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
Volume 57 2012 Issue 2
DOI: 10.2478/v10172-012-0056-x

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LOW ALLOY STEEL WELDING WITH MICRO-JET COOLING

SPAWANIE STALI NISKOSTOPOWEJ Z MIKROJETOWYM CHŁODZENIEM

Low alloy steel is used for many important structures. In that material there is a small amount of carbon and controlled percentage of alloy elements such as Ni, Mn, Mo, Si in steel and welded joints. Especially Ni, Mo, O could be treated as elements positively influencing impact toughness of welded structures. Metallographic structure of weld metal deposit (WMD) having composition of 400 ppm O and 2% Ni or 0.4% Mo and is very beneficial because of high percentage of acicular ferrite (until 65%) and thus WMD 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? Micro-jet technology could be treated as a chance to resolve that problem. The present paper describes the influence of artificially lifted amount of acicular ferrite in WMD (above 65%) on the behaviour of steel weld properties using micro-jet cooling.
Keywords: micro-jet cooling, weld, metallographic structure, acicular ferrite, impact toughness

Do ważnych konstrukcji używana jest stal niskostopowa, bardzo często z małą ilością węgla i kontrolowana zawartością pierwiastków stopowych, takich jak Ni, Mn, Mo, Si. Zwłaszcza Ni, Mo, O są uważane za pierwiastki pozytywnie wpływające na udarność spawanych konstrukcji. Struktura metalograficzna stopiwa posiadającego 400 ppm O i 2% Ni albo 0,4% Mo korzystnie wpływa na własności mechaniczne złącza z powodu wysokiej zawartości drobnoziarnistego wewnątrz-ziarnowego ferrytu (ferryt AF) w stopiwie (do 65%) i przez to na dobre własności mechaniczne. Przez długi czas badacze zadają dwa pytania: jak można podnieść zawartość ferrytu AF w spoinie i jakie to przyniesie następstwa? Technologię microjetową uważa się za szanse na rozwiązanie tego problemu. Przedstawiony artykuł opisuje wpływ sztucznie zawyżonej zawartości ferrytu AF w stopiwie (ponad 65%) na właściwości stalowego złącza ze względu na zastosowanie mikrojetowego chłodzenia.

1. Introduction

The influence of positively influencing elements on mechanical properties of steel car body welds such as manganese, nickel, molybdenum, and oxygen were well analysed in the last 15 years [1-6]. Especially nickel, molybdenum and oxygen could have the positive influence on impact properties of steel car body welds. Authors of the main publications present that nickel content should not exceed 3%, molybdenum content should not exceed 0,5% and the oxygen amount should not be greater than 500 ppm [3-6]. WMD 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 [7-8]. There were also analysed great role of oxide inclusions on acicular ferrite formation [5]. 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]. To obtain higher amount of acicular ferrite in WMD 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 ferrite AF).

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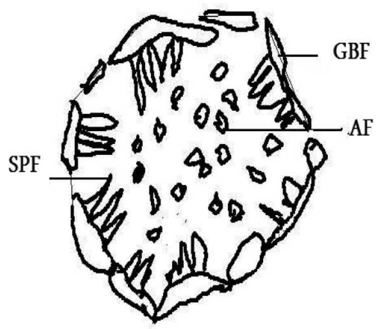

Fig. 1. Fraction of ferrite (GBF, SPF, AF) in WMD

The goal of that paper was analyse welding with micro-jet cooling and possibilities of getting higher amount of AF instead of GBF and SPF forms.

2. Experimental procedure

Weld metal deposit was prepared in two ways (Fig. 2):

- standard MIG process,
- welding with micro-jet cooling.

The principal diameter of wire was 4 mm. The standard current was 220 A, and the voltage was 24 V, argon was chosen as a shielded gas. Argon was also chosen for micro-jet cooling with diameter of 40 μm of stream). Firstly there were tested welding conditions without and with installed micro-jet injector. Results are presented on Figures 2, 3.

