.8×12 mm. Hardness distribution within repaired welded joint has its own hardness range and meet all the standard requirements of API 5L-X65.

Key words: Hardness distribution, pipelines, plastic deformation, welded joint, welding process, vanadium steel

INTRODUCTION

The microstructure produced in a weld deposits is very complex and may contain several phases and hence has pronounced effect on the mechanical properties, such as hardness, strength and toughness. The microstructure of the double sided welds joint is generally non-uniform, being composed of areas of as deposited weld metal (first weld) and areas that have reheated by subsequent pass (second weld).

The hardness values within double sided submerged arc weld metals are different and depend to the exact positioning of the measurements.

Research on the weld metal microstructures has evolved along different lines when compared against the mainstream of steel research and there are considerable difficulties in identifying microstructural constituents which differ in transformation mechanism (Taylor and Farrar, 1975; Dolby, 1983).

The interrelation of microstructure and properties is an important factor in any investigation of the behaviour of metals. Wed metal properties are mainly controlled by the microstructure in the low alloy steel welds (Ohkita and Hori, 1995; Bhadeshia *et al*., 1985; Sugden and Bhadeshia, 1988).

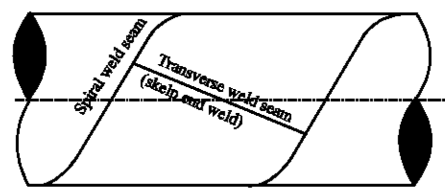

Fig. 1: Sketch of the weld joints of the welded line pipes

In practice, welded line pipes contains spiral weld entire length of the pipe and transverse or skelp end weld which joins coils together in the production line (Fig. 1).

Double sided single pass submerged arc weld seam and transverse weld or skelp end weld seam welded by submerged arc welding process before repair are given in Fig. 2.

Welded joint considered as heterogeneous parts whose global behaviour cannot be predicted precisely without a carefully analysis of each region. The effects of mismatch properties of the different sub-zones across a weld joint are therefore a field of considerable research efforts throughout the world.

Transverse weld or skelp end weld of submerged arc welded pipe must be subjected to repair in accordance with requirements of purchaser or API 5L standard. Repair welding procedure must be carried out in accordance with

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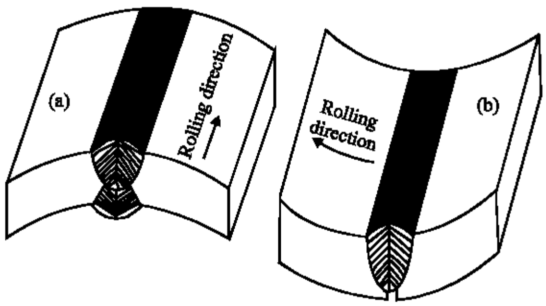


Fig. 2: a): Double sided single pass submerged arc weld seam and b): Transverse ore skelp end weld seam

requirements outlined in purchaser specification or in accordance with requirements outlined in API 5L standard.

By agreement between the purchaser and the manufacturer, transverse weld or skelp end weld in finished pipe may be permitted or prohibited i.e., the pipe section containing transverse weld or skelp end weld must be cut out from the pipe length. If transverse weld or skelp end welds are permitted for spiral welded pipes these weld after repair process must be inspected by the same methods as used for the spiral weld.

Because integral parts of the welded joint are located in a very small volume of the weld, only by hardness measurements is possible to determine the mechanical properties of these parts. Hardness is an important parameter for the evaluation of cold cracking resistance, strength, ductility, toughness and corrosion resistance.

MATERIALS AND METHODS

Materials and welding procedure: Spiral line pipes Ø 812.8×12 mm were fabricated using high strength steel coils X65 according to API (American Petroleum Institute) standard, which chemical composition and mechanical properties are given in Table 1 and 2.

Spiral line pipes Ø 812.8×12 mm were fabricated in two-stage process according to the BLOHM+VOSS, with welding parameters given in Table 3.

Repair welding operation were made by Manual Arc Welding (MAW) method by skilled and certified welders, using electrodes EVB 60, which mechanical properties are given in Table 4.

In repair welding, the decisive factors are the welding process used, the filler material added, the measure taken before, during and after welding. The weld joint preparation by grinding and typical bead placement welding pass sequence for the repair of transverse weld joint are given in Fig. 3.

