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WELDING MOBILE PLATFORMS ELEMENTS MADE OF AHSS STEEL IN VIEW OF NEW REQUIREMENTS IN CIVIL ENGINEERING AND TRANSPORT

Summary. The developing automotive industry has prompted an increase in the demand for new welding technologies in civil engineering and transport that reduce the mass of mobile platforms mounted on vehicles and increase their operational range at the same time. The AHSS steels are the materials most commonly adapted for the production of motor vehicles due to their high tensile strength. Nonetheless, the joints created with their use are less strong from the native material. This article examined whether the application of micro-jet cooling would alter the mechanical properties of the welds. Based on the performed tests, joints with better quality that passed positively in the hardness and tensile strength evaluations were obtained. The presented research proves that the use of additional elements in the welding process significantly affects the quality of the obtained welds and brings satisfactory results with a greater repeatability than before.

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1. INTRODUCTION

New trends prevailing in civil engineering, architecture and urban planning postulate spatial limitations of cities, creation of buildings in an appropriate scale and shaping of a strong urban centre. In accordance with these trends and with the ever-shrinking space available for development, constructors are obliged to design and erect higher and higher buildings. Their construction requires the use of modernised mobile platforms with an expanded operational range and a weight that remains unchanged [1, 2].

The technology of constructing mobile platforms mounted on vehicles is constantly adapting in terms of meeting changing safety standards. The revised regulations on exhaust emissions in automotive vehicles require the application of additional components such as particulate filters, exhaust catalysts, elements of exhaust systems, for example, ejectors or assisting mufflers that significantly increase their total mass. In trucks, the difference may reach up to 200 kg. Requirements imposed upon mobile platforms are presented in Figure. 1.

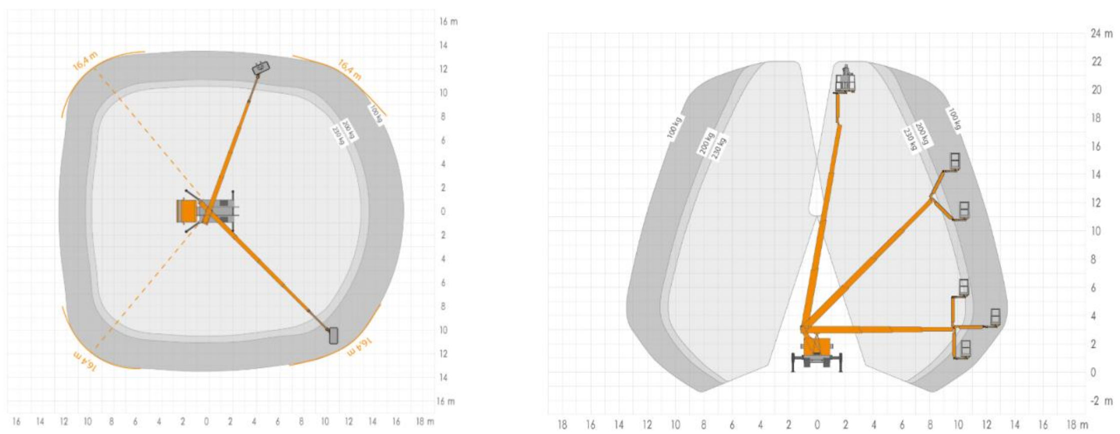


Fig. 1. Requirements imposed upon mobile platforms [3]

Manufacturers of mobile platforms mounted on vehicles are constantly looking for new solutions that enable the reduction of the extra weight of these additional elements and elevation of the working range of these platforms. In order to increase the properties of platform structures, another goal is to reinforce their tensile strength [3-8].

The article aims to verify whether the use of modernised technology will allow the achievement of the above-mentioned objectives. It is assumed that the use of micro-jet cooling during the welding of mobile platform elements made of Advanced High Strength Steel (AHSS) will increase the mechanical properties of the joint [9, 10].

2. MATERIALS AND METHODS

The AHSS steels are repeatedly applied in civil engineering and transport due to their high tensile strength, max. up to 1700 MPa, high yield strength, about 1300 MPa and high elongation point up to 20%. AHSS steels are used mainly for thin-walled constructions as their strength allows for the reduction of the overall weight of the structure [11, 12]. The basic welding problem of this group of steels is that the strength of the produced joint is much lower from the native material, despite the steel's good technological properties such as weldability and machinability [13, 14].