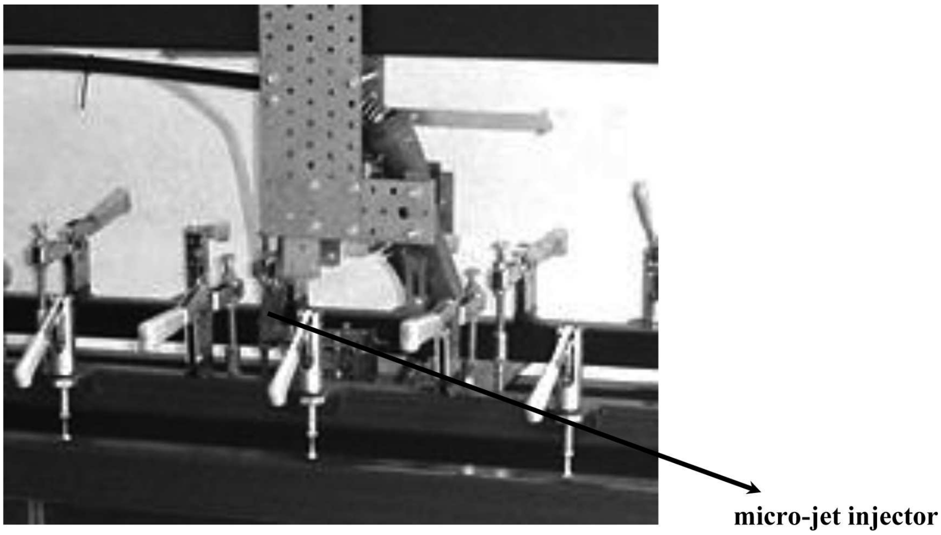

Fig. 2. Equipment for MIG welding with micro-jet cooling

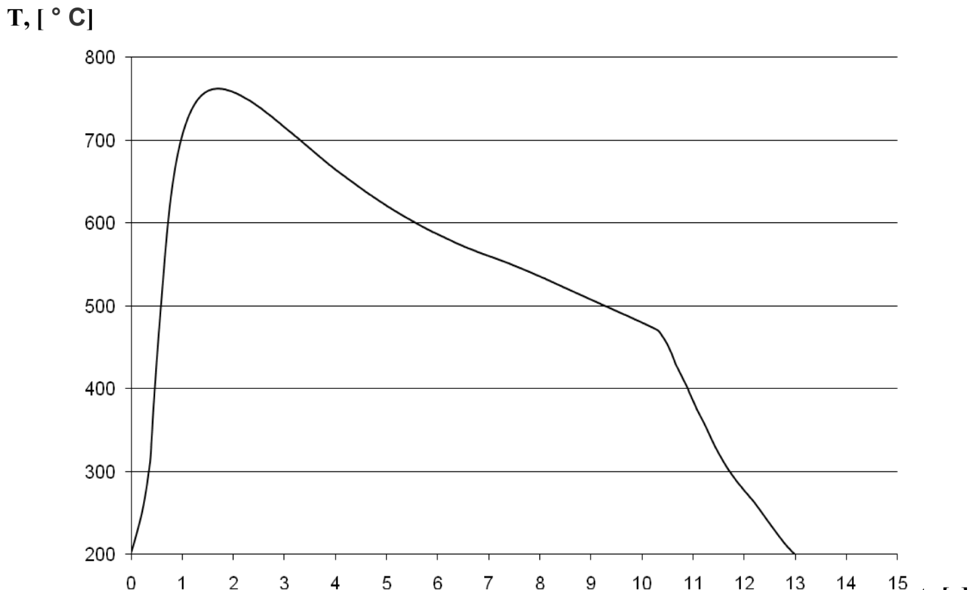

Fig. 3. Weld cooling conditions without micro-jet injector

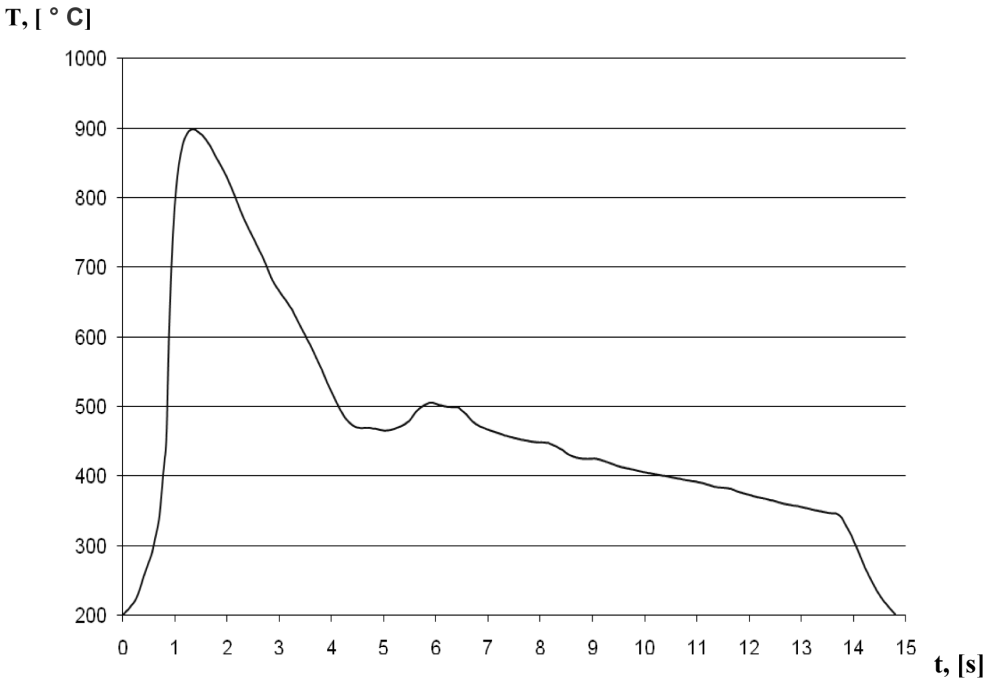

Fig. 4. Weld cooling conditions with micro-jet injector

Cooling with micro-jet infector is more intensively (Fig. 3) than in firth standard case. Cooling micro-jet parameters (argon pressure) were slowly varied to obtain cooling system with temperature- time characteristic shown on Figure 3, that was treated as optimal, because there were gettable very similar amount of total amount of ferrite (also without martensite and bainit structures). For further tests were chosen cooling system with temperature- time characteristic shown on Fig. 4.

3. Results and discussion

A typical weld metal deposited had similar chemical composition in two tested cases (showed in Table 1).

