APARATURA
BADAWCZA I DYDAKTYCZNA

MIG welding of thin-walled structures of means of transport made of DOCOL 1200M steel

BOŻENA SZCZUCKA-LASOTA[1], TOMASZ WĘGRZYN[2], JAN PIWNIK[3], ADAM JUREK[4], KRZYSZTOF I. WILCZYŃSKI[5]

[1,2]SILESIAN UNIVERSITY OF TECHNOLOGY, [3]CENTRAL RESEARCH AND DEVELOPMENT CENTRE OF SCIENTIFIC AND DIDACTIC EQUIPMENT COBRABID WARSAW, [4]NOVAR SP. Z O.O. GLIWICE, [5]WARSAW UNIVERSITY OF TECHNOLOGY

Keywords: civil engineering, transport, means of transport, AHSS steel

ABSTRACT:

An important material in the construction of means of transport are AHSS (Advanced High-Strength Steel) steels with high yield stress of approx. 900 MPa. Joints made of these steels are difficult to weld and do not ensure comparable mechanical properties. The purpose of the studies described in this article is to select the parameters for welding thick-walled AHSS structures on the example of DOCOL 1200M steel. It was decided to check the impact of welding parameters on the correctness of the joint made.

Spawanie MIG cienkościennych konstrukcji środków transportu ze stali DOCOL 1200M

Słowa kluczowe: inżynieria lądowa, transport, środki transportu, stal AHSS

STRESZCZENIE:

Ważnym materiałem stosowanym w budowie środków transportu są stale z grupy AHSS (AHSS – *Advanced High-Strength Steel*) z uwagi na ich wysoką granicę plastyczności na poziomie 900 MPa. Złącza z tych stali są trudnospawalne i nie gwarantują porównywalnych własności mechanicznych. Celem prac przedstawionych w artykule jest dobór parametrów do spawania cienkościennych konstrukcji ze stali AHSS na przykładzie stali DOCOL 1200M. Postanowiono sprawdzić wpływ parametrów spawania na poprawność wykonanego złącza.

1. INTRODUCTION

This article aims at presenting the results of the tests leading to the selection of the parameters for welding the thin-walled structure made of DOCOL 1200M steel (AHSS).
DOCOL 1200 steels' applications in civil engineering and in the construction of means of transport are being extended due to their high yield stress of 1200 MPa. The disadvantage of this steel is low relative elongation (8%) [2-4]. It is therefore recommended to reduce the linear energy during welding to 4 kJ/cm [5] and use preheating.

2. TEST MATERIALS

DOCOL 1200M steels are considered to be difficult to weld because both the weld and the heat affected zone tend to crack. However, the fundamental welding-related problem pertaining to this group of steels is significantly lower strength of the manufactured joint than the strength of the parent material and worse plastic properties [6]. Table 1 presents the mechanical properties of DOCOL 1200M steel in as-delivered condition.

Table 1 DOCOL 1200M steel and its mechanical properties

Yield stress R_e	Tensile strength R_m	Elongation A_5
MPa	MPa	%
720	1155	8.1

DOCOL 1200M steel has significantly higher titanium and aluminium content than the non-alloy steels used in the construction of the means of transport and in civil engineering. A very low sulphur content (Table 2) should be noted. This chemical composition allows for increased strength while maintaining acceptable plastic properties.

Table 2 DOCOL 1200M steel – chemical composition [7]

Steel grade	C%	Si%	Mn%	P%	S%	Al%	Nb%	Ti%
DOCOL 1200M	0.15	0.20	1.30	0.008	0.001	0.045	0.009	0.021

A 3 mm thick metal plate was used to assess the weldability of DOCOL 1200M steel.
It was decided to make the joints using the MIG (Metal Inert Gas) method with argon or helium as the shielding gas. UNION X96 welding electrode was selected (EN ISO 16834-A G 89 6 M21 Mn4Ni2CrMo). The tests focused mainly on the impact of the shielding gas and preheating on the correctness of the MIG joint made.
The chemical composition of the welding electrode is given in Table 3.

Table 3 UNION X96 welding electrode – chemical composition [8]

C%	Si%	Mn%	P%	Cr%	Mo%	Ni%	Ti%
0.1	0.8	1.8	0.010	0.45	0.65	2.45	0.007

The chemical composition of the electrode is not completely similar to the steel composition. The electrode was provided with chromium for improved strength, as well as with nickel and molybdenum for improved plastic properties.
Welding parameters were as follows: welding electrode diameter – 1.0 mm, arc voltage – 18 V, welding current intensity – 115 A. The weld was of a single-pass type. Welding velocity was 400 mm/min. Joints were made without preheating and with preheating up to 80°C.

3. RESULTS AND DISCUSSION

After MIG welding with argon (and then helium) as the shielding gas, the following non-destructive tests (NDT) were carried out:
• Visual inspection (VI) of the welded joints made was carried out with corrected vision at the magnification of 3× – the tests were performed according to the requirements of PN-EN ISO 17638, whereas the assessment criteria were in accordance with EN ISO 5817.
• Magnetic particle inspection (MPI) – the tests were performed according to PN-EN ISO 17638; the assessment was performed according to EN ISO 5817; the test equipment used was REM 230 magnetic flaw detector.
The results of the joints of the mobile platform are presented in Table 4.

