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Bożena SZCZUCKA-LASOTA¹, Tomasz WĘGRZYN², Bogusław ŁAZARZ³, Adam JUREK⁴

WELDING OF MOBILE PLATFORM ELEMENTS MADE OF AHSS STEEL AND A NON-ALLOY STEEL

Summary. In the construction of mobile platforms, there is an increasing necessity to weld steels from the AHSS group (AHSS - Advanced High-Strength Steel) with low-alloy steels. This article verifies the possibility of obtaining accurate mixed welded joints from different grades of AHSS steel with S355J2 steel. The structure, as well as mechanical properties of the obtained welded joints, were thoroughly analysed.

Keywords: civil engineering, transport, mobile platforms, welding

1. INTRODUCTION

In civil engineering and transport, mixed joints made of AHSS steel and non-alloy steel play an important role [1]. High-strength AHSS steels find increasing use in civil engineering and transport due to their high tensile strength at the level of around 700-1200 MPa [2-6].

¹ Faculty of Transport, The Silesian University of Technology, Krasińskiego 8 Street, 40-019 Katowice, Poland. Email: bozena.szczucka-lasota@polsl.pl

² Faculty of Transport, The Silesian University of Technology, Krasińskiego 8 Street, 40-019 Katowice, Poland. Email: tomasz.wegrzyn@polsl.pl

³ Faculty of Transport, The Silesian University of Technology, Krasińskiego 8 Street, 40-019 Katowice, Poland. Email: boguslaw.lazarz@polsl.pl

⁴ Novar Sp. z o. o. Gliwice, Gliwice, Poland. Email: adamo507@wp.pl

This article aims to present the results of tests designed for proper selection of welding parameters of mobile platforms thin-walled construction elements made of tested steel grades. It was decided to create mixed AHSS/non-alloy steel joints using the MAG process and two different welding parameters. Welding of AHSS steels used for the construction of mobile platforms has been previously analysed, however, welding of AHSS steels with non-alloy steels is novel and not widely presented in technical literature. The possibility of welding AHSS/non-alloy steel joints correctly and repeatably could affect new design constructions and usage of mobile platforms with increasing lifting capacity and working range.

2. RESEARCH MATERIALS AND WELDING PARAMETERS

From the available AHSS materials, two grades were selected (Tab. 1) and combined with a non-alloy steel S355J2. The welded steel grades differ significantly due to their chemical composition (Tab. 1). Steels from the AHSS group are typically considered as difficult to weld because of cracks that appear in the weld and in the heat-affected zone after the welding [7]. Non-alloyed steels are considered as rather well-weldable.

Tab. 1

Chemical composition of selected steel grades [7]

Steel grade	C%	Si%	Mn%	P%	S%	Al%	Ni%	Ti%
Docol 1200M	0.11	0.20	1.70	0.01	0.002	0.04	-	0.025
S700MC	0.12	0.1	2.1	0.025	0.01	0.015	0,09	0.15
S355J2	0.2	0.4	1.50	0.03	0.03	0.02	0.3	-

When welding AHSS steel it is recommended to limit the linear energy during welding to 5 kJ/cm level [1,4,8], whereas S355J2 steel does not pose any major welding problems. The weldability of mixed joints has not been yet sufficiently investigated and there is deficient literature information on it, especially regarding its use in the construction of transport means. Non-alloy steels might be welded applying various processes, with the best results obtained using the low oxygen methods [9,10]. During the welding of non-alloy steels, micro-jet cooling is employed with an increasing frequency in order to control the structure and to enhance the plastic properties of the joint [7].

3. PREPARATION OF SAMPLES FOR TESTING

MAG welded joints were made using the following steel grades: S355J2 with S700MC and Docol 1200. Significant differences in the chemical composition of the selected steel grades affect the structure, weldability and mechanical properties of the joint. Selected mechanical properties of the steels used to create a connection in the mobile platform are presented in Tab. 2.

It is worth pointing out the vast difference in strength and yield strength for both material groups.

It was decided to make mixed joints using two different types of electrode wires: Union X90 and Union X96. The chemical composition of both wires is presented in Tab. 3.

