Arch. Metall. Mater., Vol. 61 (2016), No 3, p. 1405–1408

DOI: 10.1515/amm-2016-0230

D. HADRYŚ*,#, T. WĘGRZYN**, J. PIWNIK***, Z. STANIK**, W. TARASIUK***

THE USE OF COMPRESSED AIR FOR MICRO-JET COOLING AFTER MIG WELDING

The material selected for this investigation was low alloy steel weld metal deposit (WMD) after MIG welding with micro-jet cooling. The present investigation was aimed as the following tasks: obtained WMD with various amount of acicular ferrite and further analyze impact toughness of WMD in terms of acicular ferrite amount in it. Weld metal deposit (WMD) was first time carried out for MIG welding with micro-jet cooling of compressed air and gas mixture of argon and air. Until that moment only argon, helium and nitrogen were tested as micro-jet gases for MIG/MAG processes. An important role in the interpretation of the results can give methods of artificial intelligence.

Keywords: MIG, welding, micro-jet, nitrogen and oxygen in WMD, acicular ferrite, impact toughness, compressed air

1. Introduction

It has recently been invented MIG/MAG/TIG welding with micro-jet cooling [1-3]. Especially micro-jet cooling after MIG welding (Fig. 1) give chance to obtain weld metal deposit with very high amount of acicular ferrite (AF) in weld metal deposit (WMD) that corresponds with much higher impact toughness of weld [4-6]. Because of precise and selective micro-jet cooling it is possible to get even higher amount of acicular ferrite than after laser welding process [7, 8]. Micro-jet cooling gives results also in surface steel welding [9, 10].

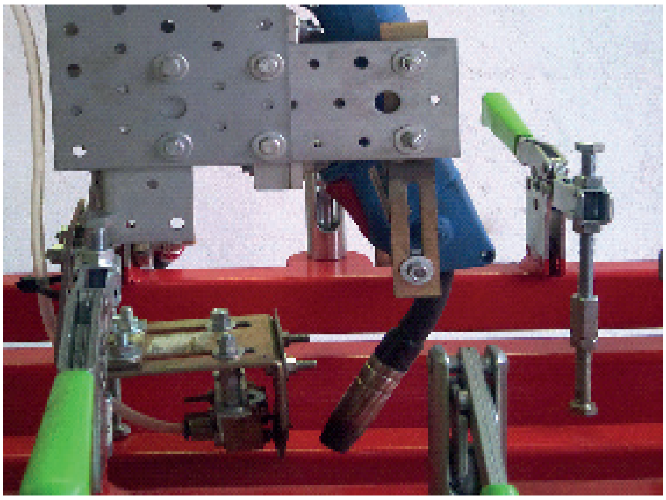

Fig. 1. MIG welding head with micro-jet injector [11]

This figure also describes how that montage can be used in the study of vibration problems by considering a very simple system in detail [11, 12]. Generally amount of AF is as the most beneficial structure in low alloy steel WMD that directly corresponds with with low-nitrogen and low-oxygen processes (50 ppm of N, 350 ppm of O). Having the most optimal oxide and nitride inclusion parameters in WMD it is only possible to get maximal 55% of AF in weld, but no more [2, 5]. In TIG welding, the acicular ferrite content is observed at the maximum of 48%. In laser process the acicular ferrite amount is observed on the higher level of max. 60% [10-12]. The micro-jet cooling was tested for low alloy steel with various micro-jet parameters (micro-jet gas pressure, stream diameter, various gas mixtures of argon-air). It was assumed that increase the air content in that gas mixture should correspond to the grows of the oxygen content in WMD.

2. Plan of the research

The present paper aims at outlining micro-jet innovations only in MIG process. It was decided to investigate the properties of weld metal deposit having various amount of oxygen in WMD after MIG welding with micro-jet cooling (depending on the parameters of the micro-jet cooling just after welding). The weld metal deposit was prepared by welding with micro-jet cooling with varied gas mixtures of argon and air. To obtain various amount of nitrogen and oxygen in WMD and perhaps consequently various amount of acicular ferrite in weld, the micro-jet injector was installed after welding head. Main parameters of micro-jet cooling were slightly varied:

- cooling steam diameter was varied (between: 40 μm and 50 μm),
- gas pressure was varied (between: 0.4 MPa and 0.5 MPa),

* UNIVERSITY OF OCCUPATIONAL SAFETY MANAGEMENT IN KATOWICE, 8 BANKOWA STR., 40-007 KATOWICE, POLAND
** SILESIAN UNIVERSITY OF TECHNOLOGY, 8 KRASINSKIEGO STR., 40-019 KATOWICE, POLAND
*** BIALYSTOK UNIVERSITY OF TECHNOLOGY, 45C WIEJSKA STR., 15-351 BIALYSTOK, POLAND
# Corresponding author: dhadrys@wszop.edu.pl

- micro-jet gases were varied (gas mixture of argon and air).
- MIG welding processes based on argon only.

