

Article

Welding of mobile elevating work platforms

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Received: 02.05.2019; Accepted: 14.06.2019

Abstract: The demand for new welding technologies in civil engineering and transport is increasing. An example of this is the tendency to increase the operating range of a mobile platform mounted on motor vehicles while maintaining the weight of the vehicle. The most commonly used material in the production of mobile platforms are AHSS steels due to their high tensile strength at the level of 1400 MPa. However, the joints created with their use are characterized by much lower strength than the native material. In this article, the most appropriate parameters for welding elements of a mobile platform from difficult-to-use steel AHSS were selected.

Key words: civil engineering; transport; mobile platforms; AHSS; martensitic steel

Introduction

In civil engineering and transport, the modernization of construction and transport equipment is observed. A representative example is the modernization of mobile platforms allowing for their increasing operational range, while maintaining the lowest possible mass of the vehicle [1].

The updated legislation on exhaust emissions in motor vehicles requires the introduction of additional components such as: diesel particulate filters, exhaust gas catalysts, components of exhaust systems, which significantly increase the total weight of vehicles. In trucks, the weight gain can be up to 200 kg [1]. In recent years, there has been a significant increase in the use of high strength steels in various areas of welded structures [2,3].

In order to increase the usable properties of the platform structures, it is also aimed at increasing their tensile strength. This article aims to select the welding parameters for thin-walled construction of mobile platform elements made of Advanced High-Strength Steel (AHSS).

Materials and research methods

Advanced high-strength steels find increasingly widespread use in civil engineering and transport due to their high tensile strength, up to 1400 MPa, high yield strength of around 1200 MPa and an acceptable relative elongation of 10% [4÷7]. During welding of AHSS, a decrease in mechanical properties in the heat-affected zone (HAZ) as well as an increased susceptibility to time-delay cracking can be observed. It is therefore recommended to limit the heat input during welding to the level of 5 kJ/cm [8] and to use welding energy sources that enable precise control of the amount of energy introduced into the welded joint [9,10]. In order to improve the weldability of steel, it is proposed to introduce cooling that promotes martensitic transformation [8,11].

AHSS are mainly used for thin-walled constructions, because their high strength allows to reduce the total weight of the structure. The main welding problem of this group of steel, however, is much lower strength of the joint formed than the native material and inferior plastic properties, which measure is the relative elongation [12÷20]. Table I presents the most important two steel grades from the AHSS group, which are used for the construction of mobile platforms and their mechanical properties [17÷20].

Steels from the AHSS group are considered to be difficult to weld, because the heat affected zone is susceptible to welding cracks even with preheating to max. 120 °C. This is due to their structure in which martensite prevails. Table II presents the chemical composition of the tested AHSS steels used for the construction of mobile platforms.

Table I. Selected types of AHSS steel dedicated to building of mobile elevating work platforms – mechanical properties [13]

Steel grade	Yield strength R _e (N/mm ²)		Yield strength after heat curing min	Tensile strength R _m (N/mm ²)		Elongation R _{s0} %	Minimum bending radius for the angle 90°
	min	max		min	max		
DOCOL 1200M	950	–	1150	1200	1400	3	3,0 x thickness
DOCOL 1400M	1150	–	1350	1400	1600	3	3,0 x thickness

Table II. Selected types of AHSS steel dedicated to building of mobile elevating work platforms – chemical properties [13]

Steel grade	C%	Si%	Mn%	P%	S%	Al%	Nb%	Ti%
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

The chemical composition of both steels is similar. Noteworthy is the higher carbon content in DOCOL 1400M steel compared to DOCOL 1200M steel, which translates into increased tensile strength of the material.

The work analyzed the weldability of both mentioned steel grades. The tests were carried out on sheets with a thickness of 2 mm, because for the construction of mobile lifts components, mainly structures with a thickness of less than 3 mm are used [1].