Table 1: Chemical composition of microalloyed steel X65

	Chemical composition (weight-%)					
Steel coils	C	Mn	Si	P	S	V
653395	0.12	1.37	0.46	0.020	0.009	0.050

Table 2: Mechanical properties of microalloyed steel X65

	Mechanical properties						
	Re	Rm	A	KV_1	KV_2	KV_3	KV
Steel coils	------MPa------		(%)	------------ISO-V-0°C (j)------------			
653395	549	639	34.0	77.0	73.5	71.5	74.0

Table 3: Welding parameters

	Welding flux: LWF780 and Welding wire: S_2Mo					
	Inside (first pass-W_1)			Outside (second pass-W_2)		
	I	U	v	I	U	v
Spiral line pipe	(A)	(V)	(m min^{-1})	(A)	(V)	(m min^{-1})
Ø 812.8×12 mm	550-600	27-28	0.8	650-700	29-30	0.8

Table 4: Mechanical properties of the used electrodes EVB60

Mechanical properties			
Re (MPa)	Rm (MPa)	A (%)	KV (0°C, J)
522	624	26.0	92.0

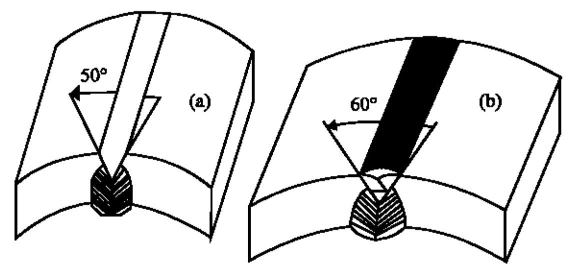


Fig. 3: (a) Preparation and (b) welding pass sequence of repaired transverse weld joint

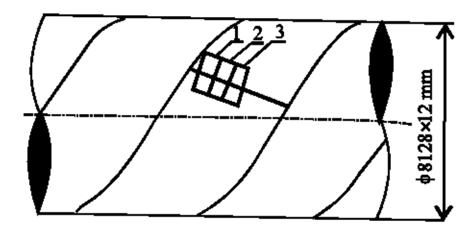
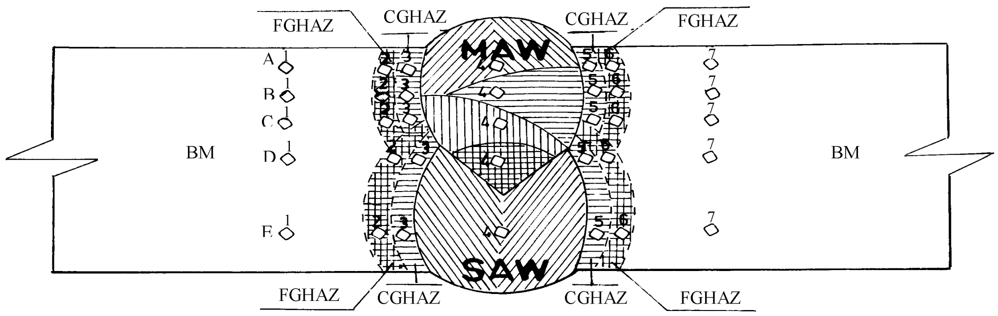


Fig. 4: Sketch illustrating the positions of the specimens for testing

Repaired weld is being verified by 100% radiographic test for weld imperfections after hydrostatic test with the required test pressure of 11.2 MPa.

Testing procedure: The specimens of the transverse weld joint were taken from the repaired transverse (skelp end) weld joint of Ø 812.8×12 mm line pipes (Fig. 4). The specimens were cut out from the repaired transverse weld joint of spiral line pipes Ø 812.8×12 mm,



Transverse (skelp end) weld joint of line pipes ∅813×12 mm							
Measurement directions	Spot marks						
	Manual Arc Weld (MAW)						
	BM	FGHAZ	CGHAZ	MAW	CGHAZ	FGHAZ	BM
A	1	2	3	4	5	6	7
B	1	2	3	4	5	6	7
C	1	2	3	4	5	6	7
D	1	2	3	4	5	6	7
	Submerged Arc Weld (SAW)						
	BM	FGHAZ	CGHAZ	MAW	CGHAZ	FGHAZ	BM
E	1	2	3	4	5	6	7

Fig. 5: Schematic illustrating of the directions and positions of hardness measurements

perpendicular to the welding direction. All specimens were wet ground and polished using standard metallographic techniques and etched in 2% Nital, for analysis with LOM (Light Optical Microscope).

