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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ACICULAR FERRITE IN MICRO WELDING TECHNOLOGIES

FERRYT AF W TECHNIKACH MIKRO-SPAWALNICZYCH

Laser is widely applied in micro welding. Apart from that method, welding with micro-jet cooling could be treated as another important method for thin structure welding. Until that moment micro-jet technology is not very popular. An article presents actual information about innovate welding technology with micro-jet cooling in comparison with standard laser welding. There were given information about influence of both micro welding method on metallographic structure of thin steel welds. Amount of AF was tested in two cases.

Keywords: micro welding, laser, micro-jet cooling in welding, weld, metallographic structure, acicular ferrite

Laser jest szeroko stosowany w mikro-spawaniu. Oprócz tej metody, spawanie z chłodzeniem mikrojetowym powinno być traktowane jako ważna metoda spawania cienkościennych konstrukcji. W artykule przedstawiono innowacyjną technologię spawania z chłodzeniem mikrojetowym w porównaniu do spawania laserowego. Uzyskano informacje o wpływie obu metod na strukturę metalograficzną stalowych cienkościennych konstrukcji. Zawartość ferrytu AF była porównana w obu przypadkach.

1. Introduction

In thin steel structure the best mechanical properties of weld correspond with acicular ferrite (AF) amount. Amount of acicular ferrite (AF) is treated as the most beneficial phase in steel WMD [1, 4, 8, 10]. Laser and micro-jet technology give chance to obtain artificially high amount of AF in weld that corresponds with better mechanical properties of weld [1÷13]. In this paper there is firstly presented comparison of laser welding with innovative welding method (with micro-jet cooling) with different parameters of the process. Weld metal deposit (WMD) was prepared by welding with two methods:

- dioxide laser with a max output of 5 kW in the continues wave mode,
- micro-jet cooling after MIG welding.

Both CO_2 laser beam welding and welding with micro-jet injector are regarded as high energy density and low heat input process. In both methods there is observed narrow heat affected zone and high amount of acicular ferrite (AF) in weld metal deposit (WMD). It is not easy to find the best of many variables in both processes. Laser welding involves such main parameters as: power, welding speed, defocusing distance, type of shielding gas. Parameters of micro-jet injector are varied by: cooling steam diameter, number of jets in injector micro-jet gas pressure and also type of shielding gas. Optimal parameters of both processes for thin structure welding was mainly compared in terms of oxygen in WMD and metallographic structure.

2. Experimental procedure

One type of low alloy S355J2G3 steel was used in both welding methods. Chemical composition of steel is presented on Table 1. The thickness always was 1 mm of upper sheet and 2 mm of lower sheet in all tested cases (Fig. 1).

TABLE 1
Chemical composition of S355J2G3 steel

C	Mn	Si	P	S	Cr	Ni	As	Cu
0.17	1.2	0.4	0.017	0.017	0.3	0.2	0.06	0.3

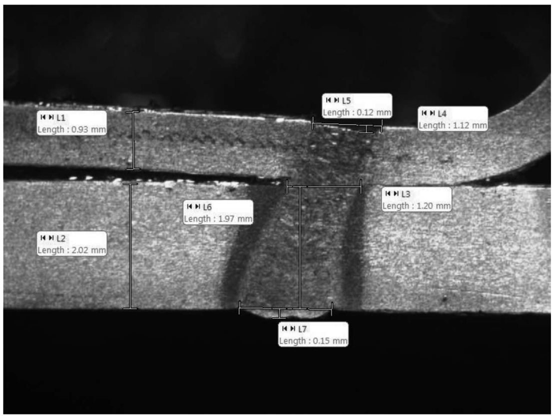

Fig. 1. Position of welded sheet thickness: upper is 1 mm, lower 2 mm

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Butt weld joints were made using firstly a carbon dioxide laser capable of producing max output of 5 kW in the continues wave mode. The main laser parameters are summarized in Table 2. Parameters of micro-jet injector are presented in Table 3.

TABLE 2

Laser welding parameters

Power, kW	Speed, m/min	Heat input, kJ/mm	Defocucing distance, mm	Shielding gas	Flow rate, l/min
3	1.2	0.4	2	Ar	15

TABLE 3

Parameters of welding process with micro-jet cooling

No.	Parameter	Value
1.	Diameter of wire	1.2 mm
2.	Standard current	220 A
3.	Voltage	24 V
4.	Shielding welding gas	Ar 81% Ar + 19% CO_2
5.	Kind of tested micro-jet cooling gas	Ar
6.	Gas pressure	0.4 MPa
7.	Diameter of jet:	40 μm
8.	Number of jets	1

Thus weld metal deposit was prepared by welding with two methods: MIG welding with micro-jet cooling and laser welding.

3. Results and discusion

There were tested and compared various welds of standard laser welding and MIG welding with innovative micro-jet cooling technology. A typical weld metal deposit had similar chemical composition in all tested cases (Table 1). Both laser and micro-jet gas could have only influence on more or less intensively cooling conditions, but do not have strong influence on chemical WMD composition, except oxygen amount (Table 4).

