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T. WĘGRZYN*,♯, J. PIWNIK**

NITROGEN AND OXYGEN AMOUNT IN WELD AFTER WELDING WITH MICRO-JET COOLING

ZAWARTOŚĆ AZOTU I TLENU W STALOWYM SPOINIE PO SPAWANIU Z CHŁODZENIEM MIKRO-JETOWYM

Micro-jet cooling after welding was tested only for MIG welding process with argon, helium and nitrogen as a shielded gases. A paper presents a piece of information about nitrogen and oxygen in weld after 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 main information about influence of various micro-jet gases on metallographic structure of steel welds. Mechanical properties of weld was presented in terms of nitrogen and oxygen amount in WMD (weld metal deposit).

Keywords: welding, micro-jet cooling gases, weld, metallographic structure, nitrogen and oxygen in weld

Chłodzenie mikro-jetowe było stosowane tylko w spawalniczym procesie MIG, gdzie gazem osłonowym były argon, hel i azot. W artykule przedstawiono informacje na temat zawartości azotu i tlenu w spoinie po chłodzeniu mikro-jetowym. Podano informacje zarówno dla gazów, które mogą być wybrane dla spawania MIG/MAG i dla mikro-jetowego procesu. Uzyskano informacje o wpływie doboru gazu mikro-jetowego na strukturę metalograficzną stalowych spoin. Własności mechaniczne złącza podano w funkcji zawartości azotu i tlenu w stopiwie.

1. Introduction

Many authors put especial attention to nitrogen and oxygen amount in MWD. 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),
– low nitrogen process (unless 50 ppm N in WMD)
– medium nitrogen process (in range 50 up to 70 ppm N in WMD,
– high nitrogen process (higher amount than 70 ppm of N).

Good mechanical properties of weld correspond respectively with low nitrogen and low-oxygen processes. Amount of nitrogen and oxygen has strong influence on metallographic structure because of influence of acicular ferrite (AF) formation. Amount of acicular ferrite (AF) is treated as the most beneficial structure in steel WMD that corresponds with high impact toughness of weld [1, 4, 8, 10]. Acicular ferrite could be easily formed with nonmetallic inclusion contact. Amount of AF in weld is connected with nitrogen and oxygen in WMD because of nitride and oxide inclusions presence in welds. Very important role plays such parameters of inclusions as: size, density, and first of all lattice parameter of nitride or oxide inclusions. Having the most optimal inclusion parameters in weld it is only possible to get maximal 60% of AF in weld, but no more [3-9]. Beneficial metallographic structure, with high amount of AF in MWD has influence on impact toughness of welds. Micro-jet cooling just after welding gives new chance to increase artificially high amount of AF in weld and consequently micro-jet cooling effects on mechanical properties of weld [9-13]. The micro-jet cooling was tested only for low alloy steel with three micro-jet gases (argon, helium, nitrogen) only for MIG/MAG welding with modern gas mixtures [2-5, 12]. Micro-jet cooling after welding can find very soon a very serious application in automotive industry [9-10, 15-17].

2. Experimental procedure

Weld metal deposit was prepared by welding with micro-jet cooling with varied gases both for MIG/MAG welding and micro-jet cooling process. To obtain various amount of nitrogen and oxygen in weld it was installed welding process with micro-jet injector. Main parameters of micro-jet cooling were slightly varied:

– cooling steam diameter was varied from 40 μm until 50 μm,
– o number of cooling jets was not varied (always 1),
– gas pressure was varied from 0.4 MPa until 0.5 MPa,
– argon, nitrogen, helium were only chosen as micro-jet gases.