Because weld joint properties are influenced by its macro and microstructure, Vickers hardness measurements (HV30/15) were made on different constitutive parts of the welded joint (BM-Base Metal, HAZ-Heat Affected Zone and WM-Weld Metal), using a diamond pyramid indenter with a 30daN load (HV30/15). Figure 5 shows the measurement directions and positions, where the hardness indentations were made within different constitutive parts of repaired transverse weld joint of spiral line pipes Ø 812.8×12 mm.

RESULTS AND DISCUSSION

Metallographic analysis: Light Optical Microscopy (LOM) is one of the most commonly used techniques for macrostructural and microstructural characterization in the development of weld metals. Macrostructure in Fig. 6 shows a typical cross section of repaired transverse (skelp end) weld joint with single pass Submerged Arc Weld (SAW) and Manual Arc Weld metal (MAW) of line pipes Ø 812.8×12 mm at low magnification.

The macrostructure of repaired transverse (skelp end) weld joint is generally non-uniform, being composed of areas of as-deposited weld metal with columnar grains and areas that have been reheated by subsequent pass and which are therefore, grain refined. From a metallurgical

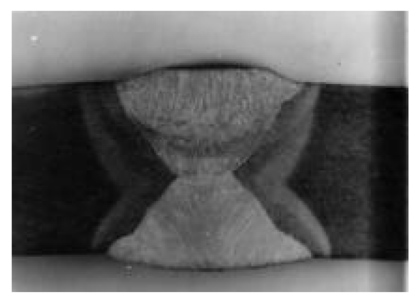


Fig. 6: Macrostructure of repaired transverse (skelp end) weld joint

point of view, these areas are normally defined by the peak temperature experienced at a certain distance from the fusion line during welding.

Figure 7 shows the microstructures of repaired transverse (skelp end) weld joint. The following characteristic are indicated: Base Metal (BM), the microstructure is composed of ferrite and pearled. MAW manual arc finish pass, the as deposited microstructure, where prior austenite grain boundaries are decorated with allotriomorphic ferrite, while the interior of the austenite grains is packed with acicular ferrite. MAW-manual arc first pass, the as reheated microstructure above the austenitization temperature. In this pass, the microstructure also was mostly transformed into austenite. SAW-single pass submerged arc weld, the as deposited microstructure also consisted of acicular ferrite delineated by grain boundary ferrite and polygonal ferrite located at the former austenite grain boundaries.

