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OXYGEN IN STEEL WMD AFTER WELDING WITH MICRO-JET COOLING

TLEN W STALOWYM STOPIWIE PO SPAWANIU Z CHŁODZENIEM MIKROJETOWYM

Until that moment micro-jet technology was tested only for MIG welding process with argon as a shielded gas. An article presents actual information about innovate welding technology with micro-jet cooling. There are put down information about gases that could be chosen both for MIG/MAG welding and for micro-jet process. There were given information about influence of various micro-jet gases on metallographic structure of steel welds. Mechanical properties of weld was presented in terms of oxygen amount in WMD (weld metal deposit).

Keywords: welding, micro-jet cooling gases, weld, metallographic structure, acicular ferrite

Dotychczas technologia mikrojetowa była stosowana tylko w spawalniczym procesie MIG, gdzie gazem osłonowym był argon. W artykule przedstawiono innowacyjną technologię spawania z chłodzeniem mikrojetowym. Podano informacje zarówno dla gazów, które mogą być wybrane dla spawania MIG/MAG i dla mikrojetowego procesu. Uzyskano informacje o wpływie doboru gazu mikrojetowego na strukturę metalograficzną stalowych spoin. Własności mechaniczne złącza podano w funkcji zawartości tlenu w stopiwie.

1. Introduction

In last 15 years many authors put special attention to oxygen amount in WMD. Welding process was even classified respectively on [1]:

– low oxygen process (unless 450 ppm O in WMD)
– medium oxygen process (in range 450 up to 700 ppm O in WMD,
– high oxygen process (higher amount than 700 ppm of O).

In the steel structure the best mechanical properties of weld correspond with low-oxygen processes (approx. 400 ppm) that have strong influence on metallographic structure because of acicular ferrite (AF) amount. Amount of acicular ferrite (AF) could be treated as the most beneficial phase in steel WMD [1, 4, 8, 10]. Amount of AF in weld is connected with oxygen in WMD because of oxide inclusions situated in welds. Very important role plays such parameters of oxides as: size, density and lattices parameters of oxide inclusion. Having the most optimal oxide inclusion parameters in weld it is only possible to get maximal 65% of AF in weld, but never more [3÷9]. High amount of AF in WMD has influence on impact toughness of welds. Micro-jet technology gives chance to obtain artificially high amount of AF in weld that corresponds with better mechanical properties of weld [10, 11]. The micro-jet technology was tested for steel welding with various gases only for MIG process. In industry much more important is MIG/MAG welding with modern gas mixtures, especially for automotive welding [2, 12, 13]. In this paper there were firstly presented results of innovative welding method (with micro-jet cooling) with different gas mixtures and various micro-jet gases.

2. Experimental procedure

Weld metal deposit was prepared by welding with micro-jet cooling with varied gases both for welding and micro-jet process. To obtain various amount of oxygen in weld metal deposit it was installed welding process with micro-jet injector. Parameters of micro-jet technology was strongly limited:

– cooling steam diameter was 40 μm and 50 μm only,
– only two jets (micro-jet cooling couple) in parallel position (parallel to the axis of the weld) was chosen in cooling injector (first 40 μm and second 50 μm),
– gas pressure always 0.4 MPa,
– argon and helium were only chosen as micro-jet gases.

MIG/MAG welding process was based on two shielded gases: argon and gas mixture of 79% Ar and 21% CO_2. Figure 1 illustrates montage of welding head and micro-jet injector.

Thus weld metal deposit was prepared by welding with two gases (micro-jet cooling with two various shielded gases (Ar and gas mixture of 79% Ar and 21% CO_2). And with

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two micro-jet cooling gases (argon, helium) without changing main micro-jet parameters. The main data about parameters of welding were shown in Table 1.

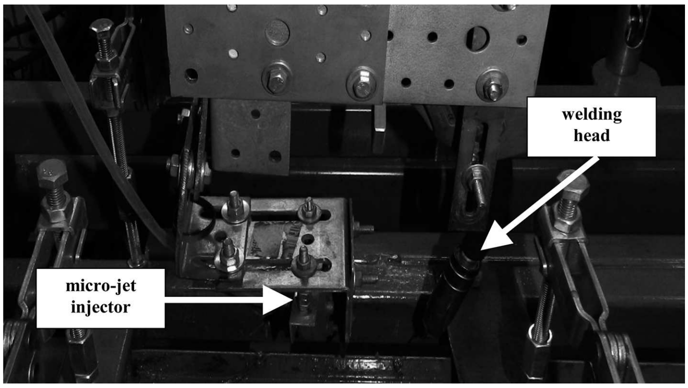

Fig. 1. Montage of welding head and micro-jet injector

TABLE 1

Parameters of welding process

No.	Parameter	Value
1.	Diameter of wire	1.2 mm
2.	Standard current	220 A
3.	Voltage	24 V
4.	Shielding welding gas	Ar 81% Ar + 19% CO_2
5.	Kind of tested micro-jet cooling gas	1 – Ar 2 – He
6.	Gas pressure	0.4 MPa
7.	Couple of jets:	first 40 μm second 50 μm
8.	Gas in injector	always the same for two jets

Thus weld metal deposit was prepared by welding with micro-jet cooling with varied parameters: two tested shielding gases, two tested micro-jet cooling gases, one couple of jets with various diameters but always with the same gas cooling).

