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Car body welding with micro-jet cooling

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ABSTRACT

Purpose: of that paper was analysing welding process with device to micro-jet cooling of weld joint during welding. The main reason of it was investigate possibilities of getting higher amount of desired phase acicular ferrite. High amount of acicular ferrite influences positively on high value of impact toughness. Increasing the value of impact toughness is particular importance when making repairs car body parts. It is necessary to determine the parameters of the micro-jet cooling so that you can introduce this method for widespread use.
Design/methodology/approach: During research 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: Micro-jet cooling of weld joint during welding could influence on amount of acicular ferrite in weld metal deposit (above 65%). This is unheard in other ways.
Research limitations/implications: That research was made for MIG method only. Another method of welding was not tested. Other methods have not been tested, but it is suspected that similar phenomena are taking place.
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 cooling; Weld metal deposit; Metallographic structure; Acicular ferrite; Impact toughness

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1. Introduction

Car bodies in popular vehicles are made by low alloy steels. In that steels there is a small amount of carbon and some of alloy elements (Ni, Mn, Mo, Si). The same elements are in welded joints too. Some alloy elements (for example nickel, molybdenum, oxygen) could be treated as elements which positively influencing on impact toughness of welded structures. Metallographic structure of weld metal deposit has composition of 400 ppm O and 2% Ni or 0.4% Mo. It is very beneficial because of high percentage of acicular ferrite AF (until 65%). In this case weld metal deposit has good mechanical properties. For a long time researchers were putting two questions: how to lift percentage of AF in weld, and further what consequence that fact gives? New micro-jet cooling technology could be treated as a way to solve that problem. This paper describes the influence of artificially lifted amount of acicular ferrite in WMD (above 65%) with using micro-jet cooling.

The influence of positively influencing elements on mechanical properties of steel car body welds such as Mn, Ni, Mo, and O were well analysed in the past [1-6]. Nickel, molybdenum and oxygen could have the positive influence on impact properties of steel car body welds. In main publications it is presented that amount of this elements must be content in characteristic ranges (Ni content should not exceed 3%, Mo content should not exceed 0.5%. O amount should not be greater than 500 ppm) [3-7]. Weld metal deposit with mentioned chemical composition has positive influence on the acicular ferrite formation in welds. Welding parameters, metallographic structure and chemical composition of weld metal deposit are regarded as the important factors influencing the impact toughness of deposits [8-11]. The influence of the most beneficial amounts of nickel, molybdenum and oxygen (oxide inclusions) could guarantee even 65% of acicular ferrite in weld, but no more [2,13]. This amount of AF could be reached with simply and ordinary welding method.

To obtain higher amount of acicular ferrite in weld metal deposit it was installed welding process with micro-jet injector (cooling stream of argon with diameter of 40 µm). Welding conditions with micro-jet cooling were similar like in standard welding procedure [2]. There was even gettable the same percentage of total ferrite percentage as a sum of its main morphology forms (Fig. 1):

- fraction of grain boundary ferrite (GBF),
- fraction of side plate ferrite (SPF),
- fraction of acicular ferrite (AF).

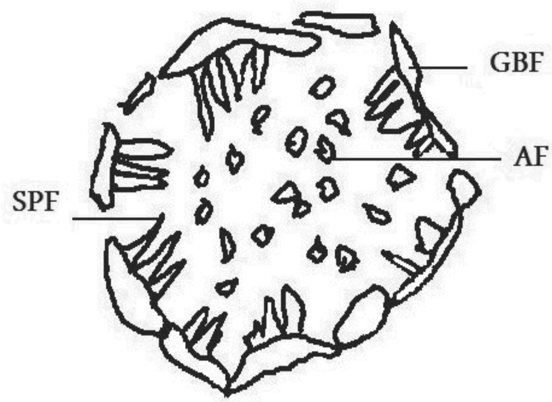

Fig. 1. Fraction of ferrite in weld metal deposit, GBF - grain boundary ferrite, SPF - side plate ferrite, AF - acicular ferrite

Method of forming a metallographic structure of weld metal deposit is described by the following steps:

- during continuous cooling austenite is formed first the below-solidus grain boundary ferrite,
- next the plate ferrite is formed, the plates are oriented almost perpendicular to the interior of the former austenite grains,
- at the end the fine-grained acicular ferrite is formed inside the grains,
- some relatively small amounts of austenite can be transformed at lower temperatures in the bainite and martensite,
- very small amounts of austenite may remain in the metallographic structure as the so-called retained austenite.