Table 1 presents some of the AHSS steels used for the construction of mobile platforms mounted on vehicles and their mechanical properties.

Tab. 1

Major AHSS steels used for the construction of mobile platforms mounted on vehicles – mechanical properties [15]

Steel type	Plasticity limit R_{el} (N/mm^2)		Limit of plasticity after thermal curing min	Tensile strength R_m (N/mm^2)	Elongation R_{80} %		Min bending radius for the angle 90^0
	min	max	min	min	max	min	
Docol 900M	70	-	900	900	1100	3	3,0 x grubość
Docol 1200M	950	-	1150	1200	1400	3	3,0 x grubość
Docol 1400M	1150	-	1350	1400	1600	3	3,0 x grubość
Docol 1500M	1200	-	-	1500	1700	3	3,0 x grubość

Steels from the AHSS group are considered as difficult to weld since the heat-affected zone (HAZ - Figure 2) is susceptible to welding cracks even when preheated to max. 120°C [1, 11]. This is the effect of the martensitic structure of these steels as well as the great hardness of their material. Table 2 presents the chemical composition of some of the AHSS steels used for the construction of mobile platforms mounted on vehicles.

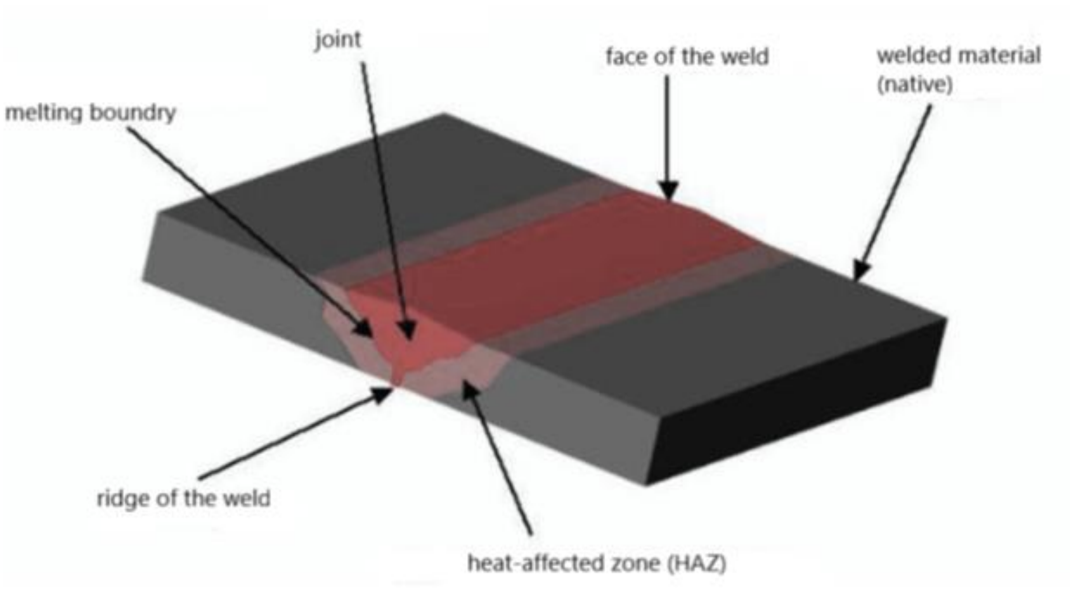


Fig. 2. AHSS steel – elements of the welded joint [3]

Tab. 2.

Major AHSS steels used for the construction of mobile platforms mounted on vehicles – chemical composition [16]

Steel type	C%	Si%	Mn%	P%	S%	Al_{tot}%	Nb%	Ti%
Docol 900M	0,05	0,20	2,00	0,010	0,002	0,040	-	-
Docol 1200M	0,11	0,20	1,70	0,010	0,002	0,040	0,015	0,025
Docol 1400M	0,17	0,20	1,40	0,010	0,002	0,040	0,015	0,025
Docol 1500M	0,21	0,20	1,10	0,010	0,002	0,040	0,015	0,025

During the welding process of AHSS steels, a decrease of mechanical properties in HAZ, as well as an increased susceptibility to delayed cracking, may be observed. It is recommended to limit the linear energy during welding to the level of 5 kJ/cm. In order to improve the weldability of steel, it is proposed to introduce cooling which promotes martensitic transformation.

