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DEGRADATION OF MECHANICAL PROPERTIES OF ARMOURED STEELS AFTER ITS WELDING

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Abstract: *The paper deals with welding process of ARMOX armoured steels. The steels are sensitive on temperature above 200°C due to their thermo-mechanical processing. The paper describes the level of degradation of mechanical properties and also changes in microstructures that are the reason of degradation at welding of those steels.*

Keywords: *armour steels, ARMOX, welding, mechanical properties, tensile strength, termo – mechanical processing*

1. INTRODUCTION

The most known and most widely used steel armory plates are ARMOX steels by Swedish company SSAB Oxelosund. The steels have lean chemical composition which simplifies welding. Carbon equivalent (1) of these steel is relative low (0.6-0.7), therefore they have very good weldability.

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15} [\%] \quad (1)$$

However, their welding is problematic due to heat influence during welding process. Armox steels have high strength, hardness and good toughness. The steels acquire these specific properties by application of thermo-mechanical treatment (TMT) and therefore the producer recommends do not exceed the temperature circa 200°C during their secondary processing as is welding. The high temperatures appeared during welding process leads to uncontrolled temperation and then to the degradation of mechanical properties level.

Submitted paper study the level of the degradation of mechanical properties during welding process of selected ARMOX steels.

2. MATERIAL AND METHODS

Armoured steel ARMOX 500 is used for experiment. Its basic characteristics are shown in the table 1.

Tab. 1 Chemical composition and mechanical properties of ARMOX 500 [1]

Chemical composition [wt. %]	C	Si	Mn	P	S
	0.32	0.1-0.4	1.2	0.015	0.010
	Cr	Ni	Mo	B	
	1.0	1.8	0.7	0.005	
Mechanical properties	Tensile strengh R_m [MPa]	Yield strength $R_{p0.2}$ [MPa]	Impact energy KU[J]	Hardness HBW	Elongation A_5 [%]
	1450 - 1750	min. 1250	25	480 - 540	8

The shape of experimental samples with and without weld joint is designed according to STN EN ISO 6892 – 1 standard. Welded joint is situated in the middle of the weldment in compliance with STN EN 895 (fig. 1).

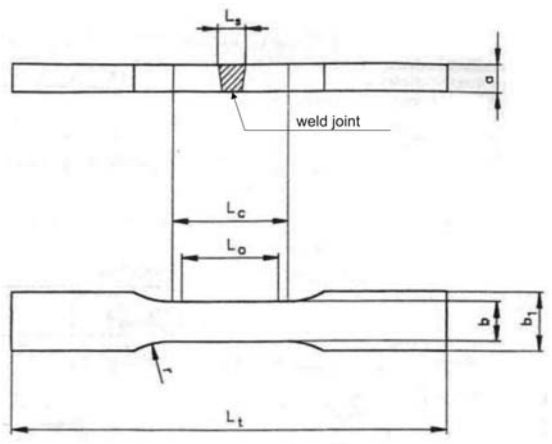

Fig. 1 Experimental specimen (a=4 mm, b=10 mm, L_0=40 mm)

Experimental specimens are cut by three various types of cutting technologies – plasma cutting, laser cutting and water jet cutting. One of experimental topics is the influence of used cutting technology on the final mechanical properties of the studied steels. The influence of cutting method choosing on the basic ARMOX material is described in [2].

Experimental specimens are welded using Metal active gas method (MAG). Thermanit X is used as a welding consumable (18 Cr/8 Ni). Protect atmosphere consist of 80 % Ar and 20 % CO2. Detailed information about welding parameters is shown in the table 2.

Tab. 2 Welding parameters

Weld method	Type of w. joint	W. position
MAG	BW (flat)	PA

Weld bead no.	Weld. consum.	Current [A]	Voltage [V]
1	Ø 1,0	145-155	27-29
2	Ø 1,0	145-155	27-29
3	Ø 1,2	160-260	18-26

3. EXPERIMENTAL RESULTS

All experimental samples were examined by tensile strength test (STN EN ISO 6892-1). Testing device Instron 5500R with automatic evaluation of mechanical characteristics (Tensile and Yield strength) is used. Results of tensile strength test are presented in table 3. The results from every presented alternative are average of ten measurements.