TABLE 1

Composition of typical weld metal

C	0.08%
Mn	0.79%
Si	0.39%
P	0.017%.
S	0.018%
O	380 ppm
N	85 ppm

There were typical analysed structures for classic MIG weldig (Fig. 5) and for MIG weldig with micro-jet cooling (Fig. 6):

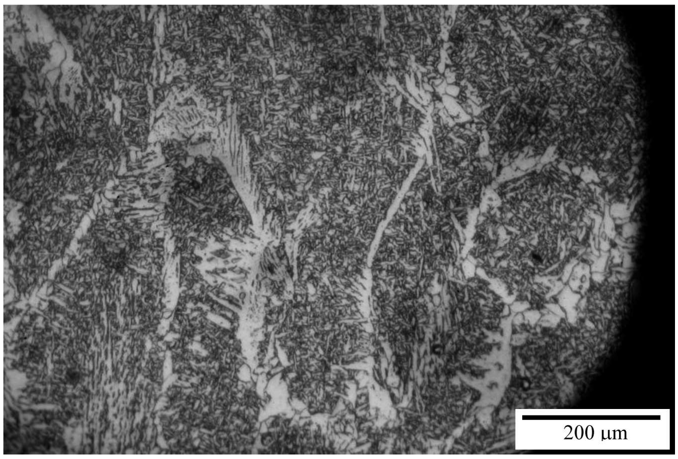

Fig. 5. Acicular ferrite in MWD, 57%. Magnification 200 x

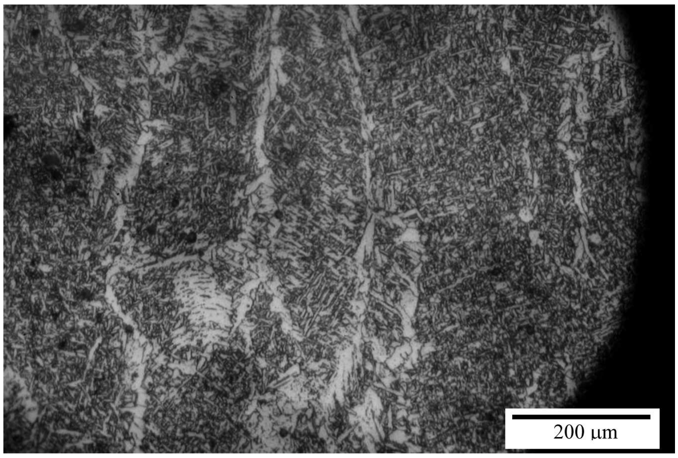

Fig. 6. Acicular ferrite in MWD, 73%. Magnification 200 x

In standard MIG process (without micro-jet) there were gettable higher amounts of GBF and SPF fraction (Fig. 7) meanwhile in micro-jet cooling both of GBF and SPF structures were not dominant.

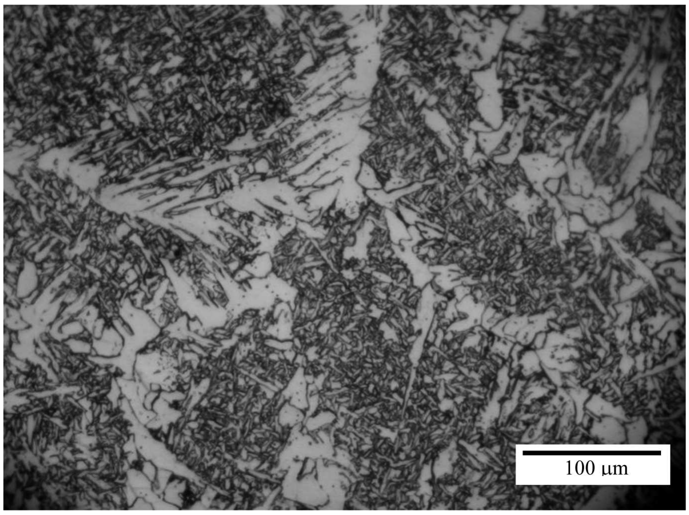

Fig. 7. High amount of GBF and SPF ferrite in MWD of MIG process. Magnification 400 x

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 on Fig. 8).