2. Experimental procedure

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

Table 1.
Parameters of welding

No.	Parameter	Value
1.	Principal diameter of wire	4 mm
2.	Standard current	220 A
3.	Voltage	24 V
4.	Shielding gas	Ar Ar + 1.5% O 82% Ar + 18% CO_2

Argon was also chosen for micro-jet cooling (with diameter of 40 µm of stream). There were tested welding conditions with installed micro-jet injector (Fig. 2). Test stand was presented in Figure 3.

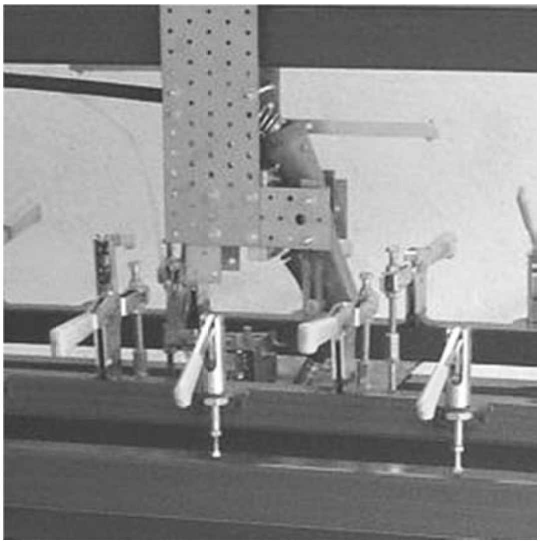

Fig. 2. Equipment for MIG welding with micro-jet cooling

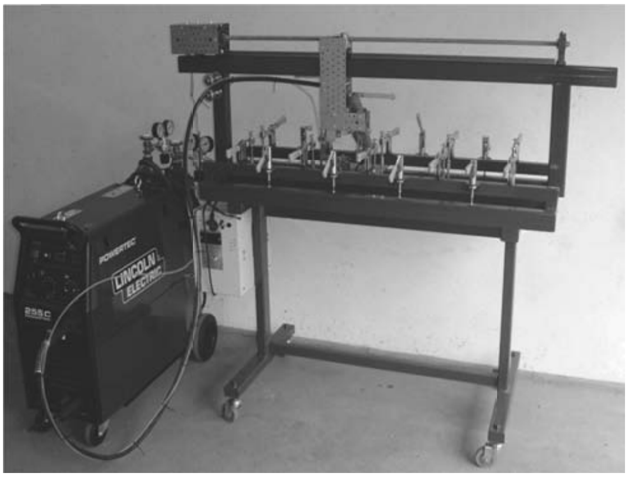

Fig. 3. Stand for welding with micro-jet cooling of weld

The use of micro-jet cooling during MIG causes a large drop in temperature of the weld. Because this is a new method, used recently is not yet fully understood mechanisms of this phenomenon. It is necessary to conduct studies illustrating the temperature drops, depending on the gas used and the base material. It should be added that such a solution, with an additional cooling has a significant impact on the quality of the weld. In this case, welding temperature drop was observed from 900°C to about 500°C. The time required to weld the temperature drops to 400°C was 3.75 s. For the optimal settings for the timers to cooling, such as argon pressure, and the like were carried out preliminary studies. The results of the temperature depending argon pressure and distance between weld and injector are presented in Figure 4. That was treated as optimal, because there were very gettable similar amount of total amount of ferrite (also without Bainite and martensite structures).

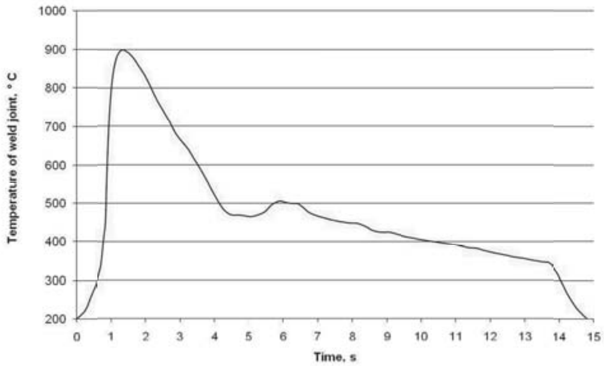

Fig. 4. Weld cooling conditions with micro-jet injector

3. Results and discussion

A typical weld metal deposit had chemical composition which was shown in Table 2. There were typical analysed structures for MIG welding with micro-jet cooling. Example of this structure was shown in Figure 5.