Tab. 3 Experimental results

Type of Armox steel	Cutting method	Yield strength $R_{p0,2}$ [MPa]	Tensile strength R_m [MPa]
500 T	Plazma	1359,60	1539,90
500 T	Laser	1392,68	1579,15
500 T	Water jet	1422,09	1614,32
500 T weldment	Plazma	593,82	614,65
500 T weldment	Laser	818	837,35
500 T weldment	Water jet	750,56	772,60

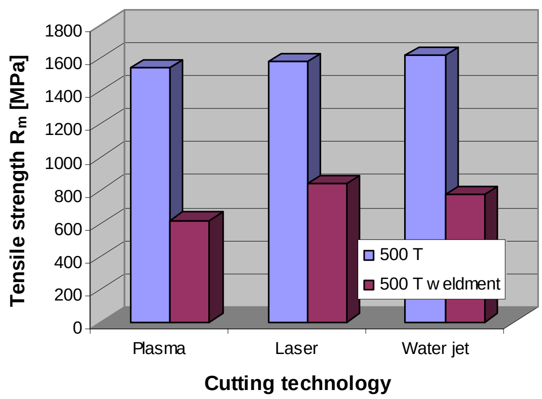

Fig. 2 ARMOX 500 - Yield strength of basic and welded material

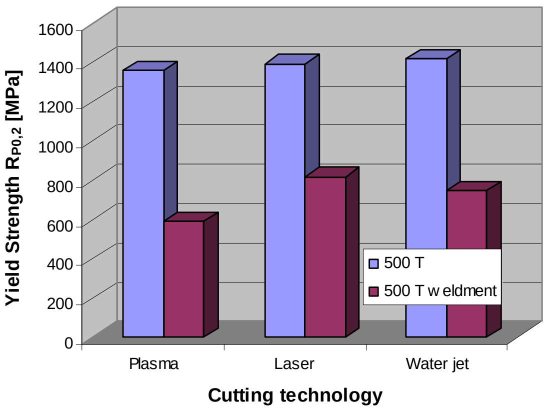

Fig. 3 ARMOX 500 - Yield strength of basic and welded material

Comparisons of all variants between weld and basic materials bring those results:
Yield strength ($R_{p0,2}$) decreases about 44% in the case of plasma cutting, about 42% in the case of laser cutting and about 45% in the case of water jet cutting. Decreases are almost equal; therefore cutting method has no influence on the yield strength level.

The highest decrease of tensile strength (R_m) indicates the alternative with plasma cutting, where the decrease is about 60%. The decrease is about 47% in the case of laser cutting and about 52% in the case of water jet cutting. Significant decrease of R_m at variant with plasma cutting means that affection by heat is so high to appear even after welding application (in contrast to other two cutting technologies).

3. INFLUENCE ON MICROSTURCTURE

The reason of degradation of mechanical properties during ARMOX 500 steel welding are changes in microstructure. The original (un-affected) microstructure is shown on fig. 4 and it consists of very fine-grained heterogeneous sorbitic structure obtained as a result of thermo – mechanical treatment.

This structure provides high strength, toughness and hardness required from this kind of steels.

Fig. 4 Mictrostructure of base material (ARMOX 500), 500x

Fig. 5 Microstructure of HAZ (area close to weld metal), 500x

Fig. 6 Microstructure of HAZ (area close to base material), 500x

The microstructure of heat-affected zone (HAZ) is absolutely different in comparison to microstructure of basic material. There is shown the microstructure of HAZ area close to welding metal. It consists of very coarse martensitic needles (fig. 5).

The needles became finest sequentially in areas farther from weld metal, but structure still remains martensitic (fig. 6).

Too much martensite and especially big coarse martensitic needle leaves HAZ area of steel brittle. In this case is the degradation effect bigger because of un-wanted change of microstructure deliberately obtained by thermo-mechanical processing.

3. CONCLUSIONS

Decrease of both mechanical properties (Rm and Rp0,2) is obvious at welding joints. The most weak place of welding joint is the weld metal where all of experimental specimens is broken. The level of decrease is in relation to the used welding consumable properties.

The study of microstructure of heat-affected zone brings detailed information about affection of ARMOX steels by welding process. Heat affection changes fine-grained sorbitic microstructure obtained by thermo-mechanical treatment to worse one, mostly consisted of coarse martensitic structure.

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