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T. WĘGRZYN*

GAS MIXTURES FOR WELDING WITH MICRO-JET COOLING

GAZOWE MIESZANKI DO SPAWANIA Z CHŁODZENIEM MIKRO-JETOWYM

Welding with micro-jet cooling after was tested only for MIG and MAG processes. For micro-jet gases was tested only argon, helium and nitrogen. A paper presents a piece of information about gas mixtures for micro-jet cooling after in welding. There are put down information about gas mixtures that could be chosen both for MAG welding and for micro-jet process. There were given main information about influence of various micro-jet gas mixtures on metallographic structure of steel welds. Mechanical properties of weld was presented in terms of various gas mixtures selection for micro-jet cooling.

Keywords: welding, micro-jet cooling, weld, metallographic structure, gas mixtures

Chłodzenie mikro-jetowe było stosowane tylko w spawalniczym procesie MIG i MAG, gdzie gazem osłonowym były tylko argon, hel i azot. W artykule przedstawiono informacje na temat wykorzystania mieszanek gazowych do chłodzenia mikro-jetowego. Podano informacje zarówno dla gazów, które mogą być wybrane dla spawania MAG i dla mikro-jetowego procesu. Uzyskano informacje o wpływie doboru mieszanek gazowych do chłodzenia mikro-jetowego na strukturę metalograficzną stalowych spoin. Własności mechaniczne złącza podano dla złączy wykonanych różnymi mieszankami gazowymi.

1. Introduction

Proper mechanical properties of weld correspond respectively with low nitrogen and low-oxygen processes. Amount of nitrogen and oxygen in weld metal deposit (WMD) has strong influence on its metallographic structure because of acicular ferrite (AF) amount. Acicular ferrite (AF) is treated as the most beneficial structure in steel WMD that corresponds with good impact toughness [1-5]. Amount of AF in weld is connected with nitrogen and oxygen in WMD because of nitride and oxide inclusions of welds. Even having optimal oxide inclusion parameters in weld metal deposit it is only possible to get maximal 60 % of acicular ferrite. [6-9]. 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 [10-11]. 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 [12-16]. Nitrogen is not treated as a good gas for micro-jet cooling. Argon and helium as micro-jet gases could give better impact toughness of WMD (0.08% C, 0.8% Mn) than classic MIG/MAG process (Table 1-2).

Tables 1 and 2 show that in all cases argon is more beneficial micro-jet gas cooling than helium. Also it is shown that micro-jet cooling improves acicular ferrite amount in weld. For automotive sector material properties, production and repair technologies are extremely important [17-23].

TABLE 1
Metallographic structure of MIG welds [1]

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

TABLE 2
Metallographic structure of MAG welds [1]

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

2. Experimental procedure

Weld metal deposit was prepared by welding with micro-jet cooling with gas mixtures both for standard MAG welding and MAG welding with micro-jet cooling. To obtain various amount of acicular ferrite in weld it was installed welding process with micro-jet injector. Main parameters of micro-jet cooling were slightly varied:

– cooling steam diameter (40 μm and 50 μm),

* THE SILESIAN UNIVERSITY OF TECHNOLOGY, FACULTY OF TRANSPORT, 8 KRASIŃSKIEGO STR., 40-019 KATOWICE, POLAND

– gas pressure (0.4 MPa and 0.5 MPa),

– gas mixtures of argon (82% Ar/18% CO2 and 98% Ar/2% O2 and Ar + 2% CO2 + 20% He) were chosen as micro-jet gases.

MAG welding process and micro-jet cooling were based on two shielded and micro-jet gases: mixture of 79% Ar and 21% CO2 and 97% Ar/3% O2. Montage of welding head and micro-jet injector illustrates Figure 1.

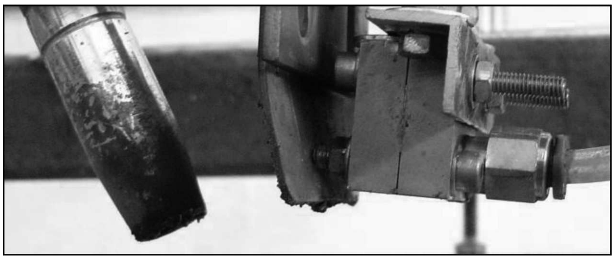

Fig. 1. Montage of welding head and micro-jet injector

The main data about parameters of welding were shown in Table 3.

TABLE 3

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	82% Ar/18% CO_2; 98% Ar/2% O_2
5.	Kind of tested micro-jet cooling gas	82% Ar/18% CO_2; 98% Ar/2% O_2; 78% Ar + 2% CO_2+ 20% He
6.	Gas pressure	0.4 MPa; 0.5 MPa
7.	Number of micro-jets:	1
8.	cooling steam diameter	40 μm; 50 μm

Weld metal deposit was prepared by welding with micro-jet cooling with great number of parameters (Table 3).

3. Results and discusion

There were tested and compared various welds of standard 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 4).

After chemical analyses the metallographic structure of WMD (of MAG method with two different shielded gases) were carried out. Example of this structure was shown respectively in Tables 5, 6.