In standard MIG welding process (without micro-jet cooling) there were usually gettable higher amounts of GBF and SPF fraction meanwhile in micro-jet cooling both of GBF and SPF structures were not dominant. High percentage of AF ferrite was gettable only for welding with micro-jet cooling. Acicular ferrite with percentage above 70% was gettable only after micro-jet cooling (shown in Figure 6).

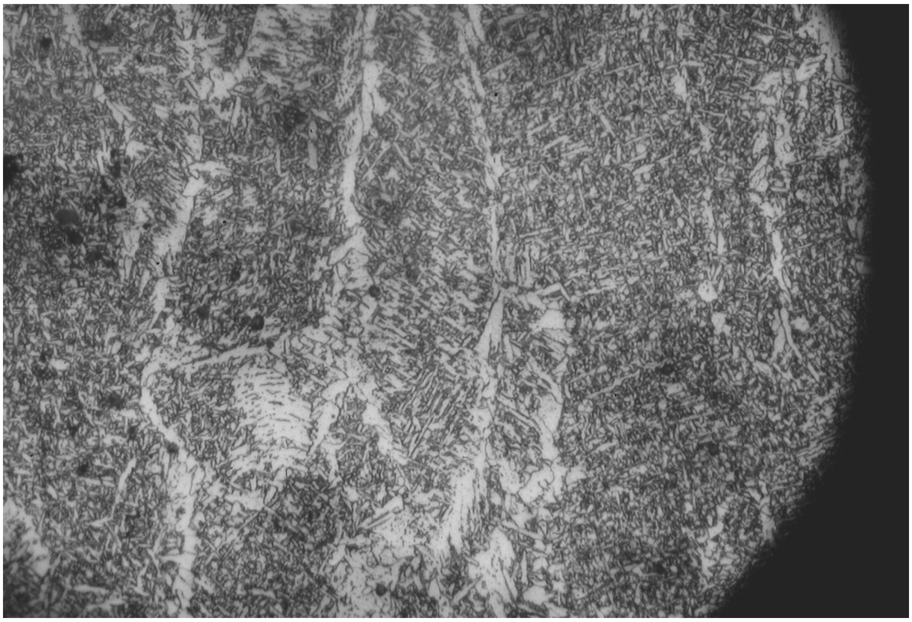

Fig. 5. Acicular ferrite in weld metal deposit, 73%, magnification 200x

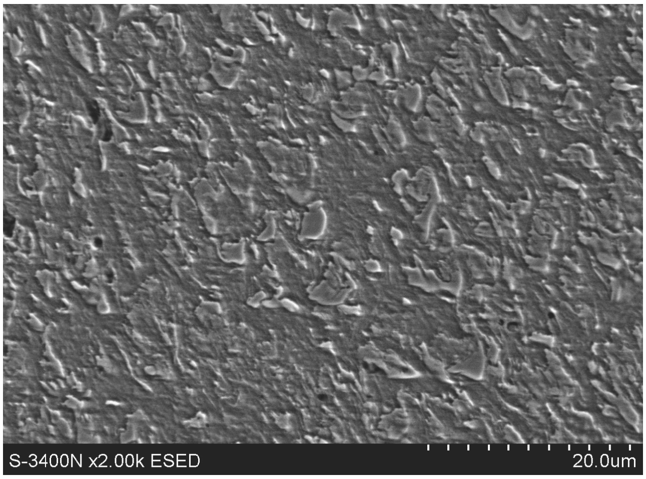

Fig. 6. Acicular ferrite in weld metal deposit after micro-jet cooling, magnification 2000x

Table 2.
A typical chemical composition of weld metal deposit

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
7.	N	85 ppm

After that the chemical analysis, micrograph tests and Charpy V impact test on pendulum machine 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 [14]. Samples for impact testing were prepared according to standard ASTM A370 [15]. The size of sample was presented in Table 3.