The best effects when welding AHSS steel lifts, and in particular thin-walled elements, are achieved in processes where shielding gases or mixtures based on argon and carbon dioxide are used. For MAG (Metal Active Gas) welding, CO_2 or a mixture of Ar- CO_2 are used. For TIG (Tungsten Inert Gas) welding with pure argon is adopted.

In order to improve the mechanical properties of welded joints made of AHSS steel, we decided to use MAG welding and the technology of micro-jet cooling. During the welding of mobile platform elements, the following micro-jet cooling parameters were adopted:

- number of cooling nozzles: 1,
- type of cooling medium: Ar,
- pressure of the cooling medium: 0.6 MPa,
- diameter of micro stream: 70 μm,
- distance of the micro-jet nozzle from the welded surface: 20 mm.

For tests, the DOCOL 1200M martensitic steel from the AHSS high strength steel group was selected due to its high strength properties. DOCOL 1200M is a material recommended for the construction of mobile platforms mounted on vehicles. It was expected to achieve an increased weld strength, better relative elongation as well as an increased content of fine-grained ferrite and martensite without the separation of bainite. For this purpose, the MAG process in combination with micro-jet cooling was applied on the face side of the weld.

To obtain the most favourable structure and an optimal juncture of the selected material (DOCOL 1200M from the AHSS group) using the MAG process, the following elements were selected accordingly: electrode wires, shielding gases as well as micro-jet cooling parameters.

In order to assess the quality of welded joints visual tests, analysis of tensile strength, as well as structure verification, were applied.

During the tests the following parameters were adapted:

- two types of shielding gases: CO_2 and a mixture of 82% Ar + 18% CO_2,
- two electrode wires:
  1. EN ISO 16834-A G 89 6 M21 Mn4Ni2CrMo - UNION X90 (C 0,10, Si 0,80, Mn 1,80, Cr 0,35, Mo 0,60, Ni 2,30),

2. EN ISO 16834-A G 89 5 M21 Mn4Ni2,5CrMo - UNION X96 (C 0,11, Si 0,78, Mn 1,9, P 0,010, S 0,009, Cr 035, Mo 0,57, Ni 2,23, V 0,004, Cu 0,02, Ti 0,057, Zr 0,001, Al 0,002).

Welding parameters for both electrode wires and both mixtures were identical: the diameter of the electrode wire was 1.0 mm, arc voltage 19 V, current of the welding 115 A, welding speed 300 mm/min, source of a direct current (+) at the electrode and the single-stitch weld. In all cases, the parameters of micro-jet cooling were at the same level: micro-jet gas - argon, stream diameter 70 μm and a gas pressure of 0.6 MPa.

3. RESULTS AND DISCUSSION

The first welding of mobile platform elements mounted on vehicles was completed without the use of micro-jet cooling. Figure 3 shows the method of constructing the joint.

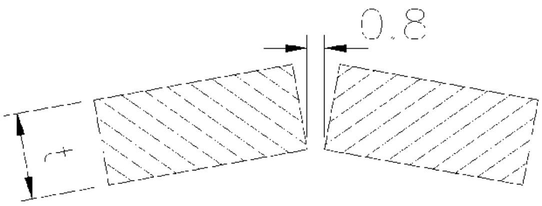


Fig. 3. Preparation of the element for manual welding
* t=1,8 mm

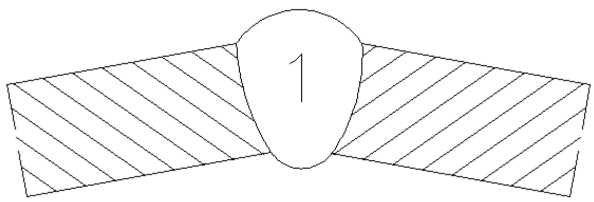


Fig. 4. The welded joint

To assess further weldability of the mobile platform, elements shielding gases 82% Ar + 18% CO_2 as well as both electrode wires (UNION X90 and UNION X96) were selected. The welding process was performed using a ceramic washer. The results of the produced connections are shown in Table 3.