Table 4 Evaluation of NDT of the mobile platform joint

Shielding gas	Without preheating	With preheating at 80°C
Ar	Cracks in welds and HAZ	No cracks
He	Cracks in welds and HAZ	No cracks

The table shows that preheating is required for proper welding of 1200M DOCOL steel. Two different shielding gases were used. In both cases, comparable results were obtained indicating that the shielding gases used were appropriate. It was stated that the preheating temperature of 80°C is sufficient. For further (destructive) tests, only the joints made with preheating were taken into account. The strength of the joints was tested using INSTRON 3369 strength testing machine. The results of the strength tests (average of 3 tests) are presented in Table 5.

Table 5 Results of the strength tests of DOCOL 1200M steel after welding with preheating at 80°C

Shielding gas	R_e [MPa]	R_m [MPa]	A_5 [%]
He	434	704	7.2
Ar	426	701	7.3

The table shows that high strength and acceptable, comparable plastic properties were obtained in all the cases tested. Slightly higher strength is attributed to MIG welded joints with helium as the shielding gas, whereas a bit higher relative elongation is featured by the joints made using argon.
Then a bending test was performed for all the joints made after preheating to 80°C. As part of the bending test, 5 measurements were performed for each tested joint thickness from the root side and from the face side. No cracks were observed in the weld and HAZ both from the root and face sides. The bending test was performed correctly, no cracks and other imperfections were detected in all tested DOCOL 1200M steel joints.
A microstructural analysis was then performed. Both after MIG welding with helium and argon, a dominant martensitic structure was observed which is shown in Figure 1.

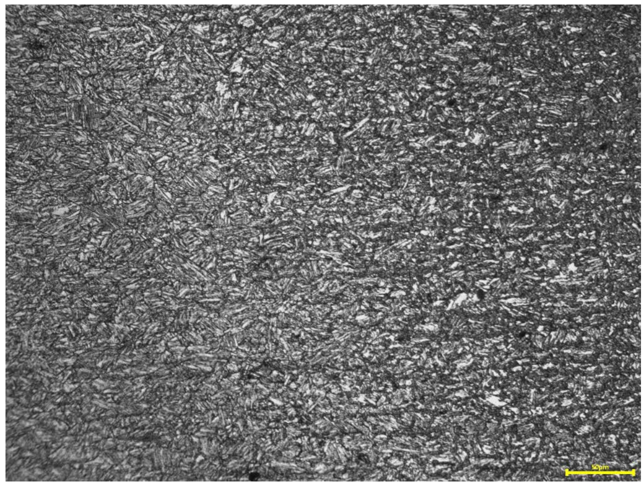

Figure 1 Microstructure of a MIG welded DOCOL 1200M steel weld made using Ar as the shielding gas at preheating temperature of 80°C and welding velocity of 400 mm/min

4. SUMMARY

In civil engineering and transportation, difficult to weld high-strength steels are used. Their high strength is considerably greater than the strength of the welded joint. The relative elongation of the processes used so far is rather low (approx. 7%). The tests indicate that preheating up to 80°C is required for making a proper 1200M DOCOL steel joint. The impact of different shielding gases was also studied. The use of helium enables a slightly higher yield stress and strength of the joint to be obtained. The use of argon allows for better plastic properties, as reflected by relative elongation. For economic reasons, for MIG welding of DOCOL 1200M steel it is recommended to use argon as the shielding gas.

Credits: The article is related to the implementation of the COST, CA 18223 project.

BIBLIOGRAPHY

[1] Jaewon L., Kamran A., Jwo P., Modeling of failure mode of laser welds in lap-shear specimens of HSLA steel sheets, Engineering Fracture Mechanics 2011, 1, pp. 347-396.
[2] Darabi J., Ekula K., Development of a chip-integrated micro cooling device, Microelectronics Journal 2003, 34(11), pp. 1067-1074, https://doi.org/10.1016/j.mejo.2003.09.010.
[3] Hadryś D., Impact load of welds after micro-jet cooling, Archives of Metallurgy and Materials 2015, 60(4), pp. 2525-2528, https://doi.org/10.1515/amm-2015-0409.

[4] Muszynski T., Mikielewicz D., Structural optimization of microjet array cooling system, Applied Thermal Engineering 2017, 123, pp. 103-110, https://doi.org/10.1016/j.applthermaleng.2017.05.082.
[5] Celin R., Burja J., Effect of cooling rates on the weld heat affected zone coarse grain microstructure, Metallurgical and Materials Engineering 2018, 24(1), pp. 37-44.
[6] Walsh S. M., Smith J. P., Browne E. A., Hennighausen T. W., Malouin B. A., Practical Concerns for Adoption of Microjet Cooling, ASME Proceedings 2018 Power Electronics, Energy Conversion, and Storage, https://doi.org/10.1115/IPACK2018-8468.
[7] https://www.yumpu.com/xx/document/view/11500058/docol-m-zimnowalcowana-stal-martenzytyczna-ssab.
[8] https://www.thyssenkrupp-steel.com/media/content_1/publikationen/grobblech_migration/perform/verarbeitung_1/schweissen_1/klassifikation_der_schweisszusaetze.pdf.