LASER AND MAG WELDING WITH MICRO-JET COOLING FOR LONG STRUCTURES

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Abstract

The purpose of this paper is to analyze mechanical properties of steel long weld structures. The main role of welding conditions in connected with materials, alloy elements in steel and filer materials, welding technology, state of stress and temperature. First time are presented properties of steel long weld structures after welding with micro-jet cooling. Because of that very important is good selection of steel, welding and micro-jet cooling parameters for proper steel structure. In this study metallographic structure and impact toughness welded joints has been analyzed in terms of welding parameters after laser and MAG welding.

Keywords: Metallurgy, welding, impact toughness, micro-jet

1. INTRODUCTION

Safety and durability frameworks largely depends first of all on impact toughness and fatigue strength [1-3]. There are still tested new techniques and materials used for steel weld long structures [4-7]. Welded steel frame is still one of the most frequently encountered structures carrying trucks vehicle [12-15]. Properties of steel welded structures depend on many factors such as welding technology, filler materials, state of stress, chemical composition. Some alloy elements, especially nickel (in range 1 - 3 %) or molybdenum (in range 0.2 - 0.6 %), oxygen could be treated as elements which very positively influencing impact toughness. Metallographic structure of weld metal deposit having composition of 400 ppm O and 2 % Ni or 0.4 % Mo could be treated as optimal, because it corresponds with high percentage of acicular ferrite AF (until 55 %) [3-4]. That composition corresponds with small size of nonmetallic inclusions in weld metal deposit influencing formation of acicular ferrite in it (**Figure 1**).

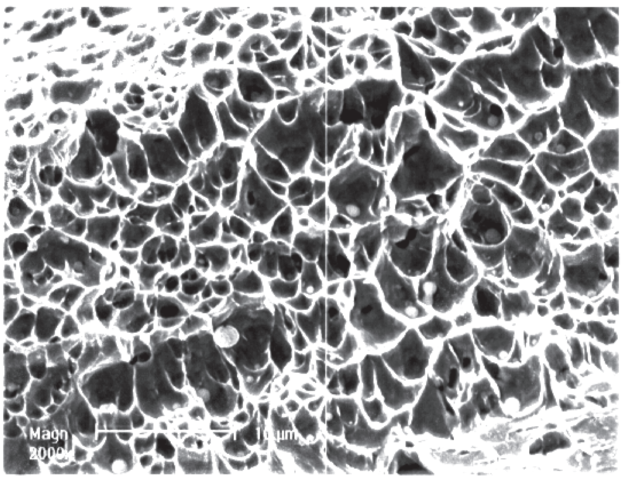

Figure 1 Fracture surface of metal weld deposit with 0.3 % Mo (small size of inclusions) [1]

Mentioned composition of weld could be also treated as a very beneficial because of low percentage of MAC phases (self-tempered martensite, retained austenite, carbide) negatively influence on impact toughness of weld. For a long time researchers tried to lift percentage of AF in weld above 55 %, unfortunately without great success. There was seriously studied great role of non-metallic inclusions during austenitic conversion, nevertheless it was impossible to exceed value of 55 % of AF in WMD. New micro-jet cooling technology [1-5] could be regarded as a new way to solve that problem. This paper describes the influence of artificially lifted amount of acicular ferrite in WMD (even above 65 %) with using micro-jet cooling. Process was tested with varied parameters of micro-jet cooling after laser welding and MAG welding process [8-12]. Comparison of those processes (laser and MAG) and micro-jet cooling was not described yet.

2. EXPERIMENTAL PROCEDURE

The weld metal deposit (WMD) was prepared by laser welding and MAG process with micro-jet cooling with varied tested gases (argon, helium, nitrogen). To obtain high amount of acicular ferrite in weld the micro-jet injector was installed just after welding head and welding laser head. Main parameters of micro-jet cooling were slightly varied:

- cooling steam diameter was twice varied (50 µm and 60 µm),
- gas pressure was also twice varied (0.5 MPa and 0.6 MPa),
- micro-jet gases were changed (Ar and He).

