Archives of Materials Science and Engineering

Volume 58
Issue 1
November 2012
Pages 40-44

International Scientific Journal
published monthly by the
World Academy of Materials
and Manufacturing Engineering

Micro-jet cooling gases for low alloy steel welding

T. Węgrzyn [a],*, J. Piwnik [b], B. Łazarz [a], M. Plata [c]
[a] Faculty of Transport, Silesian University of Technology,
ul. Krasińskiego 8, 40-019 Katowice, Poland
[b] Faculty of Mechanical Engineering, Bialystok University of Technology,
ul. Wiejska 45A, 15-351 Białystok, Poland
[c] Novaltec, Chemin Neuf, Vetroz, Switzerland
* Corresponding e-mail address: tomasz.wegrzyn@polsl.pl

Received 23.09.2012; published in revised form 01.11.2012

ABSTRACT

Purpose: of that paper was analysing main gases used in micro-jet cooling after welding. The main reason of it was to investigate possibilities of getting varied amount of acicular ferrite (AF) in WMD (weld metal deposit). High amount of acicular ferrite influences positively impact toughness of weld.

Design/methodology/approach: During research varied gases were testes as micro-jet parameters. Further the chemical analysis, micrograph tests and Charpy V impact test of the metal weld deposit on pendulum machine were carried out. The Charpy V impact test was prepared according to standard ISO EN 148-1 Metallic materials - Charpy pendulum impact test - Part 1: Test method. Samples for impact testing were prepared according to standard ASTM A370.

Findings: Varied amount of acicular ferrite in weld metal deposit (in range 55%-75%) in terms of micro-jet cooling parameters (in that case kind of gas and gas pressure). This high amount of acicular ferrite is unheard in weld metal deposit in another way or other methods of welding such as MAG or TIG.

Research limitations/implications: That research was made for MIG method (according to PN-EN ISO 4063:2009) only. Another method of welding in this article was not tested.

Practical implications: Micro-jet cooling it is way to get higher amount of acicular ferrite in weld metal deposit than the usual methods of welding. It is very important because it could be used to steering of weld joint structure and mechanical properties (for example impact toughness).

Originality/value: In this research new method of cooling weld joint during welding was used. At the present time use of micro-jet cooling while MIG is in the testing phase and requires an accurate diagnosis.This method is very promising and capable of industrial application, mainly due to the significant improvement of weld quality and reduces costs.

Keywords: Welding; Micro-jet gases; Weld metal deposit; Metallographic structure; Acicular ferrite; Impact toughness

Reference to this paper should be given in the following way:

T. Węgrzyn, J. Piwnik, B. Łazarz, M. Plata, Micro-jet cooling gases for low alloy steel welding, Archives of Materials Science and Engineering 58/1 (2012) 40-44.

MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

For a long time researchers were putting attention to lift impact toughness properties of weld [1-17]. There was described great role of the amount of acicular ferrite on impact toughness properties, nevertheless it was impossible to exceed value of 65% of AF in WMD during standard welding.

Oxygen in weld for a long time was assumed as a main element influencing on high amount of AF in welds because of oxide inclusions role during austenite conversion (Figure 1).

Amount of AF strongly depends on size of oxide inclusions and lattice parameters of ferrite and oxides. Nevertheless amount of 65% of acicular ferrite is very difficult to exceed.

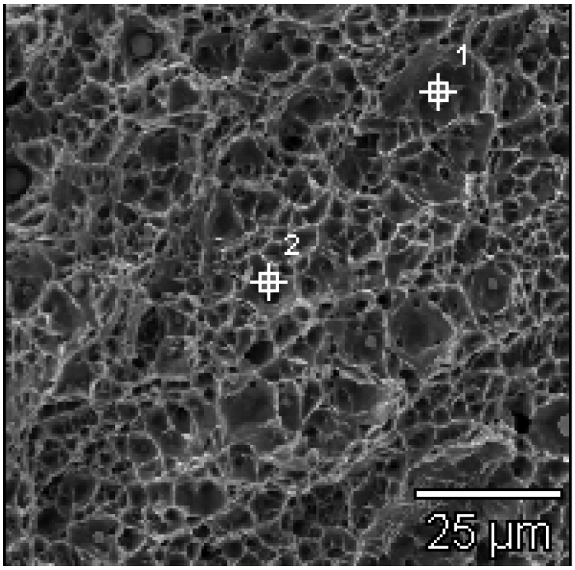

Fig. 1. Small oxide inclusions in weld, the oxygen amount (380 ppm) [3]