Metal Active Gas (MAG) joints were made using CO₂ as a shielding gas and 98% Ar + 2% O₂ and 82% Ar + 18% CO₂ mixture. Electrode wire UNION X90 (EN ISO 16834-A G 89 6 M21 Mn4Ni2CrMo) with the chemical composition contained in Table III was chosen.

Table III. Consumable material, electrode wire UNION X90 – chemical composition [14]

C%	Si%	Mn%	P%	Cr%	Mo%	Ni%	Ti%
0.1	0.8	1.8	0.010	0.35	0.6	2.3	0.005

The chemical composition of wire and steel is similar. Noteworthy is the higher silicon content in the wire in relation to the chemical composition of the steel tested. It affects the increase of strength. In turn, the increased content of nickel and molybdenum improves the plastic properties of the weld.

Welding parameters for both steels using the tested mixtures were the same: the diameter of the electrode wire was 1.0 mm, arc voltage 19 V, welding current 115 A, welding speed 300 mm/min, direct current source (+) on the electrode.

The method of preparation of moving platform elements for welding and the joint made is shown in figures 1 and 2. Welding was carried out using a ceramic washer.

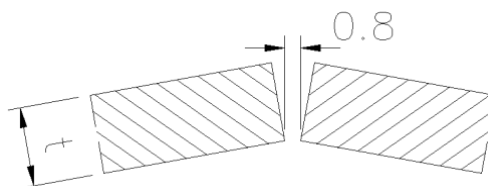


Fig. 1. Method of preparing the samples for MAG welding

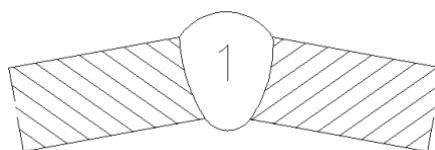


Fig. 2. The method of MAG welded joint

After welding, non-destructive examinations (NDT) were carried out:

- Visual testing (VT) of welded joints made with an eye armed with a 3× magnifying glass – the tests were performed according to the requirements of PN-EN ISO 17637 assessment criteria according to EN ISO 5817;

- Magnetic particle testing (MT) – tests were carried out according to PN-EN ISO 17638, evaluation of tests was carried out according to EN ISO 5817, using magnetic flaw detection device of REM-230 type.

Results and discussion

The results of non-destructive tests are presented in Table III. Observations of welded joints of a mobile platform, made in the shielding gas mixture, allow to state that:

- the use of a shielding gas mixture in the form of CO₂ and 98% Ar + 2% O₂ leads to cracks in the heat affected zone;
- in the case of CO₂ shielding gas, cracks in the weld itself are additionally observed..

Table III. NDT evaluation of mobile elevating work platforms welded joints

Stal	Shielding gas		
	CO ₂	82% Ar + 18% CO ₂	98% Ar + 2% O ₂
DOCOL 1200M	Cracks in the joints and HAZ	No cracks	Cracks in the HAZ
DOCOL 1400M	Cracks in the joints and HAZ	No cracks	Cracks in the HAZ

Based on the data in Table III, it can be concluded that the appropriate shielding gas for welding DOCOL 1200M and DOCOL 1400M steels is a mixture of 82% Ar + 18% CO₂. This is confirmed by the photographic documentation. An example of the surface condition of welds obtained in the welding process

in the 98% Ar + 2% O₂ shield is presented in figures 3 and 4. Figure 3 shows the view of a joint made of DOCOL 1200M steel after MAG welding from the root side. In turn, figure 4 shows the condition of the joint from the side of the face made of DOCOL 1400M steel.