The basic material to research was S355J2G3 steel (typical material for truck frames and car body). Various welds of standard laser welding were compared with and 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 laser welding were shown in **Table 1**, and data about MAG process were shown in **Table 2**.

Table 1 Parameters of welding process

Parameter	value
Laser power	2,2, 2.2 kW
Welding speed	1.2 m·min^{-1}
Diameter of beam spot	200 µm
Focal distance	200 mm
M-j gases	Ar, He
M-j gas presure	0.5 or 0.6 MPa
M-j diameter	50 or 60 µm

Table 2 Parameters of welding MAG process

No.	Parameter	Value
1.	Standard current	220 A
2.	Voltage	24 V
3.	Shielding welding gas	Ar
4.	M-j gas pressure	0.5 or 0.6 MPa
5.	Micro-jet gases	He, Ar
6.	Micro-stream diameter	40 and 50 µm

There were mainly tested and compared weld deposits of standard laser welding connected with micro-jet cooling using various micro-jet gases. A typical weld metal deposit had rather similar chemical composition in all tested cases except nitrogen amount (**Table 3**). Micro-jet cooling parameters were similar in both cases. Chemical composition of WMD was also very similar after laser and MAG welding process, **Table 3**.

Table 3 Chemical composition of WMD after welding

Element	Amount
C	0.07 % - 0.08 %
MN	0.7 % - 0.8 %
Si	0.4 % - 0.5 %
P	0.012 % - 0.015 %
S	0.013 % - 0.015 %
O	370 ppm - 400 ppm
N	50 ppm - 55 ppm

Various micro-jet parameters had some influence on intensively cooling conditions but did not have greater influence on chemical WMD composition. Metallographic structure of WMD was carried out. Especially acicular ferrite (AF) in terms of nitrogen amount in WMD was precisely analyzed. In all tested cases there were additionally also observed MAC phases (self-tempered martensite, retained austenite, carbide). Examples of the metallographic structure results after laser and MAG welding are shown in **Table 4** and **5** respectively.

Table 4 Acicular ferrite and MAC phases in WMD after laser welding with various micro-jet parameters

Micro-jet gas	Micro-jet gas pressure (MPa)	Steam diameter of micro-jet gas (μm)	Acicular ferrite (%)	MAC phases (%)
-	-	-	52	3
Ar	0.5	50	68	2
Ar	0.5	60	69	2
Ar	0.6	50	71	2
Ar	0.6	60	67	2
He	0.5	50	60	2
He	0.5	60	62	2
He	0.6	50	65	2
He	0.6	60	58	2

Analyzing **Table 4** it is easy to deduce that laser welding with micro-jet cooling could be treated as a very good option. Analyzing **Table 4** it is easy to deduce that MAG welding with micro-jet cooling could be treated as a worst option in comparison with laser welding. In both processes micro-jet cooling could be treated as beneficial choice. Only argon should be used for micro-jet cooling after laser or MAG welding. Micro-jet cooling by helium is more intensive and that fact does not translate into acicular ferrite nucleation. MAC amount in all tested cases was rather on the same level. Acicular ferrite with percentage above 60 % was gettable for laser welding with micro-jet cooling by argon or helium. Acicular ferrite with percentage above 60 % was gettable for MAG welding only with micro-jet cooling by argon (shown in **Figure 2**).

Table 5 Acicular ferrite and MAC phases in WMD after MAG welding with various micro-jet parameters

Micro-jet gas	Micro-jet gas pressure (MPa)	steam diameter of micro-jet gas (μm)	Acicular ferrite (%)	MAC Phases (%)
-	-	-	45	3
Ar	0.5	50	61	2
Ar	0.5	60	63	2
Ar	0.6	50	59	2
Ar	0.6	60	57	2
He	0.5	50	51	2
He	0.5	60	53	2
He	0.6	50	55	3
He	0.6	60	52	3

