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ANALYSIS OF THE APPLICABILITY OF HIGH STRENGTH STEEL OF YS = 1300 MPa IN THE MARINE INDUSTRY

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Abstract

The paper shows the results of non-destructive and destructive tests carried out on high strength martensitic steel – Weldox 1300. It is used for the construction of crane lorries, mining equipment and submarines. During testing a test joint of the following dimensions was used: length – 600 mm, width – 300 mm, and thickness – 9.5 mm. Welding was executed using flux-cored wire Union x90. The results obtained in the following tests were analysed: non-destructive tests, tensile and bend test, impact test, hardness test, and macrotexture test. Non-destructive testing: visual, magnetic particle and ultrasonic inspections showed no irregularities. The material met the acceptance requirements. The results of the tensile test of the examined steel amounted to 1047 MPa on average. The samples were broken in the weld. During root bend and tensile test the specimen was bent up to the 180° angle during which no welding discontinuities were observed. During face bend and tensile test, the sample was bent to the angle of approx. 40°– visible cracks. Rupture of the sample in the weld and cracks created when bending are due to the reduced flow stress of the additional material against the tested steel. Energy of the impact test for specimens notched in the weld was 37.9 [J], and for specimens notched in the heat affected zone was 41.5 [J]. The average hardness of the specimen was determined at the level of 317 HV. Macroscopic testing did not show any delamination or welding discontinuations. In addition, strength tests of the base material were carried out. The results were compared with the product certificate provided by the steel manufacturer. The paper presents the results of tests, which can be used during factory production control of high strength steel.

Keywords: *high strength steel, martensitic steel, welding*

1. Introduction

Due to the dynamic development of land transport and marine manufacturers have developed new technologies for structural steels with higher yield strength of the order of 1300 MPa. The development of structural steel over the last 50 years is shown in Fig. 1. The requirements that are placed on modern steels are mainly high strength while maintaining the best properties of plastic. Thanks produced steel construction with the use of these steels have a low material-, lighter, thinner, yet retain the same strength values. Finish welding process allows to use less adhesive, while reducing the time required [3].

The use of high strength steel is limited because of their limited weldability. These steels require proper selection of heat input welding, in order to eliminate the risk of cold cracking and to avoid a reduction in the strength of the connector. Selection of welding method depends on the type of calls, welding position and the thickness of connected elements. Particular attention should be paid to the selection of an additional material to the strength properties of the resulting weld corresponded to the properties of the base material. High-strength steels used in the shipbuilding industry should meet the requirements of classification societies regarding the chemical composition and mechanical properties [2].

The aim of this study is to analyse the possibility of using high strength steel in shipbuilding, taking as a criterion the results of test joint steel Weldox 1300. This steel has a high carbon equivalent (CEV), and thus, limited weldability. Analysis of the results in order to assess whether it is possible to obtain welded structures with high strength properties at satisfactory plastic properties.

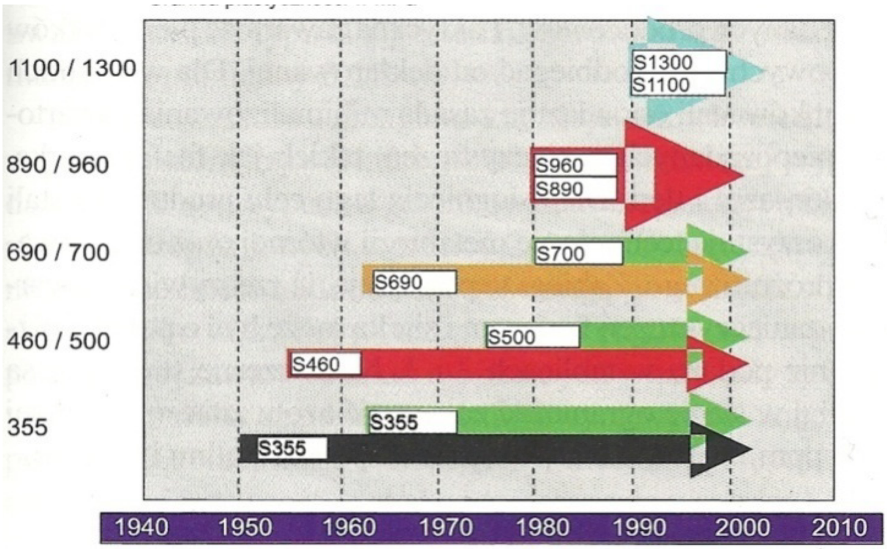

Fig. 1. Development of structural steel high-strength [1]

2. The research methodology

Material for research

The study used the connector welded steel Weldox 1300 made by MAG (135) using an additional material – Union x90. The chemical composition of the steel and welding filler material in % of weights is given in Tab. 1.

