A R C H I V E S O F M E T A L L U R G Y A N D M A T E R I A L S
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MAIN MICRO-JET COOLING GASES FOR STEEL WELDING

WAŻNIEJSZE GAZY DO MIKRO-JETOWEGO SPAWANIA STALI

An article presents actual information about innovate welding technology with micro-jet cooling. There are put down information about gases that could be chosen for micro-jet process. There were given information about influence of various micro-jet gases on metallographic structure of steel welds.
Keywords: welding, micro-jet cooling gases, weld, metallographic structure, acicular ferrite

W artykule przedstawiono innowacyjną technologię spawania z chłodzeniem mikro-jetowym. Podano informacje nt gazów, które mogą być wybrane dla mikro-jetowego procesu. Uzyskano informacje o wpływie doboru gazu mikro-jetowego na strukturę metalograficzną stalowych spoin.

1. Introduction

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. Especially an maximal amount of acicular ferrite (AF), the most beneficial phase is translated by role of oxygen in metal weld deposit (MWD) [1-6]. AF in weld is connected with size, density and lattices parameters of oxide inclusion in weld. Having the most optimal inclusions in weld it is only possible to get even 65% of AF in weld, but no more [6-9]. High amount of AF in MWD has influence on impact toghness of welds. It was necessary to develop completely new welding technology to maximize of ferrite AF content. Micro-jet technology gives chance to obtain artificially high amount of AF in weld that corresponds with better mechanical properties of weld [10-14]. The micro-jet technology was tested for steel welding with various gases.

2. Experimental procedure

To obtain much higher amount of acicular ferrite in weld metal deposit it was installed welding process with micro-jet injector (with steam diameter of 40 μm). Montage of welding head and micro-jet injector illustrates Figure 1.

Weld metal deposit was prepared by welding with micro-jet cooling with varied gases. Metal weld deposit was prepared by welding with various micro-jet cooling gases (nitrogen, argon, helium) without changing other micro-jet parameters. The main data about parameters of welding were shown in Table 1.

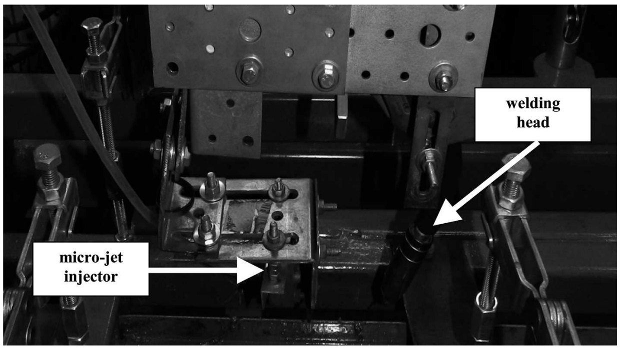

Fig. 1. Montage of welding head and micro-jet injector

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 Ar + 1.5% O_2 82% Ar + 18% CO_2
5.	Kind of tested micro-jet cooling gas	1 – Ar 2 – He 3 – N_2
6.	Gas pressure	0.4 MPa

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Argon, nitrogen and helium were chosen for micro-jet cooling (with diameter of 40 μm of stream). Cooling gas pressure was always 0.4 MPa.

MIG welding technology (with micro-jet cooling) was only used in this project. Argon is chosen because of not oxidizing potential as a shield gas. Weld metal deposit was prepared by welding with micro-jet cooling with varied geometrical parameters.

3. Results and discusion

There were tested and compared various welds of standard MIG welding with new technology: MIG welding with micro-jet cooling. All tested welding processes were realized with varied micro-jet gases: argon, helium, nitrogen. A typical weld metal deposit had chemical composition in all tested cases. Micro-jet gas could have only influence on more or less intensively cooling conditions, but does not have greater influence on chemical WMD composition (except nitrogen amount in MWD), Figure 2, Table 2.

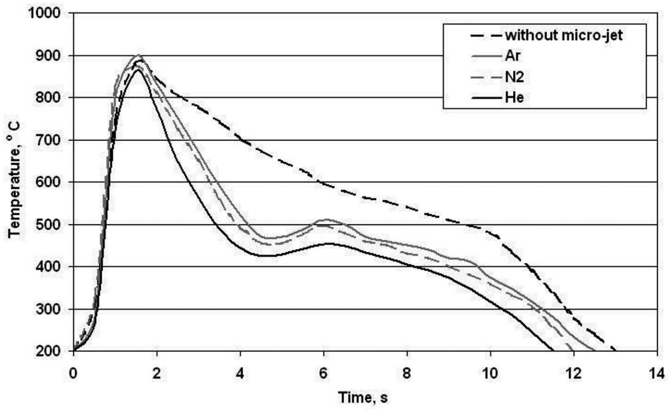

Fig. 2. Weld cooling conditions (without micro-jet and with different cooling gases)

