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CHANGE OF PHYSICAL-METALLURGICAL PROPERTIES OF LOW-ALLOY STEEL 16Mo3 IN THE HEAT AFFECTED ZONE IN WELDING PROCESSES MMA AND MAG

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ABSTRACT

Low alloy steel 16Mo3 designed to operate at elevated temperatures has a very wide application in power plants. Increased requirements for quality and safety of welded joints in certain service conditions require achieving a series of mechanical and structural properties of welded joints. This paper presents the results of microstructure, grain size, hardness and impact test in the HAZ in the welded samples of thickness 10 mm are welded MMA and MAG. Hardness testing of welded joints according to standard BAS EN 1043-1 and microstructure examination in places where it tested the hardness of HAZ show some differences in the mechanical and metallographic properties of the applied welding processes.

Keywords: steel, microstructure, hardness, grain size, impact test

1. PREFACE

Increased requirements for quality and safety of welded joints in difficult working conditions, set strict requirements for achieving a series of welded joints. Changes in physical-metallurgical properties in the heat affected zone, among other things, reflected in the change of hardness, impact test (toughness), the microstructure and grain size in relation to the base material.

In the heat affected zone occurs of grain increase, which can be taken as one of the main degradation mechanism in welding, especially after input large amounts of heat. Grain growth in the heat affected zone depends on the type of steel and its chemical composition and previous treatment. The grain size significantly affects the toughness of heat affected zone. In the heat affected zone, the hardness is higher than the hardness of the base material and this change depends on the amount heat input and cooling rate.

2. TESTING MATERIAL

The base material is low alloy steel 16Mo3 with specified properties at elevated temperatures, according to standard BAS EN 10028-2:10 [1]. Prescribed chemical composition and impact fracture energy, and chemical composition of the sample sheet thickness 10 mm are given in table 1.

Table 1. Chemical composition and impact fracture energy steel 16Mo3.

16Mo3 WN 1.5415	Chemical composition, %											Impact fracture energy
	C	Si max	Mn max	P max	S max	Cu max	N max	Cr max	Mo	Ni max	CE*	
Prescribed BAS EN 10028-2	0,12 0,20	0,35	0,40 0,90	0,025	0,010	0,30	0,012	0,30	0,25 0,35	0,30	0,52	31 J
Sheet 10 mm	0,17	0,22	0,72	0,010	0,008	0,04	0,0056	0,09	0,28	0,05	0,37	-

*Carbon equivalent is calculated by the formula IIW

3. EXPERIMENTAL PART

The primary goal of this paper is research the influence of welding procedures for MMA and MAG on physical-metallurgical properties of steel 16Mo3, monitoring the relationship between the parameters: current, voltage and wire feed speed and obtained hardness and impact test in the heat affected zone.

3.1 Welding parameters

Preparation V notch in the sheet thickness 10 mm. In all samples, welding is performed with one root and two cover layers. The review of applied processes, welding devices, electrodes, interlayer preparation, preheating temperature and welding parameters are given in table 2 [2].

Table 2. Welding parameters.

Material	Process	Electrode	Device	Preh. °C	Interl. preparat.	No	Welding parameters		
							Voltage (V)	Current (A)	Wire speed (m/min)
16Mo3 WN 1.5415	MMA	EVB Mo Alkali	Fronius	130-150	Brushing	I	21,0-23,0	80-83	-
						II	19,5-23,0	80-82	-
						III	21,5-25,0	81-83	-
	MAG	Bohler CrMo1Si	Varstroj	130-150	Brushing	I	16,5-17,6	110-135	2,8-3,2
						II	26,0-27,0	230-245	6,8-7,8
						III	30,0-31,0	265-275	7,2-8,5

3.2 Testing of hardness and microstructure

Hardness testing of welding joints are performed in accordance to standard BAS EN 1043-1:09 [3], which specifies testing the hardness of the cross section of arc welded joints of metallic materials, the Vickers method in accordance with standard BAS EN ISO 6507-1, loading HV10. Hardness testing performed under ambient condition, temperature 23±5°C, was conducted on the device for testing the hardness and micro hardness ZWICK. Applied hardness test method is identification in a row, where the examination included basic material, heat affected zone and weld metal at a distance ≤2 mm from surface and 0,5 mm from fusion line. Schematic representation of butt welded joint with the locations of hardness testing and examination of microstructure is shown in Figure 1.