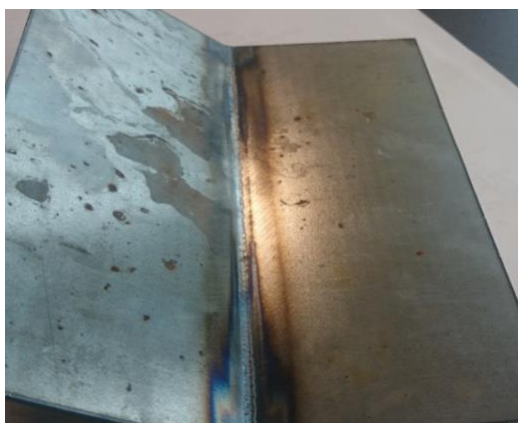


Fig. 3. View of the DOCOL 1200M steel joint after MAG welding using the shielding gas mixture 82% Ar + 18% CO₂ from the root side

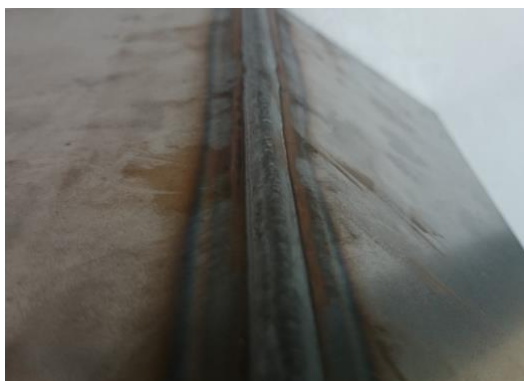


Fig. 4. View of the DOCOL 1400M steel joint after MAG welding using the shielding gas mixture 82% Ar + 18% CO₂ from the face side

Both joints are characterized by proper construction, visual examination did not reveal imperfections and surface defects from the side of the root and face. Analysis of the obtained results of non-destructive testing clearly indicates that MAG welding in the 82% Ar + 18% CO₂ shielding gas mixture gave better

results than MAG welding in the cover of the other gases tested, therefore the samples made with the MAG method in the 82% Ar + 18% CO₂ shielding gas mixture were selected for strength tests.

After obtaining positive results of non-destructive tests, the tensile strength tests under static conditions of the welded elements of the platform were carried out. The strength of the joints made was tested using the INSTRON 3369 testing machine. The following analyzes were carried out:

- strength of DOCOL 1200M steel,
- strength of DOCOL 1400M steel.

Each test was repeated 3 times (samples 1, 2, 3). The results of strength tests are presented in figures 5 and 6 and in Tables V and VI.