* SILESIAN UNIWERSITY OF TECHNOLOGY, FACULTY OF TRANSPORT, 8 KRASIŃSKIEGO STR., 40-019 KATOWICE, POLAND
** BIAŁOSTOCK UNIVESITY OF TECHNOLOGY, FACULTY OF MECHANICAL ENGINEERING, 45C WIEJSKA STR., 15-351 BIAŁYSTOK, POLAND
♯ Corresponding author: Tomasz.Wegrzyn@polsl.pl

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

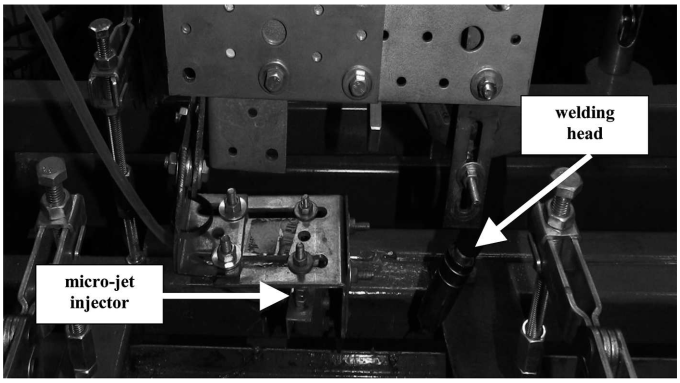

Fig. 1. Montage of welding head and micro-jet injector

Thus weld metal deposit was prepared by MIG?MAG welding with two different gases (Ar and gas mixture of 79% Ar and 21% CO_2) and with three micro-jet cooling gases (argon, helium, nitrogen). The main data about parameters of welding were shown in Table 1.

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 gases	Ar 81% Ar + 19% CO_2
5.	Kind of tested micro-jet cooling gas	1 – Ar 2 – He 3 – N_2
6.	Gas pressure	0.4 MPa 0.5 MPa
7.	Number of jets:	always 1
8.	cooling steam diameter	40 μm 50 μm

Weld metal deposit was prepared by welding with micro-jet cooling great number of parameters.

3. Results and discusion

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

For standard MIG welding there were observed much lower amount of oxygen in WMD than in MAG welding according to oxygen process classification [9, 10]. For standard MIG and MAG welding there were observed comparable

TABLE 2
Chemical composition of WMD

Welding process	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
MIG welding (N_2), Ar as micro-jet gas	O	370 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
MAG welding (79% Ar and 21% CO_2), N_2 as micro-jet gas	O	520 ppm
MIG welding (Ar), without micro-jet cooling	N	50 ppm
MIG welding (Ar), He as micro-jet ga	N	50 ppm
MIG welding (Ar), Ar as micro-jet gas	N	50 ppm
MIG welding (Ar), N_2 as micro-jet gas	N	70 ppm
MAG welding (79% Ar and 21% CO_2) without micro-jet cooling	N	55 ppm
MAG welding (79% Ar and 21% CO_2), He as micro-jet gas	N	55 ppm
MAG welding (79% Ar and 21% CO_2), Ar as micro-jet gas	N	55 ppm
MAG welding (79% Ar and 21% CO_2), N_2 as micro-jet gas	N	75 ppm

amount of nitrogen. It is easy to deduce that micro-jet cooling after welding does not have strong influence on nitrogen and oxygen amount in WMD. After chemical analyses the metallographic structure was given. Example of this structure was shown in Table 3 (a detailed analysis of all micro-jet parameters), and in Table 4 (simplified version).

Tables 3, 4 show that in all cases argon is more beneficial micro-jet gas cooling than helium and nitrogen. Nitrogen as micro-jet gas could be treated as a wrong choice. 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 also 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 3, Table 3). The higher amount of MAC phases was especially gettable for more intensive nirogen micro-jet cooling in MAG process (Tabl. 3, 4).