Tab. 1. Chemical composition of tested joints (wt. %)

Chemical composition (%)													
	C	**Si**	**Mn**	**P**	**S**	**Cr**	**Cu**	**Ni**	**Mo**	**B**	**Ti**	**Nb**	**V**
Steel Weldox 1300	0.22	0.23	0.89	0.01	0.001	0.5	0.01	1.31	0.392	0.001	0.004	0.21	0.21
Filler Union x90	0.11	0.78	1.76	0.008	0.009	0.36	-	2.3	0.36	-	-	-	-

Connection is made according to the qualification of welding technology PN EN IS0 15614-1: 2008 [4], developed based on the Preliminary Manual welding in the flat position (PA). The method of MAG (135), the wire – Union x90 and shielding gas M21. A method of preparing a material for welding is shown in Fig. 2. Made welded joint dimensions 300 x 600 x 9.5 mm.

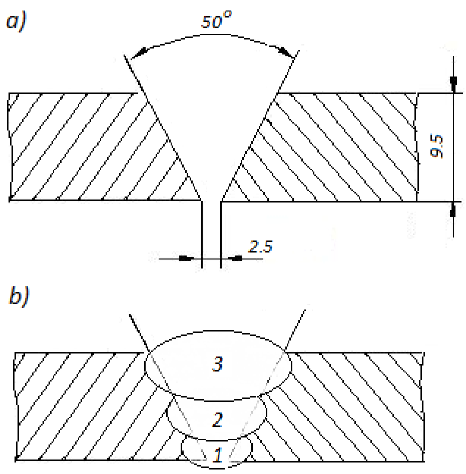

Fig. 2. Preparation of the material to be welded, wherein a) a sketch of the connector; b) the sequence of welding

Methodology of research

The scope of research performed welded joint are determined in accordance with PN-EN 15614-1: 2008 were performed non-destructive testing: Visual Testing (VT) Magnetic-Particle Testing (MT), Ultrasonic Testing (UT) and destructive tests: Static tensile test specimens transverse bending test, the impact strength, hardness and the macroscopic.

3. The research results

Visual examination showed no surface defects. Magnetic Testing performed on the entire length of the connector and in the heat affected zone also showed no discontinuity welding. During the test, ultrasonic (UT) have been detected 2 discontinuity point. Due to its very small dimensions are not subject to assessment criteria and therefore were classified as acceptable. The rest of the test connector and SWC found no irregularities.

Tensile properties

The test results of mechanical properties of the native material and welded joints carried out in flat samples (according to EN ISO 15614-1:2008) are presented in Tab. 1.

Tab. 1. Mechanical properties of the native material and welded joints (average value from two-four specimens)

Material	UTS [MPa]	YS [MPa]	EL [%]
Weldox 1300/native material	1557.3	1408.5	9.8
Weldox 1300/MAG	1051.1	-	-

where:
UTS – ultimate tensile strength,
YS – yield stress,
EL – elongation.

The break occurred in the weld samples (Fig. 3), which provides a lower yield strength filler material used during welding. Because of heterogeneity in terms of the property of plastic welded joint, no such extension of the sample, but only the tensile strength.

Fig. 3. View samples of welded joints of steel Weldox 1300 after tensile test

Bending test of welded joints

Samples of the welded joint were subjected to a transverse bending stretch from the face and root of the weld. The samples were collected and prepared in accordance with PN-EN 910: 1999. Basic dimensions of samples: 300x25x9.5 [mm]. During bending the bending angle α = 180° joints showed no discontinuities and exfoliation (Fig. 4).

Fig. 4. Samples after the bending test

Impact test

Samples of the material used to weld impact test were taken in accordance with the PN-EN ISO 15614-1: 2008 and prepared in accordance with PN-EN ISO 148-2: 2009. 2 sets of samples were prepared: 3 pieces of notched in the weld and 3 pieces of notched notch in the heat-affected zone. The basic dimensions of samples: 55x10x7.5 [mm]. Impact test was performed at -40°C. The average work breaking the samples from the notched in the weld was 37.9 [J]. This is lower than the average breaking work samples with incised notch in the heat affected zone, which was set at 41.5 [J] at breakthroughs samples, there was no imperfections. Sample of breakthrough obtained after the bursting of the samples with a notch cut in the weld in the weld resetting in Fig. 5.