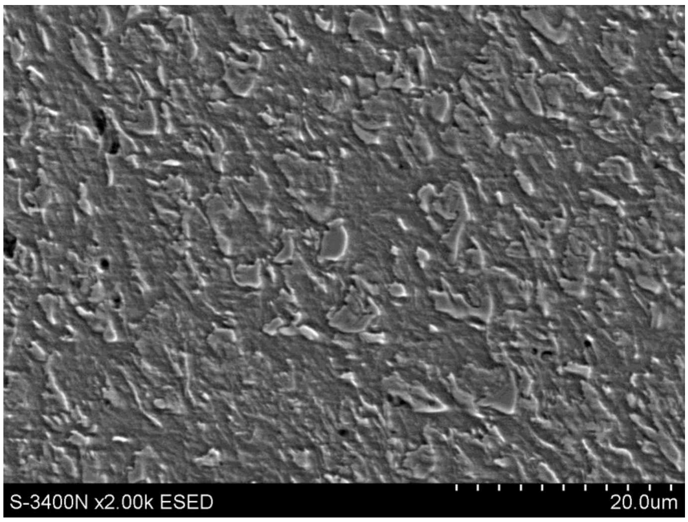

Fig. 8. Acicular ferrite in WMD after micro-jet cooling

After that the chemical analysis, micrograph tests and Charpy V impact test of the deposited metal were carried out. The Charpy tests were done mainly at + 20°C and – 40°C on 5 specimens having been extracted from each weld metal. The impact toughness results are given in Table 2.

TABLE 2

Impact toughness and amount of AF ferrite of WMD for tested processes

MIG process without micro-jet cooling	AF, %	KCV (– 40°C), J	KCV (– 40°C), J
	57	43	182
MIG process with micro-jet cooling	AF, %	KCV (– 40°C), J	KCV (– 40°C), J
	73	57	187

It is possible to deduce after the analysis of Table 2 that impact toughness at negative temperature of weld metal deposit is not strongly affected by the micro-jet cooling system.

In automotive welded structures there are two general types of tests performed: impact toughness and structure. Acicular ferrite and MAC (self-tempered martensite, upper and lower bainite, retained austenite, carbides) phases were analysed and counted for each weld metal deposit. MAC phases were on the similar level of 4% in both deposits, also total amount of ferrite was on the similar level. The main marked difference in tested deposits (with and without 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:

1. Micro-jet-cooling could be treated as a important element of MIG welding process.
2. Micro-jet-cooling after welding can prove amount of acicular ferrite, the most beneficial phase in low alloy steel WMD.
3. High amount of acicular ferrite can guarantee respectively good impact toughness properties.
4. Because of using micro-jet after welding it could be possible to steer the metallographic structure.

REFERENCES

[1] P. Judson, D. Mc Keown, Advances in the control of weld metal toughness, Offshore welded structures proceedings, London **2**, 1982.

[2] T. Węgrzyn, J. Piwnik, P. Baranowski, A. Silva, M. Plata, Micro-jet welding for low oxygen process, Interational Conference ICEUBI2011 Inovation and Development, Covilha, Portugal 2011.

[3] A. Gruszczyk, J. Górka, Heterogeneity of chemical composition and the structure of welded joints and padding welded joints. Welding Technology Review 3, 3-6 (2010).

[4] T. W ę g r z y n, D. H a d r y ś, M. M i r o s, Optimization of Operational Properties of Steel Welded Structures, Maintenance and Reliability 3, 30-33 (2010).
[5] T. W ę g r z y n, J. M i r o s ł a w s k i, A. S i l v a, D. P i n t o, M. M i r o s, Oxide inclusions in steel welds of car body, Materials Science Forum **636-637**, 585-591 (2010).
[6] V.K. G o y a l, P.K. G h o s h, J.S. S a i n i, 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 A **39**, 13, 3260-3275 (2008).
[7] K. K r a s n o w s k i, 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, 1059-1072 (2009).
[8] T. W ę g r z y n, Mathematical Equations of the Influence of Molybdenium and Nitrogen in Welds. Conference of International Society of Offshore and Polar Engineers ISOPE/2002, KitaKyushu, Japan 2002, Copyright by International Society of Offshore and Polar Engineers, vol. IV, ISBN 1-880653-58-3, Cupertino – California – USA, 263-267 (2002).

Received: 10 December 2011.