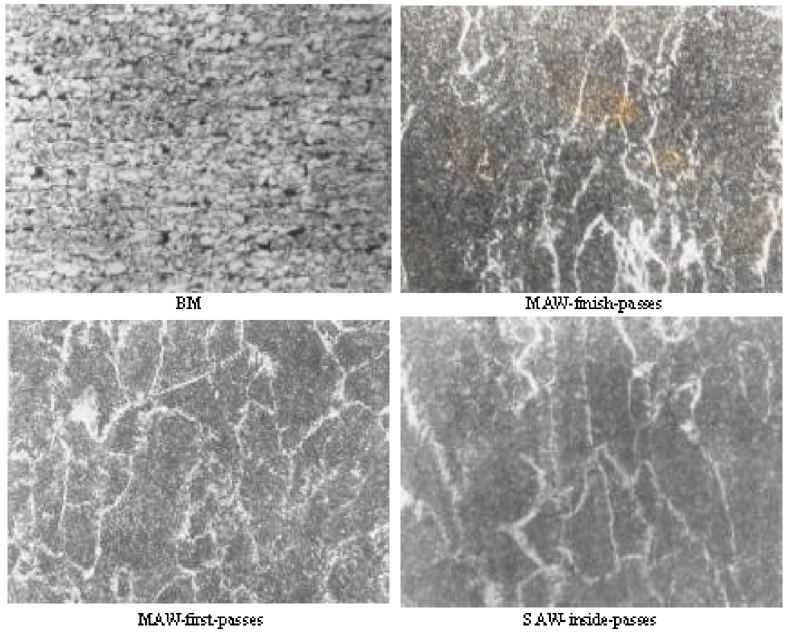


Fig. 7: Microstructures of transverse (skelp end) weld joint

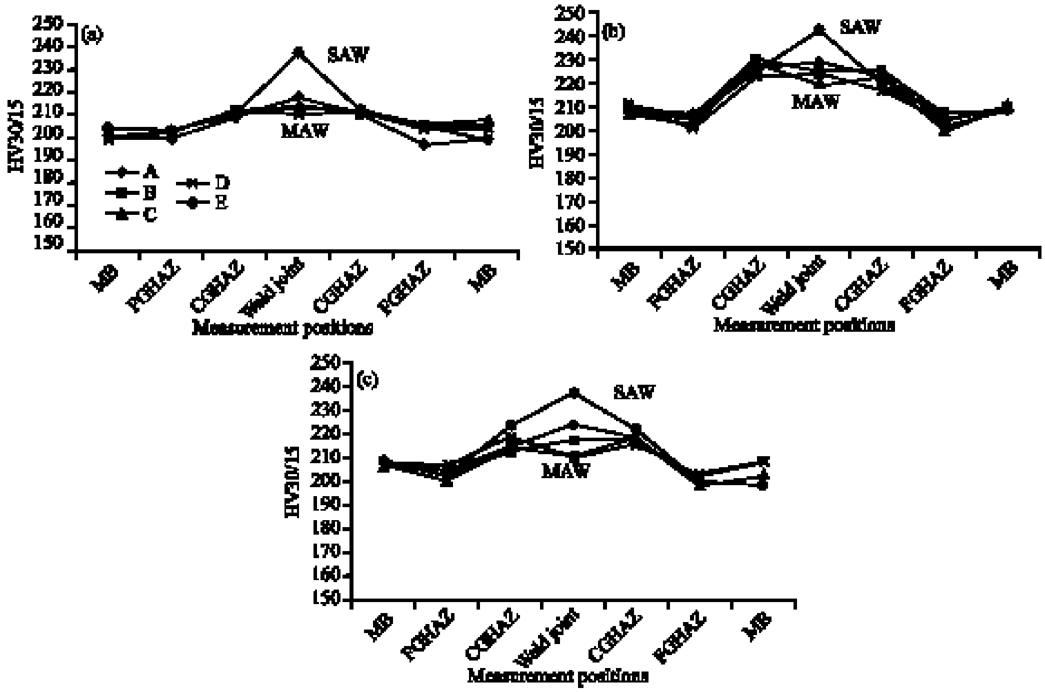


Fig. 8: Measured hardness profiles of repaired transverse (skelp end) welded joints

Hardness testing: Hardness surveys were carried out from the Base Metal (BM), across the Fine Grained Heat-Affected Zone (FGHAZ) and Coarse Grained Heat Affected Zone (CGHAZ) and into the Manual Arc Weld (MAW) and into the single pass Submerged Arc Weld (SAW), as schematically shown in Fig. 4.

The measured hardness values of three repaired transverse (skelp end) weld joint are shown in Fig. 8.

A comparison between the measurement directions reveals the same pattern in all specimens i.e., all measurement directions (ABCD) in Manual Arc Weld (MAW) has shown relatively lower hardness, while direction (E) in Submerged Arc Weld (SAW) shown higher hardness. The lowest hardness, 210HV/15 was recorded in the first pass of the Manual Arc Weld (MAW) in the specimens of the welded joint-1 and 3, while highest hardness, 242HV30/15 was recorded in the single pass Submerged Arc Weld (SAW) in the specimen of the welded joint-2. The resulting vickers hardness value at any point not exceeds allowable hardness (248 HV). These hardness values generally indicate that there is no martensite formation in the weld joint and no risk for cold and others cracking formation. Hardness profiles exhibits in all cases decrease in hardness between Manual Arc Weld (MAW) and single pass Submerged Arc Weld (SAW) of repaired transverse (skelp end) weld joint.

CONCLUSION

The basic results that can be drawn from this research are:

Repaired transverse (skelp end) weld joint of spiral line pipes Ø 812.8×12 mm consist of a single pass Submerged Arc Weld (SAW) and Manual Arc Weld (MAW).

The microstructure containing predominantly acicular ferrite in the as deposited welds was found to be relatively harder and tougher compared to microstructure containing predominantly proeutectoid ferrite and polygonal ferrite. Hardness distribution within repaired transverse (skelp end) welded joint in V-microalloyed X65 steel pipes shows that it varies to some extend and single pass Submerged Arc Weld (SAW) is harder than Manual Arc Weld (MAW), which can be attributed to the microstructure constituents and effect of the thermal welding history. This effect is associated with secondary hardening, probably due to precipitation of extremely fine particles of vanadium carbonitrides.

Hardness of the repaired transverse (skelp end) weld joint meets all the requirement of the API 5L standard.

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