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Micro-jet Cooling by Compressed Air after MAG Welding

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Abstract

The material selected for this investigation was low alloy steel weld metal deposit (WMD) after MAG welding with micro-jet cooling. The present investigation was aimed as the following tasks: analyze impact toughness of WMD in terms of micro-jet cooling parameters. Weld metal deposit (WMD) was first time carried out for MAG welding with micro-jet cooling of compressed air and gas mixture of argon and air. Until that moment only argon, helium and nitrogen and its gas mixture were tested for micro-jet cooling.

Keywords: MAG, Welding, Micro-jet, Acicular ferrite, Impact toughness, Compressed air

1. Introduction

It has recently been invented steel welding with micro-jet cooling [1-5]. Especially micro-jet cooling after MAG welding (Fig. 1) give chance to obtain weld metal deposit with higher amount of acicular ferrite (AF) in weld metal deposit (WMD).

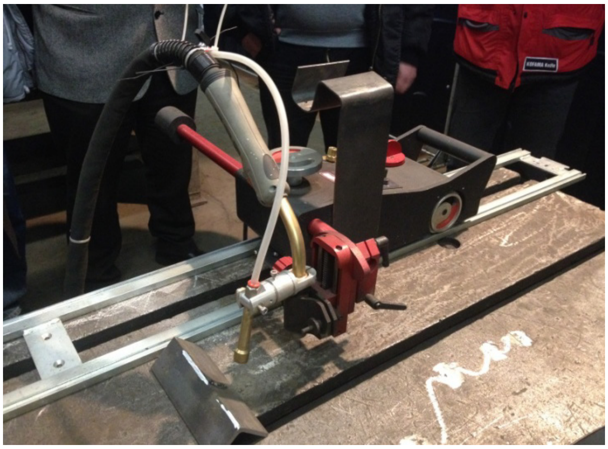

Fig. 1. MIG welding head with micro-jet injector

Generally it corresponds with much higher impact toughness of weld [6-8] because of precise and selective micro-jet cooling. 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 MAG process. It was decided to investigate the mechanical properties of WMD. Generally it corresponds with much higher impact toughness of weld [3-5] because of precise and selective micro-jet cooling. It is possible to get higher impact toughness of WMD than in standard low-oxygen processes [9-10].

The weld metal deposit was prepared by MAG welding with micro-jet cooling with varied gas mixtures of argon and air. 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), micro-jet gases were varied (gas mixture of argon and air).

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 MAG welding were compared firstly without innovative micro-jet cooling technology. Carbon dioxide was chosen as a shielding gas in that studies. A typical weld metal deposit had rather similar chemical composition in all tested cases. 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 MAG welding gas	Carbon dioxide
5	Micro-jet cooling gases	1-argon 2-50% argon, 50% air 3-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	0.79%
3.	Si	0.41%
4.	P	0.012%
5.	S	0.011%
6.	N	50 ppm-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. Precise information about metallographic structure of WMD are 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
50% argon 50% air	0.4	40	54	365	57
Air	0.4	40	58	380	44
Ar	0.5	50	50	350	71
67% argon 33% air	0.5	50	57	375	52
Air	0.5	50	60	390	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 MAG 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 0.5 MPa, and stream diameter of micro-jet cooling gas should be on the level of 50 μm. Acicular ferrite with high percentage above 55% in WMD after welding with gas mixture argon-air was gettable only three times:

- stronger cooling parameters of argon micro-jet cooling (71% of AF),
- weaker cooling parameters of argon micro-jet cooling (68% of AF),
- weaker cooling parameters of argon/air micro-jet cooling (57% of AF).

This it is obvious to deduce that micro-jet cooling has strong influence on metallographic microstructure (Fig. 3).

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/air gas mixture (50% of each) 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.

a)

b)

c)

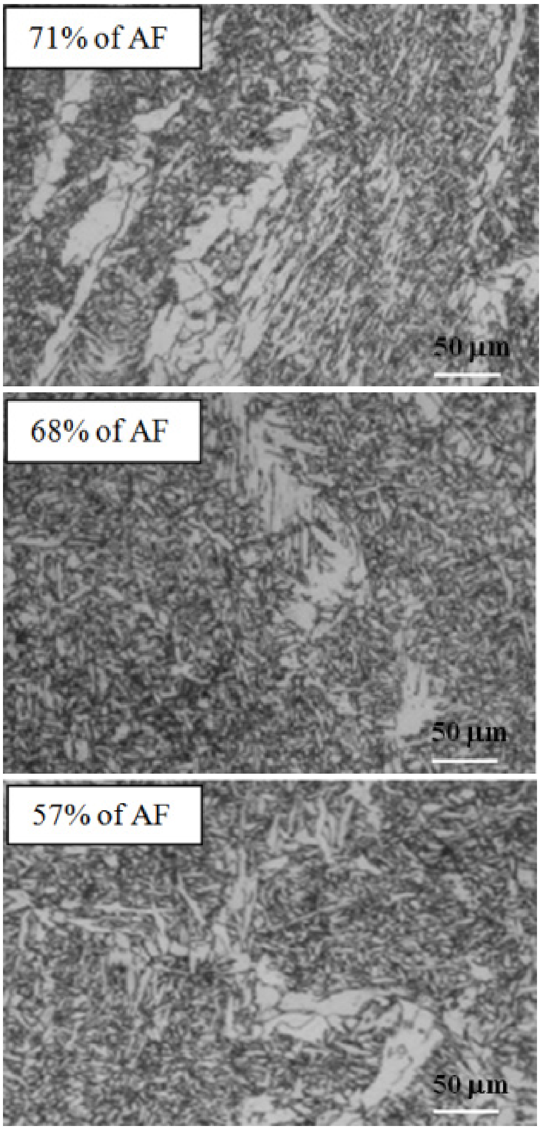

Fig. 3. Microstructure of WMD after MAG welding with micro-jet cooling gas: a) Ar-steam diameter 50 µm, b) Ar-steam diameter 40, c) 50% Ar/50 % Air-steam diameter 40 µm µm 200x

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 MAG 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 mixture with air could be treated as proper micro-jet cooling.

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

Micro-jet gas	Impact toughness, 20°C [J/cm^2]	Impact toughness, -40°C [J/cm^2]
without cooling	48	below 47
Ar (weaker parametrs of cooling)	**85**	**68**
50% argon 50% air (weaker parametrs of cooling)	**63**	**49**
air **(weaker parametrs of cooling)**	below 47	below 47
Ar (stronger parametrs of cooling)	**81**	**65**
50% argon 50% air **(stronger parametrs of cooling)**	61	below 47
Air **(stronger parametrs of cooling)**	below 47	below 47

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