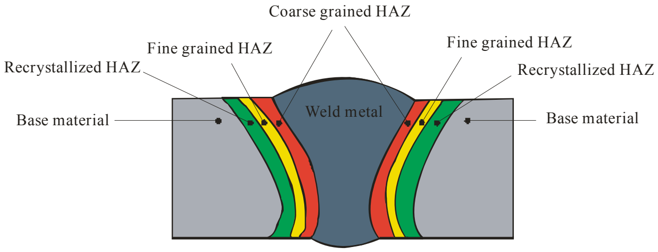
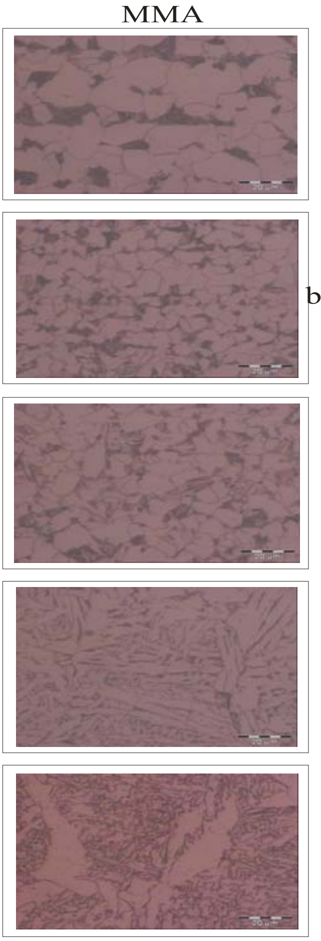


Figure 1. Schematics representation of butt welded joint with the locations of hardness testing and examination of microstructure.

Metallographic examination of butt welds is performed on optical microscope Olympus PMG3 with magnification x500. Examination of microstructure [4] was performed by etching in reagent NITAL (2%HNO_3) according to standard EN 1321:1997 [5]. Representative images of microstructure the base material, HAZ and weld metal are given on figures 2 and 3.



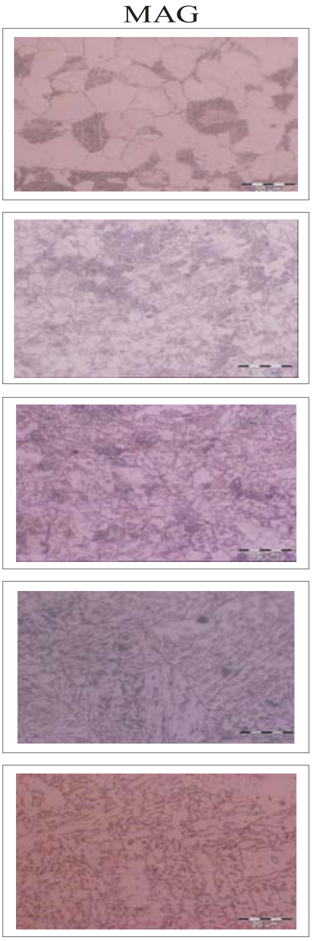


Figure 2. Microstructure by zones of butt weld joint –steel 16Mo3, process MMA

Figure 3. Microstructure by zones of butt weld joint – steel 16Mo3, process MAG

The results of hardness testing of butt weld joints, welded processes MMA and MAG are given in the table 3 [2].

Table 3. Hardness test results.