TABLE 4

Chemical composition of WMD

Welding method	Oxygen in WMD
MIG welding with micro-jet cooling	380 ppm
Laser welding	280 ppm

For laser welding there were observed much lower amount of oxygen in WMD than in MIG welding with micro-jet cooling. According to main author's opinion, there should be rather higher amount of oxygen in WMD than 350 ppm, just to have high amount of acicular ferrite [1, 4, 8]. After chemical analyses the metallographic structure was given. Example of this structure was shown in Table 5.

TABLE 5

Metallographic structure of welds

Welding technology	Ferrite AF	MAC phases
Laser welding	57%	4%
Standard MIG welding without micro-jet cooling	61%	4%
MIG welding with micro-jet cooling	73%	2%

Table 5 shows that in standard MIG/MAG welding process (without micro-jet cooling) and in laser welding there were usually gettable higher amounts of MAC (self-tempered martensite, retained austenite, carbide) phases on the level of 4%. Acicular ferrite with percentage above 70% was gettable only in one case after MIG welding with argon micro-jet cooling (shown on Fig. 2, Table 5). The higher amount of MAC phases was especially gettable for more intensive laser welding and welding without micro-jet cooling. Various AF amount in tested cases corresponds with respectable various amount of oxygen in WMD. After that compared penetration and weld quality in tested cases, Figures 3-5.

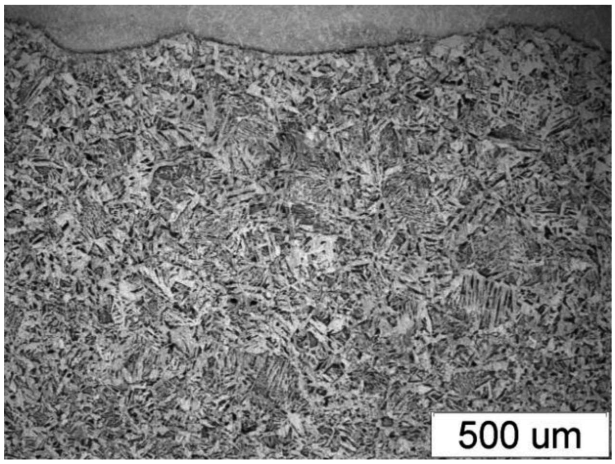

Fig. 2. High amount of acicular ferrite in weld (73%) after Ar micro-jet cooling

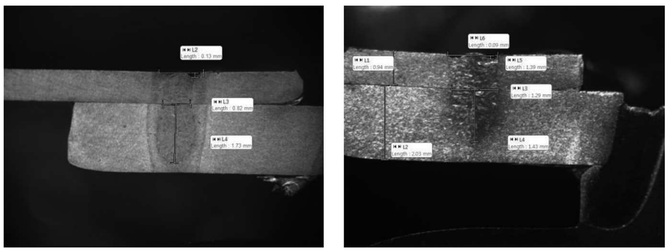

Fig. 3. Good quality of laser weld, 80% of penetration

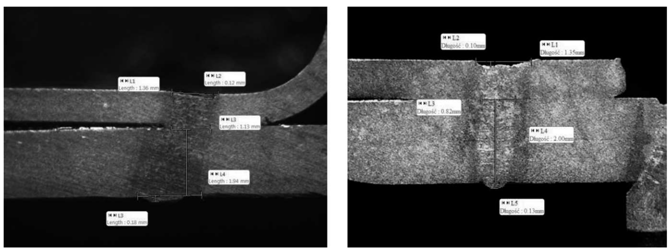

Fig. 4. Very good quality of welded sheet after micro-jet cooling, 100% of penetration

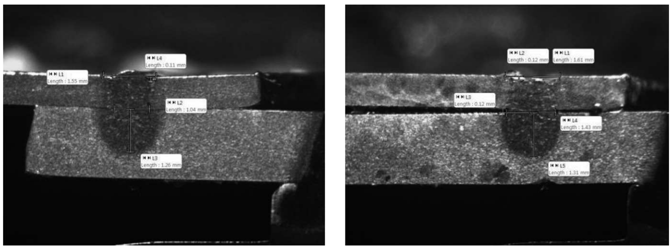

Fig. 5. Good quality of MIG welding without micro-jet cooling, 70% of penetration

It was observed that quality is rather good in all cases, nevertheless penetration is perfect only during welding with micro-jet cooling.

4. Summary and conclusions

In steel welding there is main type of test performed: metallographic 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 methods (laser welding and MIG welding with micro-jest cooling) proved that micro-jet technology gives more beneficial properties of welds. The innovative micro-jet technology was firstly recognized with great success for thin sheet welding. On the basis of investigation it is possible to deduce that micro-jet technology could be important alternative for laser welding.

Final conclusions:

a) micro-jet cooling could be treated as an important element of thin sheet welding process,
b) micro-jet cooling after welding can prove amount of ferrite AF, the most beneficial phase in low alloy steel WMD,
c) laser welding could give weld with comparable quality, but with lower amount of AF in weld metal deposit
d) laser welding corresponds with higher amount of not beneficial MAC phases in weld metal deposit in comparison with micro-jet process

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