TABLE 3

Metallographic structure of MIG welds

Micro-jet gas	**Micro-jet gas pressure [MPa]**	**Micro-jet diameter [μm]**	**Ferrite AF**	**MAC phases**
without micro-jet	without micro-jet	without micro-jet	55%	4%
He	0.4	40	60%	3%
He	0.4	50	61%	3%
He	0.5	40	61%	3%
He	0.5	50	59%	3%
Ar	0.4	40	71%	2%
Ar	0.4	50	73%	2%
Ar	0.5	40	73%	2%
Ar	0.5	50	72%	2%
N_2	0.4	40	53%	4%
N_2	0.4	50	51%	5%
N_2	0.5	40	50%	5%
N_2	0.5	50	49%	5%

TABLE 4

Metallographic structure of MAG welds

Micro-jet gases	**Ferrite AF**	**MAC phases**
without micro-jet	53%	4%
He	59%	3%
Ar	63%	2%
N_2	53%	5%

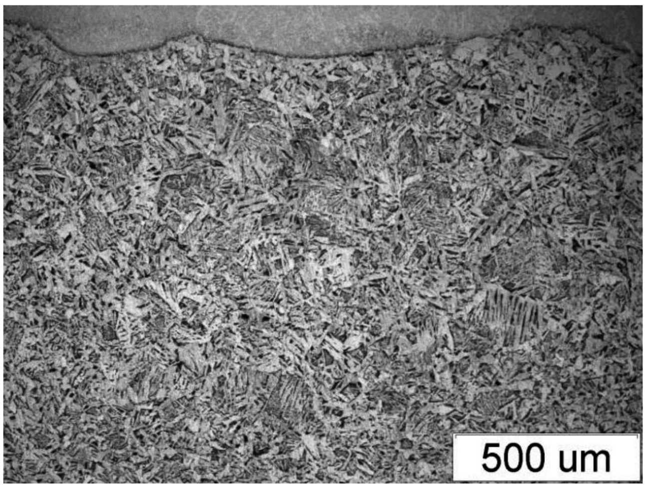

Fig. 2. High amount of acicular ferrite in weld (73%) after Ar micro-jet cooling

After microstructure studies the 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 and +20°C.

It is possible to deduce that impact toughness both at ambient and 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.

TABLE 5

Metallographic structure of MAG welds

Welding method	Micro-jet gas	Impact toughness KCV, J (at - 40°C)	Impact toughness KCV, J (at +20°C)
MIG	-	43	181
MAG	-	below 40	175
MAG	Ar	54	183
MIG	Ar	59	195
MAG	He	46	186
MIG	He	51	182
MAG	N_2	below 40	152
MIG	N_2	below 40	155

4. Summary and conclusions

In low alloy steel welding there are two general types of tests performed: impact toughness and microstructure. Acicular ferrite and MAC phases (self-tempered martensite, upper and lower bainite, retained austenite, carbides) were fully 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 also precisely described and tested for MAG welding process with three various micro-jet gases: argon, helium, nitrogen. 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. An important part of the article was to analyze the content of oxygen and nitrogen in the weld. MAG welding process is treated as average oxygen process (because of 525 ppm O in weld regardless of the micro-jet parameters). MIG welding process is treated as low oxygen process (because of 375 ppm O in weld regardless of the micro-jet parameters). The use of nitrogen as the cooling gas will significantly influence the structure and properties of welds.

Final conclusions:

a) micro-jet cooling could be treated as an important element of both MIG and MAG welding process,
b) micro-jet cooling after welding can prove amount of ferrite AF, the most beneficial phase in low alloy steel WMD,
c) argon could be treated as optimal micro-jet gas for low alloy steel welding processes both for MIG and MAG,
d) helium and nitrogen 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,

e) micro-jet injector after welding has only influence on more or less intensively cooling conditions, but does not have strong influence on oxygen amount in WMD,

f) micro-jet injector after welding has only influence on more or less intensively cooling conditions, but does not have strong influence on nitrogen amount in WMD when argon and helium are used as micro-jet gases,

g) micro-jet injector after welding has strong influence on nitrogen amount in WMD when nitrogen is used as micro-jet gas.

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