3. Results and discussion

There were tested and compared various welds of standard MIG/MAG welding with innovative micro-jet cooling technology. A typical weld metal deposit had similar chemical composition in all tested cases. Micro-jet gas could have only influence on more or less intensively cooling conditions, but does not have any influence on chemical WMD composition (Table 2).

For standard MIG welding there were observed lower amount of oxygen in WMD than in MAG welding according to oxygen process classification [9, 10]. Micro-jet technology does not have any influence oxygen amount in WMD. After chemical analyses the metallographic structure was given. Example of this structure was shown in Tables 3 and 4.

TABLE 2

Chemical composition of WMD

Comment	Element	Amount
in all tested cases	C	0.08%
in all tested cases	Mn	0.79%
in all tested cases	Si	0.39%
in all tested cases	P	0.017%
in all tested cases	S	0.018%
MIG welding (Ar), without micro-jet cooling	O	380 ppm
MIG welding (Ar), He as micro-jet gas	O	380 ppm
MIG welding (Ar), Ar as micro-jet gas	O	380 ppm
MAG welding (79% Ar and 21% CO_2), without micro-jet cooling	O	530 ppm
MAG welding (79% Ar and 21% CO_2), He as micro-jet gas	O	530 ppm
MAG welding (79% Ar and 21% CO_2), Ar as micro-jet gas	O	530 ppm

TABLE 3

Metallographic structure of MIG welds

Micro-jet gases	Ferrite AF	MAC phases
without micro-jet	55%	3%
He	61%	5%
Ar	73%	2%

TABLE 4

Metallographic structure of MAG welds

Micro-jet gases	Ferrite AF	MAC phases
without micro-jet	43%	4%
He	59%	6%
Ar	63%	2%

Tables 3 and 4 show that in all cases argon is more beneficial micro-jet gas cooling than helium. In standard MIG/MAG welding process (without micro-jet cooling) there were usually gettable higher amounts of grain boundary ferrite (GBF) and site plate ferrite (SPF) fraction meanwhile in micro-jet cooling both of GBF and SPF structures were not so dominant in all tested cases (with both argon and helium as micro-jet gases). In all tested cases there were observed MAC (self-tempered martensite, retained austenite, carbide) phases on various level. Acicular ferrite with percentage above 70% was gettable only in one case after MIG welding with argon micro-jet cooling (shown on Figure 2, Table 3). The higher amount of MAC phases was especially gettable for more intensive helium micro-jet cooling in MAG process (Tabl. 3, 4).

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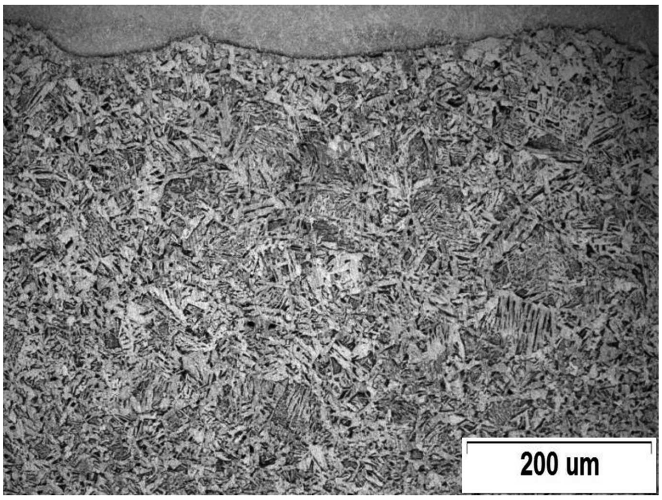

Fig. 2. High amount of acicular ferrite in weld (73%) after Ar micro-jet cooling

Heat transfer coefficient of various micro-jet gases influences on cooling condions of welds. This is due to the conductivity coefficients ($\lambda \cdot 10^5$), which for Ar and He in the 273 K are various, respectively: 16.26 and 143.4 J / (cm·s·K). Helium could give stronger cooling conditions and that fact translates higher amount of MAC phases in WMD and lower of AF.

After that Charpy V impact toughness of the deposited metal were carried out (5 specimens). The impact toughness results is given in Table 5. The Charpy tests were only taken at temperature – 40°C.

TABLE 5

Metallographic structure of MAG welds

Welding method	Micro-jet gas	Test temperature, °C	Impact toughness KCV, J
MAG	Ar	- 40	54
MIG			59
MAG	-		below 40
MIG			43
MAG	He		46
MIG			51

It is possible to deduce that impact toughness at negative temperature of weld metal deposit is apparently affected by the kind of micro-jet cooling gas. Micro-jet technology always strongly proves impact toughness of WMD. Argon must be treated as better micro-jet gas than helium, however micro-jet cooling with helium gives better results than simple MIG/MAG welding without micro-jet cooling.