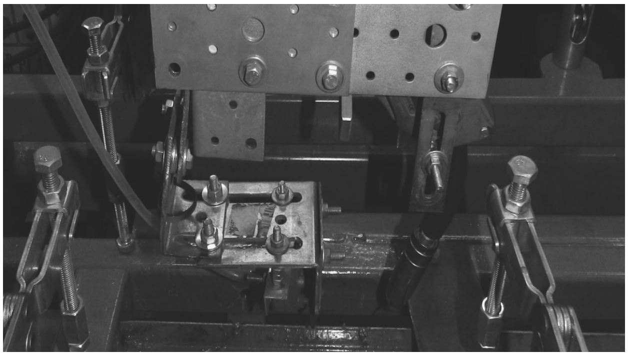

Fig. 2. Montage of welding head and micro-jet injector

New micro-jet cooling technology could be suggested as a new way to solve that problem [2, 3]. This paper describes the influence of artificially lifted amount of acicular ferrite in WMD (above 65%) with using micro-jet cooling and varied micro-jet gases as parameters of the process [3]. The material properties after repair are very important. For example in the automotive the vibration propagation in materials are very important [20, 21].

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 2.

2. Experimental procedure

Weld metal deposit was prepared by welding with micro-jet cooling with varied gases. The main data about parameters of welding were shown in Table 1.

Table 1.
Parameters of welding process

No.	Parameter	Value
1.	Principal diameter of wire	1.2 mm
2.	Standard current	220 A
3.	Voltage	24 V
4.	Shielding welding gas	Ar Ar + 1.5% O 82% Ar + 18% CO_2
5.	Kind of tested micro-jet cooling gas	1 – Ar 2 – He 3 – N_2
6.	jet numbers shielded gas, gas pressure	1, 0.4 MPa
7.	Standard of welding wire	EN 440: G4S:1

The study was carried out for low alloy steel S355J2G3 (with thickness of 16 mm) on a special prepared research station. Welding process ensures the cooling of the overall joint. Argon, helium, nitrogen were chosen for micro-jet cooling (always with diameter of 40 µm of stream). Cooling gas pressure was always constant on the level of 0.4 Pa. Equipment for MIG welding with micro-jet injector ready to tests is shown in Figure 3.

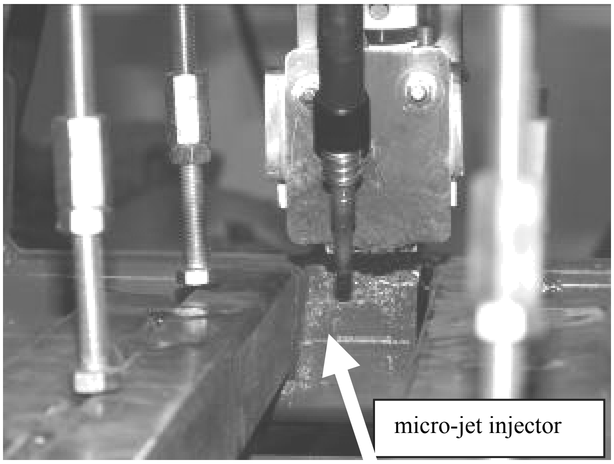

Fig. 3. Equipment for MIG welding with micro-jet injector

3. Results and discussion

All tested welding processes were realized with varied micro-jet gases: argon, helium, nitrogen. A typical weld 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 any influence on chemical WMD composition (Table 2).

Table 2.
A typical chemical composition of welds

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

There were typical analysed structures for MIG welding with micro-jet cooling. Example of this structure was shown in Figure 4.

In standard MIG welding process (without micro-jet cooling) there usually exist higher amounts of GBF and 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% exist only after argon micro-jet cooling (shown in Figure 5, Table 3). The higher amount of MAC phases especially occures for nitrogen micro-jet cooling and for standard MIG (Table 3).

Table 3.
Metallographic structure of welds

Micro-jet gas	Ferrite AF	MAC phases
without micro-jet	55%	3%
He	65%	2%
Ar	73%	2%
N_2	55%	4%

After that the chemical analysis, micrograph tests and Charpy V impact test of the deposited metal were carried out. The Charpy V impact test was preformed according to standard ISO 148-1 Metallic materials - Charpy pendulum impact test - Part 1: Test method [18-19]. Samples for impact testing were prepared according to standard.