Tab. 2

AHSS steels used to build mobile platforms - mechanical properties [7]

Steel grade	The yield point YS [MPa]	Tensile strength UTS [MPa]	Elongation A ₅ [%]
Docol 1200M	950	1150	5
S700MC	700	900	9
S355J2	355	600	11

Tab. 3

Electrode wire UNION X90 - chemical composition [7]

Electrode wire	C%	Si%	Mn%	P%	Cr%	Mo%	Ni%	Ti%
Union X90	0,1	0,81	1,8	0,01	0,35	0.6	2.3	0,005
Union X96	0,12	0,87	1,89	0,010	0,29	0.46	3.3	0,005

The steel welding parameters were as follows: the diameter of the electrode wire was 1 mm, the arc voltage was 19 V and the welding current was 115 A. The welded sheets had dimensions of 1000 × 150 × 3 mm and the weld was of single stitch type. In the MAG process, 80% Ar, 18% CO₂, 2% O₂ and a mixture of 82% Ar and 18% CO₂ were selected to act as shielding gases. The shielding gases flow rate was at a level of 15 l/min. The joints were made at a speed of 400 mm/min. The linear energy was at 4.34 kJ/cm. A 3 mm thick welded butt joint (BW) was made (KT sample). The MAG (135) welding method was applied in the down position (PA) and according to the requirements of EN 15614-1 norm. The preparation of the material for single stitch welding as well as created weld made from AHSS/non-alloy steel with thickness of 3 mm are presented in Fig. 1.

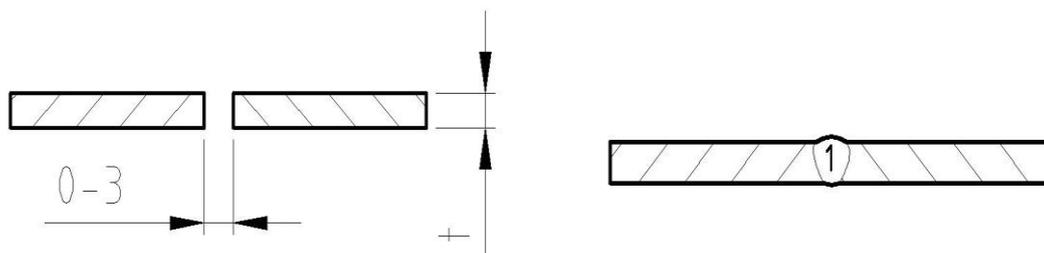


Fig. 1. Groove shape of P3 (a), welding order of P3 (b)

4. RESULTS AND DISCUSSION

Once the joints welded with various parameters were completed, tests of immediate tensile strength were performed. Joint strength tests were carried out on the ZWICK 100N5A strength testing machine. The results of the mechanical tests of the welds:

S355J2/Docol1200M and S355J2/S700MC (average of three measurements) are presented in Tabs. 4-5.

Tab. 4

Mechanical properties of the mobile platform joint
(mixed joint S355J2/Docol1200M).

Welding types	Electrode wire	Shielding gases	R _m , MPa	R _e , MPa	A ₅ , %
S355J2/ Docol 1200M	Union X90	80% Ar-18% CO ₂ -2% O ₂	517	422	7.4
S355J2/ Docol 1200M	Union X96	80% Ar-18% CO ₂ -2% O ₂	524	434	7.1
S355J2/ Docol 1200M	Union X96	82% Ar-18%	533	439	6.4
S355J2/ Docol 1200M	Union X90	82% Ar-18%	538	447	6.3

The analysis of the array data shows that the connectors were made correctly. The best plastic properties had a joint created of Union X90 electrode wire and made in the shielding gas mixture containing 80% Ar, 18% CO₂ and 2% O₂. Union X96 wire supports greater joint strength, but at the cost of plastic properties deterioration. The highest relative elongation value of the mixed joint was obtained when welding with the use of MAG method, Union X90 electrode wire and a gas mixture containing 2% O₂. Again, the weldability of S355J2/S700MC steel was verified. The test results are presented in Tab. 5.

Tab. 5

Mechanical properties of the mobile platform joint (mixed joint S355J2/S700MC)

Welding types	Electrode wire	Shielding gases	R _m , MPa	R _e , MPa	A ₅ , %
S355J2/ S700MC	Union X90	80% Ar-18% CO ₂ -2% O ₂	502	401	7.7
S355J2/ S700MC	Union X96	80% Ar-18% CO ₂ -2% O ₂	487	386	7.4
S355J2/ Docol 1200M	Union X96	82% Ar-18%	507	397	7.2
S355J2/ Docol 1200M	Union X90	82% Ar-18%	513	401	7.1

Also, in this case, the analysis of the array data shows that the joints were made correctly. The strength of the joints after the welding with two different electrode wires was at the level of 500 MPa, and the relative elongation was always above 7%. Similarly in this situation, the best effects were obtained using 80% Ar, 18% CO₂, 2% O₂ shielding gas and UNION X90 wire.

Next, the bending test of the created joints was performed. For the test, a sample with thickness of $a = 3$ mm, width of $b = 20$ mm, mandrel of $d = 22$ mm and support spacing of $d + 3a = 31$ mm was used, the required bending angle was at the level of 180°. Five bending tests measurements were carried out both on the face side and on the root side of the weld.