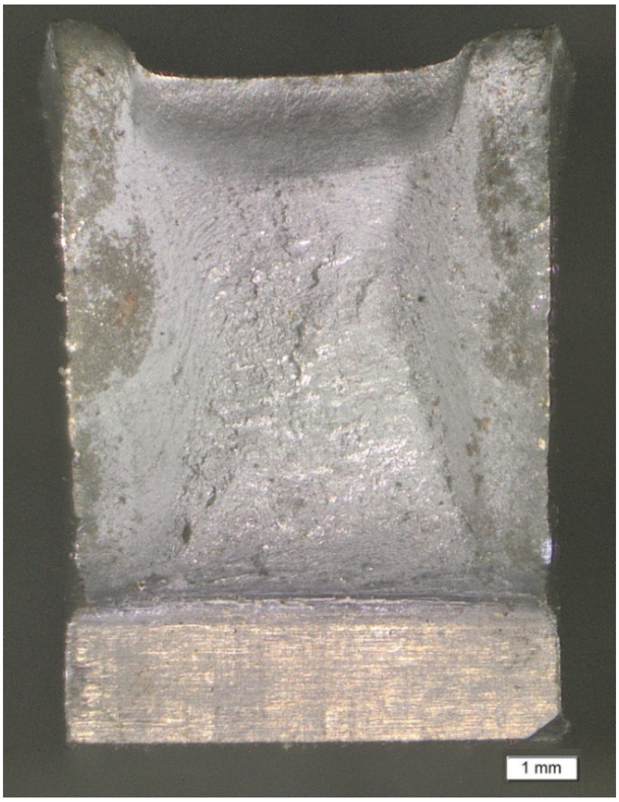

Fig. 5. View late sample notched in the weld

Hardness testing of welded joints

Hardness test samples made of welded Vickers (HV10) along the 3 measuring lines (Fig. 6), where: line 1 defines the measuring points from the weld face, line No. 2 centre weld line 3 points from the ridge. Location of measurement: 1-3, 17-19 – the basic material; 4-8, 12-16 – heat affected zone; 9-11 – weld.

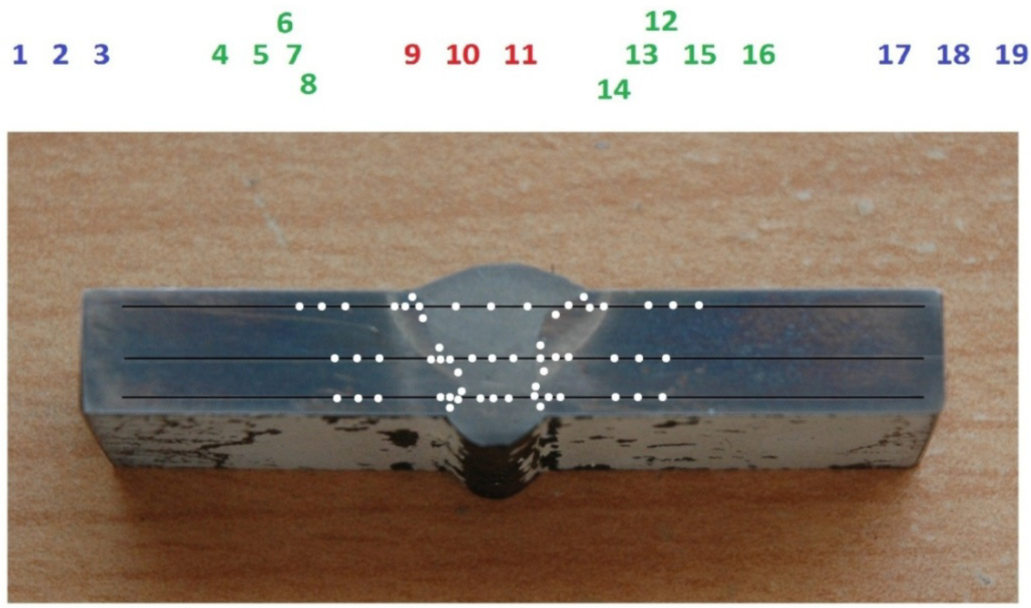

Fig. 6. Scheme of measuring the hardness of welded joints of steel Weldox 1300

Distribution of hardness in the welded joint is presented in tabular form (Tab. 2).

Tab. 2. The results of the hardness of the welded joint

Hardness test HV10 Vickers																				
Steel Weldox 1300 – welded material																				
No. line	Hardness HV																			
	Basic material			HAZ					Joint			HAZ					Basic material			Medium hardness
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
1	451	457	444	406	402	338	408	487	317	326	325	442	424	443	441	435	449	451	451	415 HV
2	454	452	430	371	351	365	350	321	331	338	329	364	329	325	350	374	437	438	437	376 HV
3	468	463	465	336	339	323	342	318	322	326	329	297	332	312	321	328	464	475	476	370 HV

Hardness test showed that the lowest value of hardness characterized by joint – the average hardness of 326 HV. The average hardness of the heat-affected zone was increased hardness of the weld and amounted to 365 HV. The highest value of the parameter examined showed basic material – an average of 453 HV.

4. Summary

Based on the study's own joint trial Weldox 1300 steel can be determined by properly developed welding technology. This connector is not detected welding defects and gives the optimum mechanical properties and satisfactory operation violations at -40°C (37.9 J cut the notch in the weld). The use of high-strength steel in shipbuilding is justified, especially for structural components, e.g. Submarine hulls, bulkheads and booms lift loading statically loaded large forces of bending, stretching or compression. The use of materials with high strength design reduces material consumption and reduce the weight of which is particularly important in the shipbuilding industry. This causes a reduction in the unit cost of the materials used, both basic and additional. The requirement for a correct welding process, which provides sufficient strength and ductility to the use of a suitable additive material. Studies show it has a significant impact on the strength of the weldment. Due to the relatively, short period of use of steel Weldox 1300 polish market are not yet available additional relevant materials to carry out the welding process, such that the weld was characterized by comparable strength as the base material.

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