3. Materials to research

Weld metal deposit was mainly prepared by welding with micro-jet cooling with various gas mixtures of argon-air (with changing other micro-jet parameters: gas pressure, cooling stream diameter). The basic material to research was low alloy steel S355J2G3. Various welds of standard MIG welding were compared firstly without innovative micro-jet cooling technology. A typical weld metal deposit had rather similar chemical composition in all tested cases (table 1). 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 MIG welding gas	argon
5.	Micro-jet cooling gas mixtures	1. argon 2. 33% argon, 67% air 3. 67% argon, 33% air 4. air
6.	Micro-jet gas pressure	0.4 MPa 0.5 MPa
7.	Steam diameter of micro-jet gas	40 μm, 50 μm
8	Cooling streams in injector	always 1

4. Results and discussion

It was decided to test amount of main elements in WMD after welding with various parameters. A typical weld metal deposit had rather similar chemical composition in all tested cases except oxygen and nitrogen amount (table 2).

TABLE 2

Chemical composition of WMD after welding

No.	Element	Amount
1.	C	0.08%
2.	Mn	0.77%
3.	Si	0.39%
4.	P	0.016%
5.	S	0.017%
6.	N	50 - 65 ppm
7.	O	350 - 440 ppm

Various micro-jet parameters had some influence on intensively cooling conditions but did not have greater influence on chemical WMD composition (especially except nitrogen and oxygen in WMD). Metallographic structure of WMD was carried out after chemical analyses of WMD. Acicular ferrite (AF) amount in WMD was precisely measured. A piece of information about metallographic structure of WMD is shown in table 3.

TABLE 3

Acicular ferrite and MAC phases in WMD after MIG welding with various micro-jet parameters

Micro-jet gas	Micro-jet gas pressure [MPa]	Steam diameter of micro-jet gas [μm]	N in WMD [ppm]	O in WMD [ppm]	Acicular ferrite [%]
without cooling	-	-	50	350	48
Ar	0.4	40	50	350	68
67% argon 33% air	0.4	40	53	365	63
33% argon 67% air	0.4	40	55	390	52
air	0.4	40	58	420	44
Ar	**0.5**	**50**	**50**	**350**	**71**
67% argon 33% air	0.5	50	55	395	57
33% argon 67% air	0.5	50	58	425	49
air	0.5	50	60	440	41

Analyzing tables 3 it is easy to deduce that welding with micro-jet cooling must be treated as a very good option. Amount of acicular ferrite in WMD after MIG welding without micro-jet cooling was only on the level of 48%. It is also shown that argon pressure as a micro-jet gas after MIG welding should be on the level of 0.4 MPa or even better 0.5 MPa, and stream diameter of micro-jet cooling gas should be on the level of 40 μm or 50 μm. These parameters correspond with the most beneficial amount of oxygen in WMD on the level of 350 ppm and consequently with 71% of acicular ferrite). Acicular ferrite with high percentage above 60% in WMD after welding with gas mixture argon-air was gettable only once (67% Ar) . Thus it is easy to deduce that micro-jet cooling has strong influence on metallographic structure (Fig. 3).

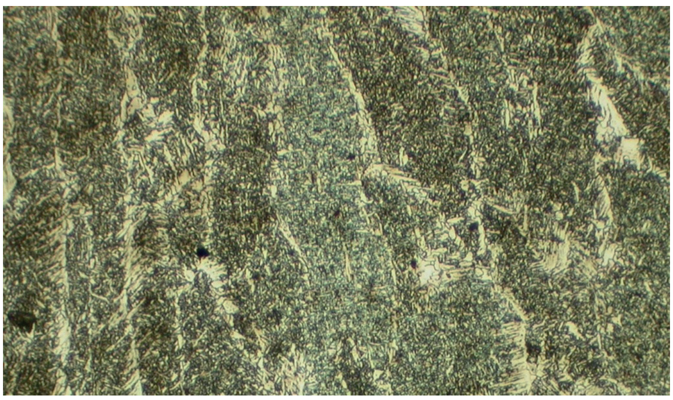

Fig. 3. Microstructure of WMD (63% of acicular ferrite) after MIG welding with micro-jet cooling of gas mixture (33% argon, 67% air), magn. 200x