Process		Hardness, HV 10								
		BM	HAZ			Weld metal	HAZ			BM
			G	F	R		G	F	R	
MMA	Weld face	153-170	215	198	179	180-232	210	191	168	153-170
	Weld root		186	181	170		200	191	181	
MAG	Weld face		272	266	247	180-270	280	254	191	
	Weld root		300	251	240		**370**	**345**	230	
Expected maximum value of hardness [2,6] $HV_{max=}90+1050C+47Si+75Mn+30Ni+31Cr$										335
The maximum allowed value of hardness according to standard BAS EN 15614-1 [2,6]										320

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3.3 Impact test and grain size

Test specimens with a V notch in the heat affected zone for impact test fracture were performed according to standard BAS EN 10045-1:98 using Charpy pendulum. Results are given in table 4 [2]. Grain size testing is performed in base material and coarse grained part of heat affected zone, and results are given in table 4 [2].

Table 4. Results of impact test and grain size.

Process	Testing temperature (°C)	Minimum prescribed value (base material)	Impact test KV J	Toughness J/cm^2	Grain size G	
					Base material	Coarse grained HAZ
MMA	+20	31 J	136	170,0	8,5	6
MAG			89	111,2		5,5

4. ANALYSIS OF THE TEST RESULTS

Analysis of the results of hardness testing of base material, HAZ and weld metal in butt welded joints in steel 16Mo3, show that is evident that the hardness in the HAZ of MAG is greater than the hardness of MMA. Changes in microstructure accompanying changes in hardness, namely coarse grained part of HAZ microstructure revealed the presence of bainite and martensite in butt welding sample MAG process (figure 3d), while in the MMA is present bainit, Widmanstaten ferrite and some martensite (figure 2d). Figure 4 gives diagram of hardness distribution of MMA and MAG welding processes.Value of impact test for butt welded joint, obtained MMA welding process is greater than impact energy obtained MAG welding process, which is in agreement with the measured grain size in coarse grain size in heat affected zone.

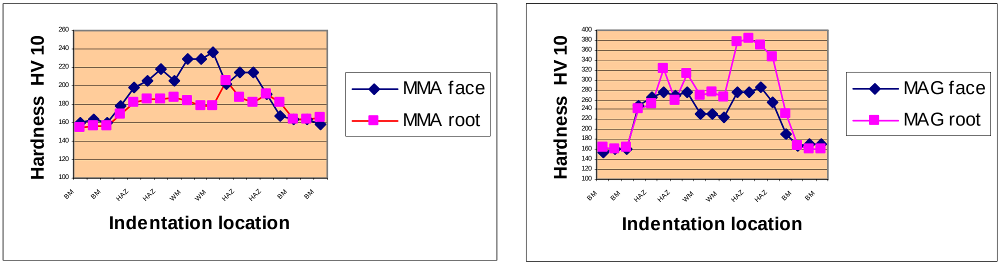

Figure 4. Diagrams of hardness distribution.

5. CONCLUSIONS

The parameters of welding and preheat, during welding steel 16Mo3 with MMA process gave satisfactory results of hardness and impact test, while in MAG welding process was measured hardness value of over 370HV10 which exceeds the maximum allowed hardness value. Regression analysis showed that reducing the value of the welding parameters of voltage and amperage than the values given in Table 2 led to an increase in impact energy MAG welding process.

6. REFERENCE

[1] BAS EN 10028-2:10 – Flat products made of steels for pressure purposes - Part 2: Non-alloy and alloy steels with specified elevated temperature properties
[2] Belma Fakić – The influence of welding procedures for physical-metallurgical properties of steel: S355J2G3, 16Mo3 and 13CrMo4-5 in the heat affected zone, FMM, Zenica, 2010.,
[3] BAS EN 1043-1:09 Destructive tests on welds in metallic materials - Hardness testing - Part 1: Hardness test on arc welded joints
[4] Metals handbook, Vol 7, Metallography, Atlas of microstructures of industrial alloys, 8th edition, Ohio, USA
[5] EN1321:1997-Destructive tests on welds in metallic materials–Macroscopic and microscopic examination weld
[6] Ivan Hrivnak – Theory of weldness of metals and alloys, Slovak Academy of Science, Bratislava, 1989.