Tab. 3
Mobile platform joints made with the use of micro-jet cooling and a ceramic backing

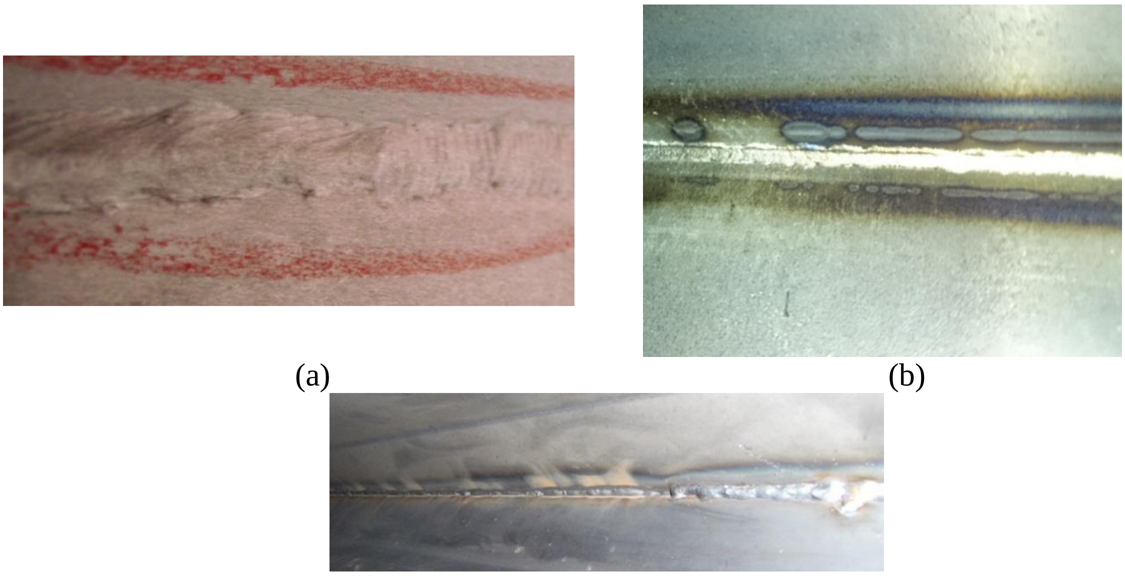
Gas / wire	UNION X90	UNION X96
CO_2	Cracks in the HAZ and in the weld	Cracks in the HAZ and in the weld
82% Ar + 18 % CO_2	Cracks in the HAZ	Cracks in the HAZ

Subsequent tests were carried out using shielding gases 82% Ar + 18% CO_2 and both electrode wires (UNION X90 and UNION X96), together with the use of a copper backing and an argon micro-jet cooling. The results of the produced connections are shown in Table 4.

Tab. 4
Mobile platform joints made with the use of argon micro-jet cooling and a copper backing

Gas / wire	UNION X90	UNION X96
CO_2	Cracks in the HAZ and in the weld	Cracks in the HAZ
82% Ar + 18% CO_2	No cracks in the HAZ	No cracks in the HAZ