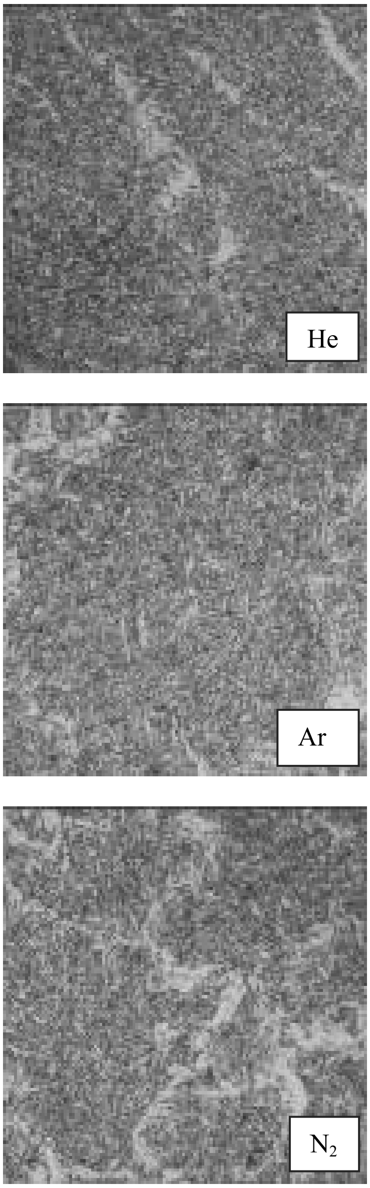

Fig. 4. Acicular ferrite in weld (68-73%) in terms on micro-jet gases, magnification × 200

Impact toughness could be always treated as major test of weld properties. It was clearly observed that metallographic structure in all tested cases was not the same. There were observed various amount of acicular ferrite and MAC phases in metal weld deposit in terms of micro-jet gas (Figures 4, 5). Toughness indicates how much energy a material can absorb before cracking [20-21]. Strength and toughness are very often related, but not in that case, because welds in all tested cases had the same composition. It was much important to do impact toughness tests instead of strength tests to get higher knowledge about welds after micro-jet cooling.

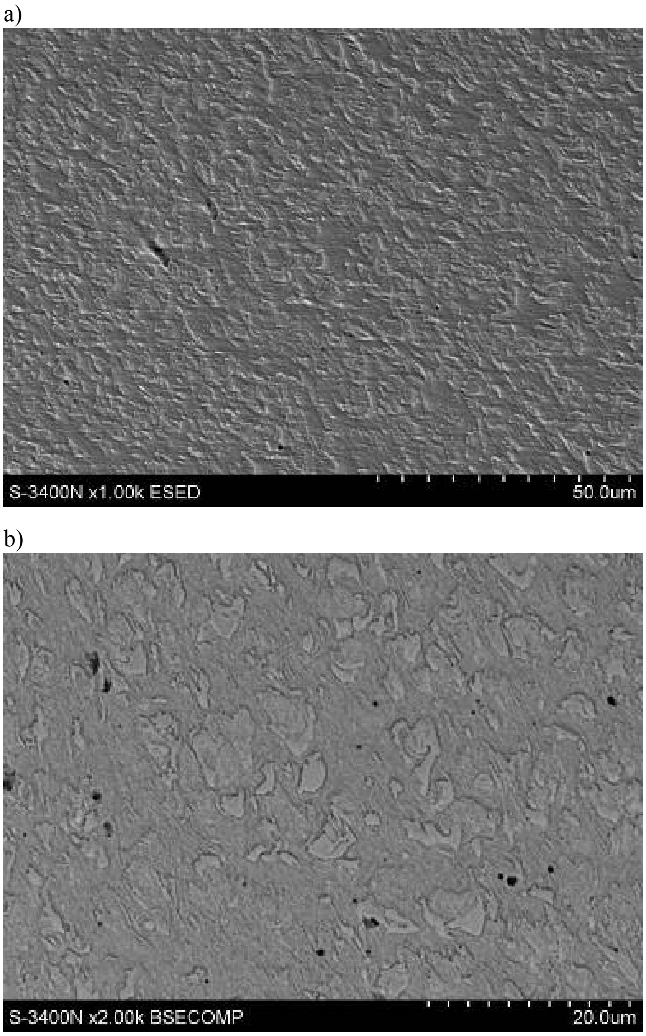

Fig. 5. Acicular ferrite in weld metal deposit after micro-jet cooling (argon), magnification: a) × 1000, b) × 2000

Charpy V impact test was carried out in such a way that the hammer blow was to the middle notch, and the axis lying in the plane of movement of the hammer and the blame was directed to the supports.

The impact toughness results is given in Table 4. The Charpy tests were done mainly at temperature + 20°C and - 40°C (5 specimens).

It is possible to deduce that impact toughness at negative temperature of weld metal deposit is apparently affected by the kind of micro-jet gas in cooling injector. Argon micro-jet gas in cooling on injector could be treated as an optimal, nitrogen could be treated as a wrong micro-jet gas choice.

In welded structures there were 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 analysed and counted for each weld metal deposit. MAC phases were on the similar level of 2%-4%.