TABLE 4

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%

TABLE 5

Metallographic structure of (MAG method 82% Ar/18% CO2) welds

Micro-jet gases	Gas Pressure MPa	Cooling steam diameter, μm	Ferrite AF	MAC phases
without micro-jet	-	-	55%	3%
82% Ar/18% CO_2	0.4	40	66%	2%
82% Ar/18% CO_2	0.4	50	71%	2%
82% Ar/18% CO_2	0.5	40	71%	2%
82% Ar/18% CO_2	0.5	50	65%	2%
98% Ar/2% O_2	0.4	40	63%	2%
98% Ar/2% O_2	0.4	50	64%	2%
98% Ar/2% O_2	0.5	40	65%	2%
98% Ar/2% O_2	0.5	50	61%	2%
Ar + 2% CO_2+ 20% He	0.4	40	61%	3%
Ar + 2% CO_2+ 20% He	0.4	50	59%	3%
Ar + 2% CO_2+ 20% He	0.5	40	59%	3%
Ar + 2% CO_2+ 20% He	0.5	50	57%	3%

Tables 5, 6 show that in all cases gas mixture of argon with carbon dioxide and Ar with oxygen is more beneficial than argon with helium. There were also observed MAC (self-tempered martensite, retained austenite, carbide) phases on various level. In standard MAG welding process (without micro-jet cooling) there are usually gettable higher amounts of grain boundary ferrite (GBF) and site plate ferrite (SPF) fraction meanwhile in micro-jet cooling WMD both of GBF and SPF structures were not so dominant. Ferrite with percentage above 70% was gettable only in one case after MAG welding (shielded gas mixture: 82% Ar/18% CO2) with micro-jet gas mixture (82% Ar/18% CO2 (shown on Figure 2, Table 5). The higher amount of MAC phases was especially gettable for more intensive micro-jet cooling with gas mixture of argon-helium (Tabl. 5, 6).

TABLE 6
Metallographic structure of (MAG method 98% Ar/2% CO2) welds

Micro-jet gases	Gas Pressure MPa	Cooling steam diameter, μm	Ferrite AF	MAC phases
without micro-jet	-	-	55%	3%
82% Ar/18% CO_2	0.4	40	64%	2%
82% Ar/18% CO_2	0.4	50	67%	2%
82% Ar/18% CO_2	0.5	40	66%	2%
82% Ar/18% CO_2	0.5	50	63%	2%
98% Ar/2% O_2	0.4	40	61%	2%
98% Ar/2% O_2	0.4	50	62%	2%
98% Ar/2% O_2	0.5	40	63%	2%
98% Ar/2% O_2	0.5	50	60%	2%
Ar + 2% CO_2+ 20% He	0.4	40	61%	3%
Ar + 2% CO_2+ 20% He	0.4	50	58%	3%
Ar + 2% CO_2+ 20% He	0.5	40	57%	3%
Ar + 2% CO_2+ 20% He	0.5	50	57%	3%

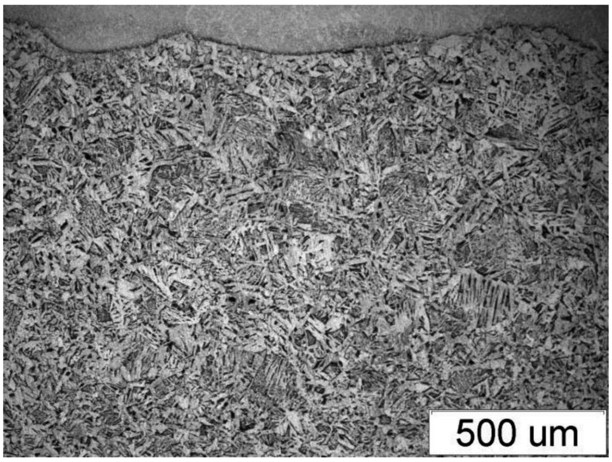

Fig. 2. High amount of acicular ferrite in weld (71%) after Ar/CO2 micro-jet cooling

Heat transfer coefficient of various micro-jet gases mixtures influences on cooling conditions 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 MWD and lower of AF.

After that Charpy V impact toughness of the deposited metal were carried out with 5 specimens of WMD with highest amount of acicular ferrite (table 5). The Charpy tests were only carried out at temperature - 40°C and +.20°C. The impact toughness results is given in Table 7.

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 mixtures. Micro-jet technology always strongly proves impact toughness of WMD. Argon with carbon dioxide or argon with oxygen must be treated as better micro-jet gas mixture than argon with helium. Nevertheless micro-jet cooling with gas mixture of argon with helium gives better results than simple MAG welding without micro-jet cooling.

TABLE 7
Metallographic structure of MAG (**82% Ar/18% CO_2**) welds

Welding method	Micro-jet gas	Test temperature, °C	Impact toughness KCV, J
MAG with micro-jet cooling	**82% Ar/18% CO_2**	- 40	57
MAG with micro-jet cooling	**98% Ar/2% O_2**	- 40	55
MAG with micro-jet cooling	**Ar + 2% CO_2+ 20% He**	- 40	43
MAG	-	- 40	below 40
MAG with micro-jet cooling	**82% Ar/18% CO_2**	+20	187
MAG with micro-jet cooling	**98% Ar/2% O_2**	+20	191
MAG with micro-jet cooling	**Ar + 2% CO_2+ 20% He**	+20	189
MAG	-	+20	183

4. Summary and conclusions

In low alloy 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 only with argon as a micro-jet gas. In that paper micro-jet cooling technology was first time described and tested for MAG welding process with various micro-jet gas mixtures of argon.

Final conclusions:

a) micro-jet cooling could be treated as an important element of 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) gas mixture of argon with carbon dioxide and gas mixture of argon with oxygen could be treated as better micro-jet cooling media than gas mixture of argon with helium,
d) micro-jet cooling with gas mixture of argon with carbon dioxide, oxygen or helium gives better results than simple MAG welding without micro-jet cooling.

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