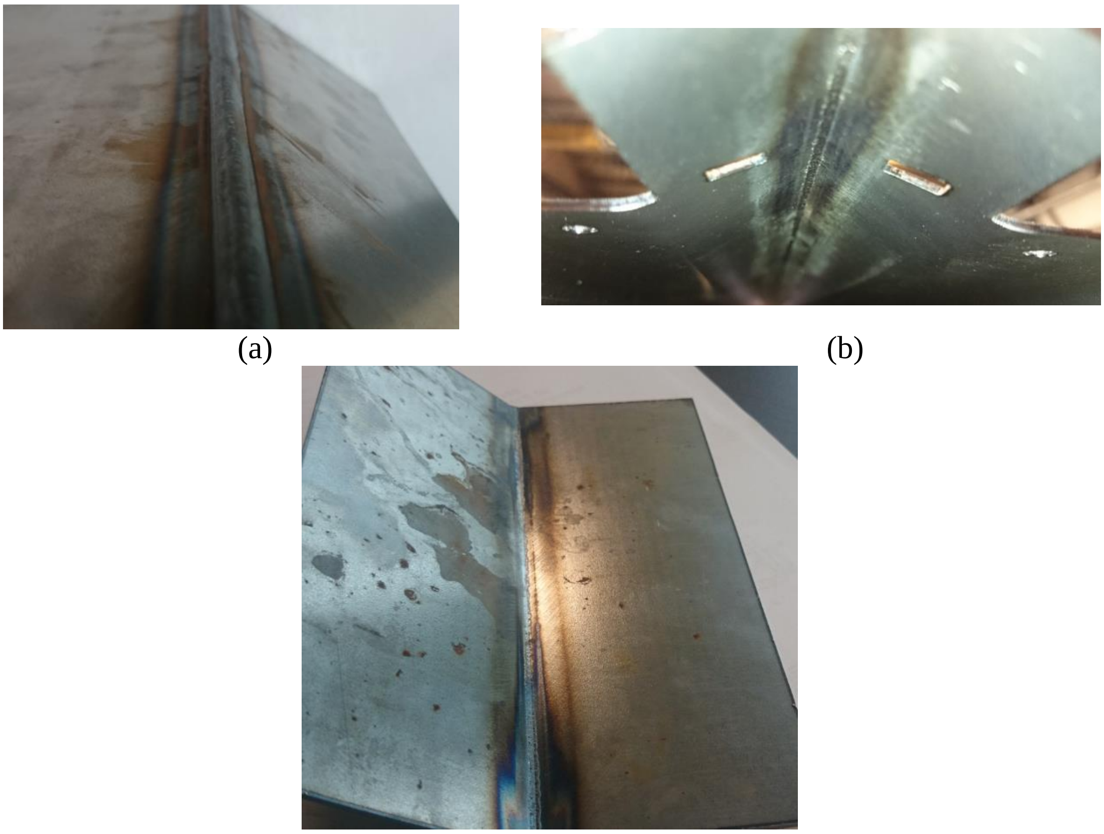
After the completion of all welding tests, visual tests of welds were carried out (Figures 5 and 6).



(a) (b)

(c)

Fig. 5. Visual condition of the welds after MAG welding



(a) (b)

(c)

Fig. 6. Visual condition of the welds after welding with the use of micro-jet cooling

The use of micro-jet cooling delivered much better results. The method produced a better quality of welds, without any visible bumps. Afterwards, the welded elements of the platform were inspected for stretching. The strength of the connections was tested using the INSTRON 3369 testing machine. The following analyses were carried out:

- strength of DOCOL 1200M steel without the use of micro-jet cooling,
- strength of DOCOL 1200M steel with the use of micro-jet cooling.

Each test was repeated 3 times (samples 1, 2, 3).

The results of the strength tests are presented in Figures 7 and 8 and in Tables 5 and 6.

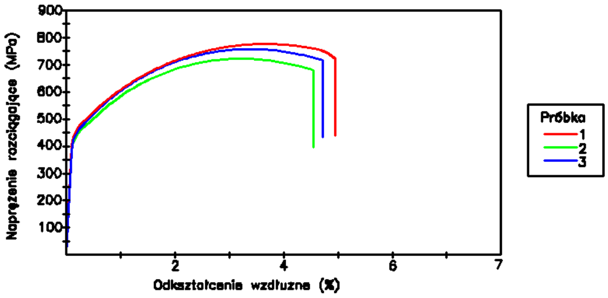


Fig. 7. The results of the AHSS steel joint strength test welded with MAG method

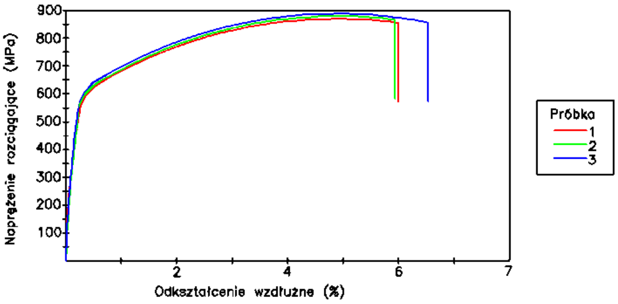


Fig. 8. The results of the AHSS steel joint strength test welded with MAG method and micro-jet cooling

Tab. 5

Results of the DOCOL 1200M steel strength tests after welding without the use of micro-jet cooling