Table 4.
Impact toughness for welding with varied micro-jet gases

Micro-jet gas	Test temperature, °C	Impact toughness KCV, J
without micro-jet	- 40	45
N_2	- 40	below 40`
Ar	- 40	57
He	- 40	47
without micro-jet	0	66
N_2	0	42
Ar	0	70
He	0	67
without micro-jet	+20	168
N_2	+20	142
Ar	+20	181
He	+20	173

4. Conclusions

Micro-jet cooling could be a very helpful technology for welding process. There are different parameters of micro-jet cooling. At the paper only kind of micro-jet was tested. It was clearly shown, that micro-jet gas could have important influence on metallographic structure and impact toughness of welds.

On the basis of the investigation it was possible to deduce that:

- micro-jet-cooling could be treated as a important element of MIG welding process,
- micro-jet-cooling after welding can prove amount of acicular ferrite, the most beneficial phase in low alloy steel weld metal deposit,
- because of using micro-jet after welding it could be possible to steer the metallographic structure,
- argon as a micro-jet-gas cooling in cooling is treated as optimal choice,
- nitrogen micro-jet gas for low alloy welding is not recommended.

References

[1] P. Judson, D. Mc Keown, Advances in the control of weld metal toughness, Offshore Welded Structures Proceedings, vol. 2, London, 1982.

[2] T. Wegrzyn, J. Piwnik, P. Baranowski, A. Silva, M. Plata, Micro-jet welding for low oxygen process, Proceedings of the International Conference “Inovation and Development” ICEUBI2011, Covilha, Portugal, 2011.

[3] T. Węgrzyn, J. Piwnik, B. Łazarz, D. Hadryś, R. Wiszała, Parameters of welding with micro-jet cooling, Archives of Materials Science and Engineering 54/2 (2012) 86-92.

[4] T. Węgrzyn, D. Hadryś, M. Miros, Optimization of operational properties of steel welded structures, Maintenance and Reliability 3 (2007) 30-33.

[5] T. Węgrzyn, J. Mirosławski, A. Silva, D. Pinto, M. Miros, Oxide inclusions in steel welds of car body, Materials Science Forum 636-637 (2010) 585-591.

[6] V.K. Goyal, P.K. Ghosh, J.S. Saini, Influence of pulse parameters on characteristics of bead-on-plate weld deposits of aluminium and its alloy in the pulsed gas metal arc welding process, Metallurgical and Materials Transactions 39/13 (2008) 3260-3275.

[7] J. Łabaj, G. Siwiec, B. Oleksiak, Surface tension of expanded slag from steel manufacturing in electrical furnace, Metalurgija 50/3 (2011) 209-211.

[8] J. Słania, Influence of phase transformations in the temperature ranges of 1250-1000ºC and 650-350ºC on the ferrite content in austenitic welds made with T 23 12 LRM3 tubular electrode, Archives of Metallurgy and Materials 50/3 (2005) 757-767.

[9] K. Krasnowski, Influence of stress relief annealing on mechanical properties and fatigue strength of welded joints of thermo-mechanically rolled structural steel grade S420MC, Archives of Metallurgy 54/4 (2009) 1059-1072.

[10] T. Węgrzyn, Mathematical Equations of the Influence of Molybdenum and Nitrogen in Welds, Proceedings of the Conference of International Society of Offshore and Polar Engineers ISOPE´2002, Kita Kyushu, Japan, 2002.

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

[12] T. Węgrzyn, The Classification of Metal Weld Deposits in Terms of the Amount of Oxygen, Proceedings of the Conference of International Society of Offshore and Polar Engineers ISOPE'99, Brest, France, 1999, 212-216.

[13] L. Blacha, Untersuchungen der antimon entfernungs geschwindigkeit aus blisterkupfer im prozess der vakuumraffination, Archives of Metallurgy and Materials 50/4 (2005) 989-1002.

[14] M. Adamiak, J. Górka, T. Kik, Structure analysis of welded joint of wear resistant plate and construction al steel, Archives of Materials Science and Engineering 46/2 (2010) 108-114.

[15] T. Węgrzyn, J. Piwnik, D. Hadryś, R. Wieszała, Car body welding with micro-jet cooling, Journal of Achievements in Materials and Manufacturing Engineering 49/1 (2011) 90-94.

[16] 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 51/1 (2011) 40-47.

[17] D. Hadryś, M. Miros, Coefficient of restitution of model repaired car body parts, Journal of Achievements in Materials and Manufacturing Engineering 28/1 (2008) 51-54.

[18] ISO 148-1 Metallic materials - Charpy pendulum impact test - Part 1: Test method.

[19] ASTM A370 Standard Test Methods and Definitions for Mechanical Testing of Steel Products.

[20] R. Burdzik, Monitoring system of vibration propagation in vehicles and method of analysing vibration modes, in: J. Mikulski (Ed.), TST 2012, CCIS 329, Springer, Heidelberg, 2012, 406-413.

[21] 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 Materials and Metallurgy 57/2 (2012) 409-416.