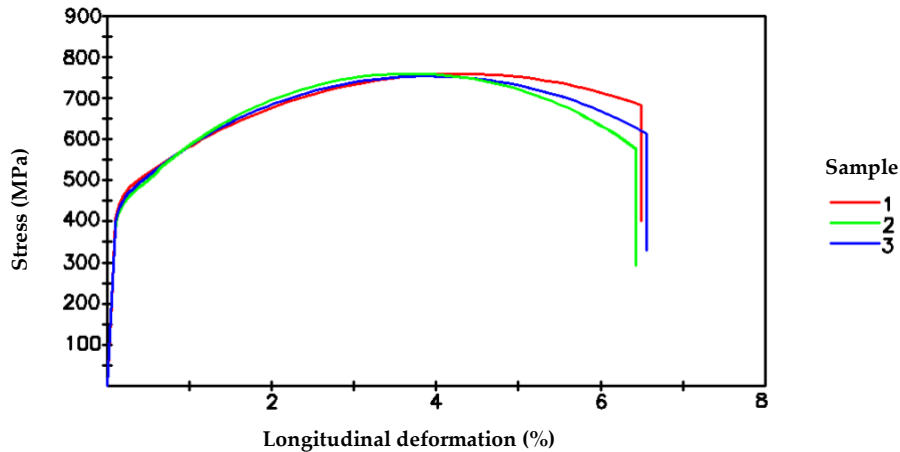


Fig. 5. The results of the DOCOL 1200M steel joint strength test

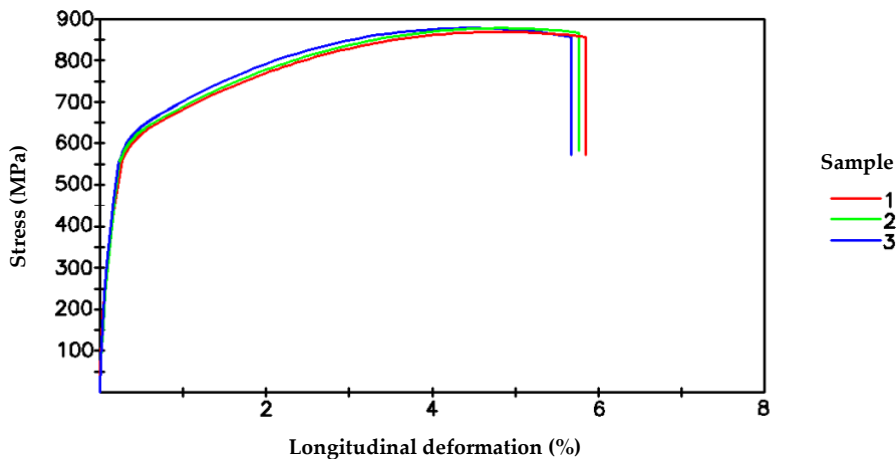


Fig. 6. The results of the DOCOL 1400M steel joint strength test

Table V. Results of strength tests of DOCOL 1200M welded joints, breaking in HAZ

Sample	R _e [MPa]	R _m [MPa]	A ₅
1	447	754	6,6
2	441	729	6,5
3	452	758	6,4
Average	447	747	6,5

Table VI. Results of strength tests of DOCOL 1400M welded joints, breaking in HAZ

Sample	R _e [MPa]	R _m [MPa]	A ₅
1	551	897	5,6
2	542	895	5,8
3	559	883	5,7
Average	548	892	5,7

Tensile strength of DOCOL 1200M steel joints was over 700 MPa and for DOCOL 1400M steel it was above 850 MPa. Breaking of the samples occurred in the heat affected zone.

The analysis of the microstructure of DOCOL 1200M steel welded using MAG in 82% Ar + 18% CO₂ and 98% Ar + 2% O₂ mixture was performed. The microstructure of the cross-section of the weld with the dominant area with a martensitic structure is shown in figures 7 and 8.



Fig. 7. Welding microstructure in DOCOL 1200M welded MAG steel with 82% Ar + 18% CO₂

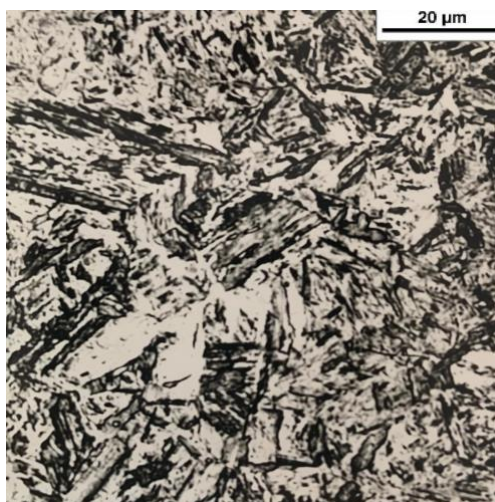


Fig. 8. Welding microstructure in DOCOL 1200M welded MAG steel with 98% Ar + 2% O₂

Figures 7 and 8 show martensite, ferrite and traces of bainite. After welding the steel in a 98% Ar + 2% O₂ shielding gas mixture, ferrite was observed. The more favorable structure is after welding of DOCOL 1200M steel with a MAG process in 82% Ar + 18% CO₂.

Summary

The increase of operational parameters (load capacity, range) while maintaining the mass of mobile platforms of motor vehicles can be obtained by modifying the technology of welding AHSS steel structures. However, this technology requires further development and additional research. The article shows that in the welding process of AHSS steels the correct choice of the gas mixture plays an important role. Non-destructive examinations were carried out, as well as examinations of the structure and tensile strength. Three different shield gases were tested. The best results were obtained by welding elements of a mobile platform made of AHSS steel using the MAG process in the 82% Ar + 18% CO₂ shielding gas mixture. The destructive and non-destructive tests of joints confirm that elements of mobile platforms made of AHSS steel can be welded together with satisfactory quality.

Conflicts of Interest: The authors declare no conflict of interest.

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