Table 3.
Size of sample

Size of sample	Nominal size, mm
Length of the sample, l	55
Height of sample, a	10
Width of the sample, b	7.5
The height of the sample in place, h (for samples V-shaped)	8
Radius of the notch bottom, r (for samples V-shaped)	0.25
Notch opening angle test-pieces from V-shaped, g	45
The angle between the plane of symmetry of the notch and the longitudinal axis of the sample, d	90

Samples prior to testing in accordance with the standard [14,15] were subjected to machining. The notch was made by milling. Used how to retrieve sections of sample and execution weighting had no impact on material properties. Due to the fact that the results obtained with impact notched bending samples are comparable only in the case tests of samples of identical size and shape notch and under the same conditions, and therefore all samples used in the tests were performed using the same tools. This is necessary because the dimension of the notch, and its shape significantly affect the acquisition values of toughness.

The way of preparation of samples for Charpy test was presented in Fig. 7. The test sample and the test stand were presented in Fig. 8 and Fig. 9. 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.

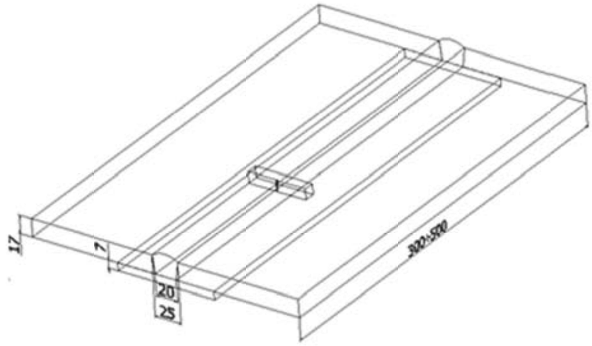

Fig. 7. The way of preparation of samples for Charpy test

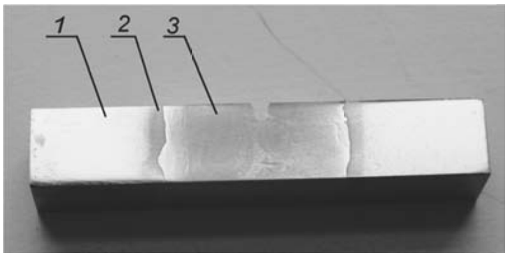

Fig. 8. The sample for Charpy test; 1 - material, 2 - heat affected zone, 3 - weld

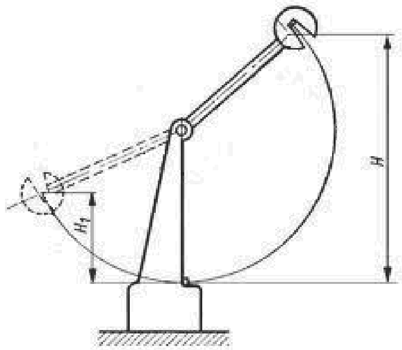

Fig. 9. The test stand for Charpy test

The impact toughness results are given in Tables from 4 to 6. The Charpy tests were done mainly at temperature + 20°C and -40°C on 5 specimens having been extracted from each weld metal.

Table 4.
Impact toughness and amount of AF ferrite for welding with shielding gas Ar

No.	Parameter	Value
1.	Amount of AF, %	73
2.	Impact toughness KCV (- 40°C), J	57
3.	Impact toughness KCV (+ 20°C), J	187

Table 5.
Impact toughness and amount of AF ferrite for welding with shielding gas Ar + 1.5% O_2

No.	Parameter	Value
1.	Amount of AF, %	78
2.	Impact toughness KCV (- 40°C), J	61
3.	Impact toughness KCV (+ 20°C), J	198

Table 6.
Impact toughness and amount of AF ferrite for welding with shielding gas 82% Ar + 18% CO_2

No.	Parameter	Value
1.	Amount of AF, %	69
2.	Impact toughness KCV (- 40°C), J	54
3.	Impact toughness KCV (+ 20°C), J	181

It is possible to deduce after the analysis of Tables from 4 to 6 that impact toughness at negative temperature of weld metal deposit is not strongly affected by the kind of shielding gas for welding with micro-jet cooling.

In automotive welded structures there are 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 4% in both deposits. Total amount of ferrite was on the similar level for each of shielding gases used in investigations, but the levels are not the same. The main marked difference in tested deposits with micro-jet system cooling was observed in AF amount. Because of the AF percentage in deposits with micro-jet cooling there are gettable respectively very good impact toughness properties.

4. Conclusions

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 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,
- because of using micro-jet after welding it could be possible to steer the metallographic structure.

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