4. Summary and conclusions

In steel welding there are two general types of tests performed: impact toughness and structure. Acicular ferrite and MAC phases (self-tempered martensite, upper and lower bainite, retained austenite, carbides) were analyzed and counted for each weld metal deposit. This two tests (microstructure and impact toughness) proved that micro-jet technology gives beneficial modification in mechanical properties of welds. The innovative micro-jet technology was firstly recognized with great success for MIG welding. In that paper micro-jet cooling technology was first time described and tested for MAG welding process with two various micro-jet gases: Ar and He. Micro-jet gas could have only influence on more or less intensively cooling conditions, but does not have any influence on oxygen amount in WMD. On the basis of investigation it is possible to deduce that micro-jet technology could be important complement of both welding methods: MIG and MAG.

5. Conclusions

1. micro-jet cooling could be treated as an important element of both MIG and MAG welding process,
2. micro-jet cooling after welding can prove amount of ferrite AF, the most beneficial phase in low alloy steel WMD,
3. argon could be treated as better micro-jet gas in low alloy steel welding processes both for MIG and MAG,
4. helium could not be treated as a good choice for low alloy steel micro-jet welding, however micro-jet helium cooling gives better results than simple MIG/MAG welding without micro-jet cooling,
5. helium as a micro-jet could be rather tested for superficial welding surface regenerative shaft because of it heat transfer coefficient,
6. Micro-jet injector after welding has only influence on more or less intensively cooling conditions, but does not have any influence on oxygen amount in WMD.

REFERENCES

[1] T. Węgrzyn, Proposal of welding methods in terms of the amount of oxygen, Archives of Materials Science and Engineering **47**, 1, 57-61 (2011).

[2] R. Burdzik, Monitoring system of vibration propagation in vehicles and method of analysing vibration modes, J. Mikulski (Ed.): Communications in Computer and Information Science **329**, 406-413, Springer, Heidelberg (2012).

[3] B. Slazak, J. Slania, T. Węgrzyn, A.P. Silva, Process Stability Evaluation of Manual Metal Arc Welding Using Digital Signals, reprint from VI International Materials Symposium, Materiais 2011, Guimarães, Portugal, 18-20 Abril 2011, full paper published in Materials Science Forum Vols. 730-732 (2013) online www.scientific.net, copywright Trans Tech Publications, Switzerland, pp 847-852.

[4] T. Węgrzyn, J. Mirosławski, A. Silva, D. Pinto, M. Miros, Oxide inclusions in steel welds of car body. Materials Science Forum 2010, vol. 6.

[5] T. Kasuya, Y. Hashiba, S. Ohkita, M. Fuji, Hydrogen distribution in multipass submerged arc weld metals, Science and Technology of Welding&Joining **6**, 4, 261-266 (2001).

[6] J. Słania, Influence of phase transformations in the temperature ranges of 1250-1000°C and 650-350°C on the ferrite content in austenitic welds made with T 23 12 LRM3 tubular electrode. Archives of Metallurgy and Materials, zeszyt 3/2005.

[7] K. Krasnowski, Influence of Stress Relief Annealing on Mechanical Properties and Fatigue Strength of Welded Joints of

Unauthenticated
Download Date | 2/20/18 8:49 PM

Thermo-Mechanically Rolled Structural Steel Grade S420MC. Archives of Metallurgy **54**, 4, (2009).

[8] T. Węgrzyn, Mathematical Equations of the Influence of Molybdenum and Nitrogen in Welds. Conference of International Society of Offshore and Polar Engineers ISOPE′2002, Kita Kyushu, Japan 2002, Copyright by International Society of Offshore and Polar Engineers, vol. IV, ISBN 1-880653-58-3, Cupertino – California – USA 2002.

[9] G. Golański, J. Słania, Effect of different heat treatments on microstructure and mechanical properties of the martensitic GX12CrMoVNbN91 cast steel. Archives of Metallurgy and Materials, zeszyt 4/2012.

[10] T. Węgrzyn, J. Piwnik, D. Hadryś, R. Wieszała, Car body welding with micro-jet cooling, Archives of Materials Science and Engineering **49**, 1 (2011).

[11] K. Lukaszkowicz, A. Kriz, J. Sondor, Structure and adhesion of thin coatings deposited by PVD technology on the X6CrNiMoTi17-12-2 and X40 CrMoV5-1 steel substrates, Archives of Materials Science and Engineering **51**, 40-47 (2011).

[12] D. Hadryś, M. Miros, Coefficient of restitution of model repaired car body parts; Journal of Achievements in Material and Manufacturing Engineering **28**, 1, Ryn, Maj 2008.

[13] P. Folęga, FEM analysis of the options of using composite materials in flexsplines. Archives of Materials Science and Engineering **51**, 1, 55-60 (2011).

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