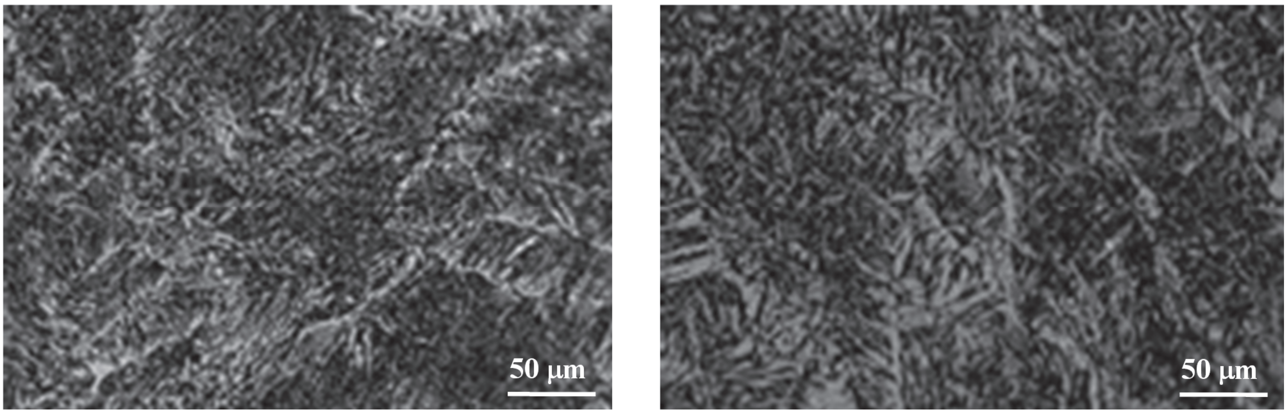

Figure 2 Acicular ferrite above 60 % in various deposits (of laser welding with micro-jet cooling on the left, of MAG welding on the right)

The next part of the research was concentrated on impact toughness tests, which are presented on **Tables 6, 7.**

Table 6 Impact toughness for laser welding with varied micro-jet gases

Micro-jet gas	Temp. (°C)	Impact toughness KV (J)
without cooling	- 40	below 47
Ar	- 40	62
He	- 40	51
without cooling	+20	175
Ar	+20	197
He	+20	191

Table 7 Impact toughness MAG welding with varied micro-jet gases

Micro-jet gas	Temp. (°C)	Impact toughness KV (J)
without cooling	- 40	below 47
Ar	- 40	53
He	- 40	below 47
without cooling	+20	171
Ar	+20	188
He	+20	183

It is possible to deduce that impact toughness at negative temperature of weld metal deposit is apparently affected by the kind of micro-jet gases in cooling injector. Only argon could be regarded as a good choice for both processes: laser and MAG welding. The last part of the research was concentrated on deflection tests of long structures (16 m of length). Results are shown on **Table 8, 9**.

Table 8 Deflection of (16 m) long structure after laser welding with micro-jet cooling

Micro-jet gas	Deflection (mm)
without cooling	70
Ar	22
He	34

Table 9 Deflection of (16 m) long structure after MAG welding with micro-jet cooling

Micro-jet gas	Deflection (mm)
without cooling	75
Ar	29
He	42

It is possible to deduce that deflection of structure is apparently affected by the kind of micro-jet gases in cooling injector. Also in that case it is observed that only argon could be regarded as a good choice for both processes: laser and MAG welding.

3. CONCLUSION

Summing up the paper it has been concluded, that especially important is a good selection of welding process for long steel structure. Connection of those processes such as laser welding and MAG welding connected with micro-jet cooling was tested with success.

It was observed, that especially argon as micro-jet cooling gas should be connected with laser and MAG welding. It is possible to get much higher amount of acicular ferrite and better impact toughness of welds. The preliminary results shows validity of theoretical assumptions and it will be possible to apply this technology in industry.

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

- micro-jet-cooling could be treated as an important element of laser welding and MAG process,
- micro-jet-cooling after welding can prove amount of acicular ferrite, the most beneficial phase in low alloy steel weld metal deposit,
- high amount of acicular ferrite can guarantee respectively good impact toughness properties,
- high amount of acicular ferrite can guarantee smaller deflection in long structures.

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