Those joints that obtained the best plastic properties (using UNION X90 electrode wire together with 80% Ar, 18% CO₂ and 2% O₂ gas mixture) were subjected to the bending test. The tests results are summarised in Tab. 6.

Tab. 6

Mixed joints bending test results

Welding types	Side deformation	Size [mm]	Bending angle [°]	Comments
S355J2/ S700MC	root of the weld	3 x 20	180	no cracks, no incompatibilities
S355J2/ S700MC	face of the weld	3 x 20	180	no cracks, no incompatibilities
S355J2/ Docol 1200M	root of the weld	3 x 20	180	no cracks, no incompatibilities
S355J2/ Docol 1200M	face of the weld	3 x 20	180	no cracks, no incompatibilities
Exterior diameter [m]	below 24	from 24 to 30	above 30 to 36	above 36
Critical gap [s]	5.0	4.8	4.6	4.5

The analysis of Tab. 6 shows that the joints were made correctly. No cracks or other incompatibilities were found in the tested samples. Next, the microstructure analysis was performed. Similarly, the structure of those mixed joints that ensured the best relative elongation was analysed. The microstructure of the cross-section of the S355J2/Docol 1200M joint is presented in Fig. 2.

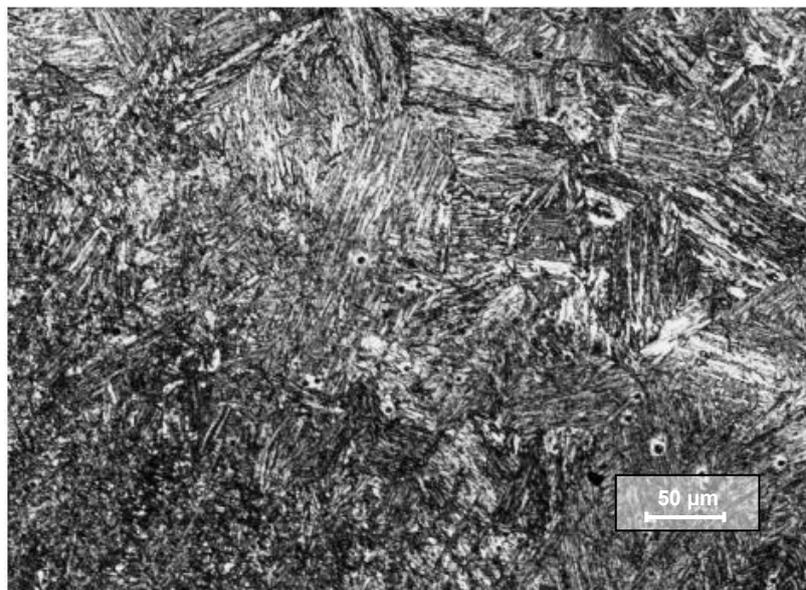


Fig. 2. Structure of the S355J2/Docol 1200M joint

Fig. 2 shows the dominant area with martensitic structure and ground ferrite grains. Furthermore, after the welding, a non-destructive testing (NDT) was carried out. It was decided to perform visual test (VT) of the created joints. The test was performed with an eye equipped with a magnifying glass at 3x magnification and was carried out according to the requirements of PN-EN ISO 17638 standard with assessment performed according to EN ISO 5817 norm.

In addition, a magnetic particle testing (MT) was performed. The test was carried out according to the PN-EN ISO 17638 standard, the assessment was performed according to EN ISO 5817 norm using a REM-230 magnetic flaw detector. All analysed welds were made correctly, the test result was positive.

5. CONCLUSION

Hard to weld AHSS steel is a material with increasing use in the construction of transport means as a result of its high strength. New solutions providing the possibility of welding AHSS steel with other materials, for example, non-alloy steels are being sought. This issue is hardly recognised and insufficiently described in technical literature. It was decided to verify the MAG welding process of thin-wall constructions of mobile platform elements with thickness of 3 mm made of AHSS steel (Docol 1200M, S700MC) with S355J2 steel. Joint strength tests, bending and structure tests were executed. The most favourable welding parameters were selected. Based on the performed research, the following conclusions can be made:

1. It is possible to create correct and repeatable joints made of two different grades of AHSS steel and non-alloy steel.
2. The strength of mobile platforms elements joints made of AHSS and non-alloy steel grades is at the required level of 500 MPa.
3. The electrode wire UNION X90 and a shielding gas mixture of 80% Ar, 18% CO₂ and 2% O₂ provide the most preferred plastic properties of a joint during the MAG welding.
4. Bending tests, structure testing, as well as non-destructive tests, confirmed the possibility of correct welding of the mobile platform elements.

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