TABLE 2

Chemical composition of metal weld deposit

No.	Element	Amount
1.	C	0.08%
2.	Mn	0.79%
3.	Si	0.39%
4.	P	0.017%
5.	S	0.018%
6.	O	380 ppm
7.	N	50-70 ppm

For standard MIG welding and welding with two micro-jet gases: argon and helium amount of nitrogen was always on the level of 50 ppm. For welding with nitrogen as a micro-jet gas amount of nitrogen was higher, on the level of 70 ppm. After chemical analyses the metallographic structure was given. Example of this structure was shown in Table 3.

TABLE 3

Metallographic structure of welds

Micro-jet gases	Ferrite AF	MAC phases
without micro-jet	55%	3%
He	61%	6%
Ar	73%	2%
N_2	55%	4%

In standard MIG 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 dominant in all tested cases (with argon, nitrogen, helium as micro-jet gas). In all tested cases there were observed also MAC (self-tempered martensite, retained austenite, carbide) phases. Acicular ferrite with percentage above 70% was gettable only after argon micro-jet cooling (shown on Figure 3, Table 3). The higher amount of MAC phases was especially gettable for nitrogen micro-jet cooling and for standard MIG (Table 3).

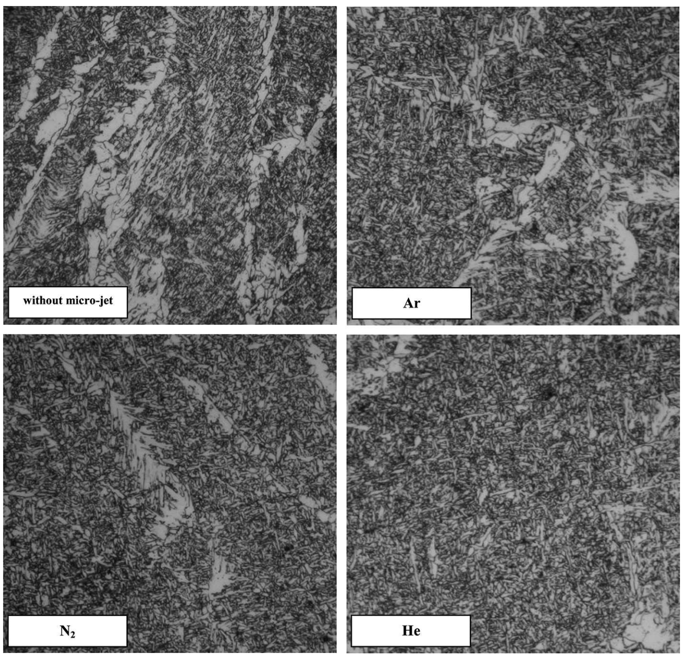

Fig. 3. Acicular ferrite in weld (68-73%) in terms on micro-jet gases, magnification ×200

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, N_2, He in the 273 K are various, respectively: 16.26, 23.74, 143.4 J / (cm·s·K). Cooling conditions are rather similar when nitrogen and argon are chosen as a micro-jet gas. Helium could give stronger cooling conditions and that fact translates high amount of MAC phases in MWD. There were no observed nitrides in MWD, so after welding with nitrogen as a micro-jet gas, higher amount of nitrogen is connected only with nitrogen as a interstitial effect in material.

4. Summary and conclusions

An innovative apparatus to welding process with micro-jet cooling of the weld made it possible to carry out technological tests which have proved theoretical consideration about this problem. This project gives a real opportunities for professional development in the field of welding with controlling the parameters of weld structure. These tests have proved that the new micro-jet technology has the potential for growth. It may be great achievement of welding technology in order to increase weld metal strength. The new technology with micro-jet cooling may have many practical applications in many fields, like for example in transport industry or to repair damaged metal elements. On the basis of investigation it is possible to deduce that:

1. micro-jet cooling could be treated as an important element of MIG welding process,
2. micro-jet cooling after welding can prove amount of ferrite AF, the most beneficial phase in low alloy steel weld metal deposit,
3. argon could be treated as an optimal micro-jet gas in welding process
4. helium could not be treated as a good choise for micro-jet welding, because metallographic structure is not very beneficial
5. nitrogen also could not be treated as a proper gas for micro-jet welding, because of higher percentage of N in MWD.

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