TABLE 4

Impact toughness for MIG welding with varied micro-jet gases

Micro-jet gas	Impact toughness, -20° C [KV, J]	Impact toughness, -40° C [KV, J]
without cooling	48	below 47
Ar (weaker parameters)	**85**	**68**
67% argon 33% air (weaker parameters)	**73**	**61**
33% argon 67% air **(weaker parameters)**	52	below 47
Air **(weaker parameters)**	below 47	below 47
Ar (stronger parameters)	**81**	**65**
67% argon 33% air **(stronger parameters)**	66	below 47
33% argon 67% air **(stronger parameters)**	50	below 47
Air **(stronger parameters)**	below 47	below 47

There were not analyzed intermediate values of main micro-jet parameters (micro-jet gas pressure and steam diameter of micro-jet gas). An important role in the interpretation of the results can give methods of artificial intelligence. This interpretation need greater database. After microscope analysis, Charpy V impact test of the deposited metal were carried out. For these studies there were selected samples containing the highest acicular ferrite content (table 4). The Charpy tests were done mainly at temperature + 20° C, 0 and - 40° C on 5 specimens having been extracted from each weld metal (table 4).

It is possible to deduce that impact toughness at negative temperature of weld metal deposit is apparently affected by acicular ferrite amount in WMD, that corresponds perfectly with micro-jet cooling parameters (tables 3, 4). Argon with small amount of air (33%) for micro-jet cooling gas mixture could be regarded as a good choice. They were not tested other intermediate values for air content in gas mixture of argon. It is easy to assume that an important role in the interpretation of the results can give methods of artificial intelligence.

5. Conclusions

This investigation has proved that the new micro-jet technology has still the potential for growth. It might be great achievement of welding technology in order to steer weld metal structure and impact toughness. On the basis of investigation it is possible to deduce that:

- micro-jet cooling could be treated as an important element of MIG welding process;
- micro-jet cooling after welding can prove amount of ferrite AF, the most beneficial phase in low alloy steel weld metal deposit;
- argon mixtures with small amount of air could be treated as proper micro-jet cooling media in welding process;
- micro-jet gas mixture pressure should be on the level of 0.4 MPa;
- optimal micro-steam diameter of gas mixture should be on the level 40 μm;

REFERENCES

[1] T. Wegrzyn, J. Piwnik, D. Hadrys, Oxygen in steel WMD after welding with micro-jet cooling, Archives of Metallurgy and Materials **58**, 4 (2013).

[2] J. Piwnik, D. Hadrys, G. Skorulski, Plastic properties of weld after micro-jet cooling; Journal of Achievements in Material and Manufacturing Engineering **59**, 1 (2013).

[3] T. Wegrzyn J. Piwnik, B. Lazarz D. Hadrys, Main micro-jet cooling gases for steel welding, Archives of Metallurgy and Materials **58**, 2 (2013).

[4] A. Kurc-Lisiecka, W. Ozgowicz, W. Ratuszek, J. Kowalska, Analysis of Deformation Texture in AISI 304 Steel Sheets, Solid State Phenomena **203-204**, 105-110 (2013), Doi 10.4028/www.scientific.net/SSP.203-204.105.

[5] B. Formanek, K. Szymanski, B. Szczucka-Lasota, New generation of protective coatings intended for the power industry, Journal of Materials Processing Technology **164-165**, 850-855 (2015).

[6] G. Siwiec, Elimination of aluminium during the process of Ti-6Al-4V alloy during in a vacuum induction furnace, Archives of Metallurgy and Materials **57**, 4, 951-956 (2012).

[7] A. Lisiecki, Titanium Matrix Composite Ti/TiN Produced by Diode Laser Gas Nitriding. Metals, 5(1), (2015).

[8] B. Szczucka-Lasota, W. Majewski, Oxidation resistance of coating obtained by innovative methods for energy boilers, Advanced Materials Research **1036**, 152-157 (2014).

[9] G. Golanski, P. Gawien, P. Slania: Examination of Coil Pipe Butt Joint Made of 7CrMoVTib10 - 10(T24) Steel After Service, Archives of Metallurgy and Materials **57**, 2, 553-557 (2012).

[10] T. Wegrzyn, J. Piwnik, B. Lazarz, W. Tarasiuk, Mechanical properties of shaft surfacing with micro-jet cooling, ISSN 1392-1207, Mechanika, **21** (5), 419-423 (2015).

[11] R. Burdzik, Z. Stanik, J. Warczek, Method of assessing the impact of material properties on the propagation of vibrations excited with a single force impulse, Archives of Metallurgy and Materials **57**, 2, 409-416 (2012).

[12] R. Burdzik, P. Folega, B. Lazarz, Z. Stanik, J. Warczek: Analysis of the impact of surface layer parameters on wear intensity of friction pairs, Archives of Metallurgy and Materials **57**, 4, 987-993 (2012).