Sample	R_e [MPa]	R_m [MPa]	A5
1	451	765	4,3
2	446	722	4,2
3	450	751	4,1
Median	449	746	4,2

Tab. 6

Results of the DOCOL 1200M steel strength tests after welding with the use of micro-jet cooling

Sample	R_e [MPa]	R_m [MPa]	A5
1	556	890	5,7
2	548	893	5,9
3	552	887	5,8
Median	552	890	5,8

The average R_e value of the MAG welded joint was 449 MPa and the average R_m value was 746 MPa. As a result of micro-jet cooling used during the welding process, R_e and R_m values increased accordingly to R_e =552 MPa and R_m =890 MPa.

Thereafter, the microstructure analysis was performed. The microstructure of the cross-section of the weld with a visible martensitic structure is shown in Figures 9 and 10.

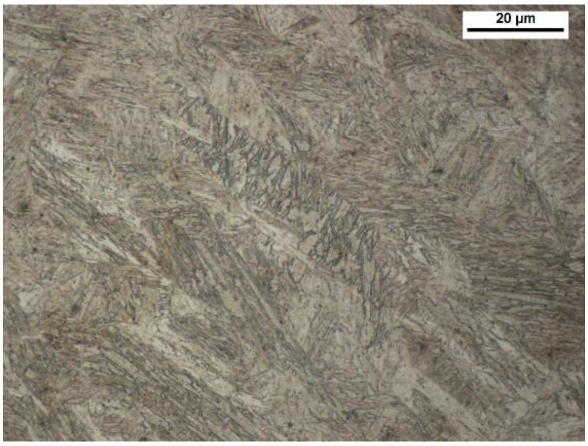


Fig. 9. Microstructure of the weld cross-section without the use of micro-jet cooling

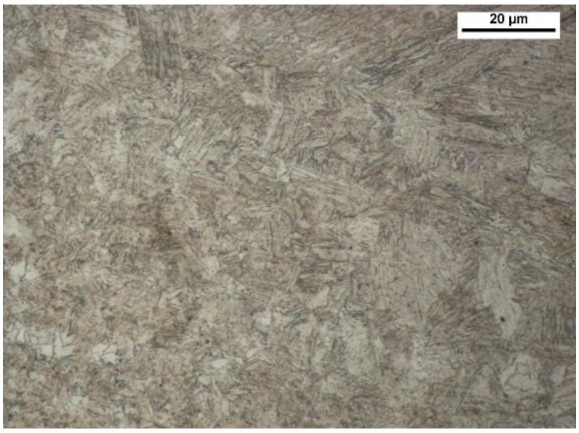


Fig. 10. Microstructure of the weld cross-section with the use of micro-jet cooling

Figure 9 presents visible martensite, coarse ferrite and bainite. This is an unfavourable structure causing inferior plastic properties (relative elongation is at the level of 4%). Martensite and fine-grained ferrite are visible in Figure 10. This structure is more advantageous: allows obtaining of better plastic properties (with the relative elongation at the level of 6%), and elimination of cracks in the joint and in the heat affected zone.

4. CONCLUSIONS

Civil engineering and transport designate new requirements for the constructors of mobile platforms. A need for new welding technologies that significantly reduce the weight of mobile platforms mounted on vehicles and increase their operating range and lifting capacity at the same time is constantly growing.

Material that is increasingly used for mobile platforms manufacturing is the hard-to-weld AHSS steel. Its high strength is almost double from the strength of the welded joint. The relative elongation obtained in the previously used processes is low, which indicates poor plastic properties of the joint. Therefore, new solutions that aim to improve the weldability of thin-walled AHSS steel structures, increase the tensile strength and expand the relative elongation at the same time are being sought.

The increase of the operational parameters (such as load capacity and range) while maintaining the mass of mobile platforms mounted on vehicles can be obtained by modifying the AHSS steel welding technology. The research presented in this article proves that the use of micro-jet cooling enables production of better quality welds with much higher repeatability than before. This technology requires, however, further development and additional research. With the appropriate selection of technological parameters of MAG welding and micro-jet cooling (type of micro-jet gas), it will be possible to determine the welding criteria for various steel grades used in the construction of mobile platforms.

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