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Plastic properties of weld after micro-jet cooling

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Properties

ABSTRACT

Purpose: of that paper was analysing main plastic properties of welds made by MIG method with micro-jet cooling. The main reason of it was investigate possibilities of getting better plastic properties of welds made by MIG method with micro-jet cooling than welds made by ordinary welding method. It is possible because higher amount of acicular ferrite (AF) in WMD (weld metal deposit) is obtained in MIG method with micro-jet cooling in relation to ordinary welding method.
Design/methodology/approach: During research Erichsen cupping tests and bending tests were carried out for welds made by MIG method with micro-jet cooling and ordinary welding method.
Findings: High amount of acicular ferrite influences positively on plastic properties. Higher value of plastic parameters were observed for welds made by MIG method with micro-jet cooling.
Research limitations/implications: That research was made for MIG method only. Another method of welding was not tested. Other methods of welding have not been tested, but it is suspected that similar phenomena are taking place.
Practical implications: MIG method with micro-jet cooling `it is way to get better plastic properties of welds in relation to welds made by ordinary welding method. It is very important because it could be used to steering of mechanical properties of welded constructions.
Originality/value: In this research welds made by new method of welding (welding with micro-jet cooling) were compare witch welds made by ordinary welding method. New method of welding is very promising and capable of industrial application, mainly due to the significant improvement of weld properties and quality.
Keywords: Micro-jet welding; Plastic properties; Acicular ferrite; Erichsen cupping test; Bending test

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1. Introduction

In case of constructions which are made by steel a few things are very important. One of them is plastic properties of the construction. Properties of the construction it means properties of the elements material and properties of the connection. Very often elements of the constructions were connected by welding. In this case plastic properties of welds are also very important. The high content of acicular ferrite (AF) is a guarantee of high plastic properties. Proper values of these parameters are required for safety maintenance of welded construction [1-15].

New technology of micro-jet welding could be regarded as a new way to improve plastic properties of welds [16-24].

The reason of it is the fact that during micro-jet welding higher amount of AF in WMD is observed than in traditional welding method. High amount of AF has positively influence on improve plastic properties of the weld.

This paper describes the influence of micro-jet welding on plastic properties of the weld in comparison to weld made by ordinary welding method.

Erichsen cupping tests and bending tests were carried out for welds made by micro-jet welding and ordinary welding method.

2. Experimental procedure

Three kinds of test samples were prepared:

- test sample without weld,
- test sample with weld made by MIG method,
- test sample with weld made by MIG method with micro-jet cooling.

Two kinds of weld were prepared. The first kind was welded with traditional MIG method. The second was welded with MIG method with micro-jet cooling. In both cases argon was chosen as shielding welding gas and as a gas for micro-jet cooling. The diameter of stream in micro-jet injector was 40 µm. Cooling gas pressure was 0.1 MPa. Welding process ensures the cooling of the overall joint. Velocity of the processes (both welding and micro-jet cooling) was on the same level of 150 mm / min (because of great number of other parameters of micro-jet cooling). The welding machine for MIG welding with micro-jet cooling was presented in Figs. 1 and 2. Figs. 3 and 4 show idea of welding with micro-jet cooling.

The main data about parameters of welding were shown in Table 1. Micro-jet cooling does not have influence on chemical composition of the weld.

A typical weld metal deposit had chemical composition which was shown in Table 2.

One type of low alloy S355J2G3 steel was used in both welding methods. Chemical composition of steel is presented on Table 3. The thickness of the test sample always was 3 mm.

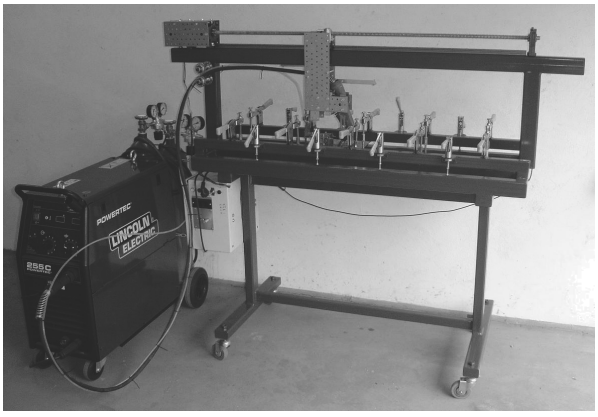


Fig. 1. Apparatus for micro-jet welding

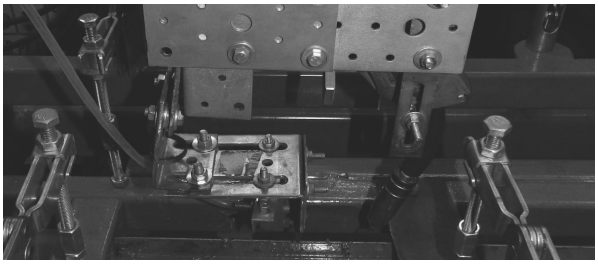


Fig. 2. Montage of welding head and micro-jet injector

The first research was Erichsen cupping tests. In order to determine changes in the plastic properties comparison of depth of the indentation for test sample was done. It involves injecting a slow spherical ended die in a sample sheet aligned against the die, until the indentation of the first crack.

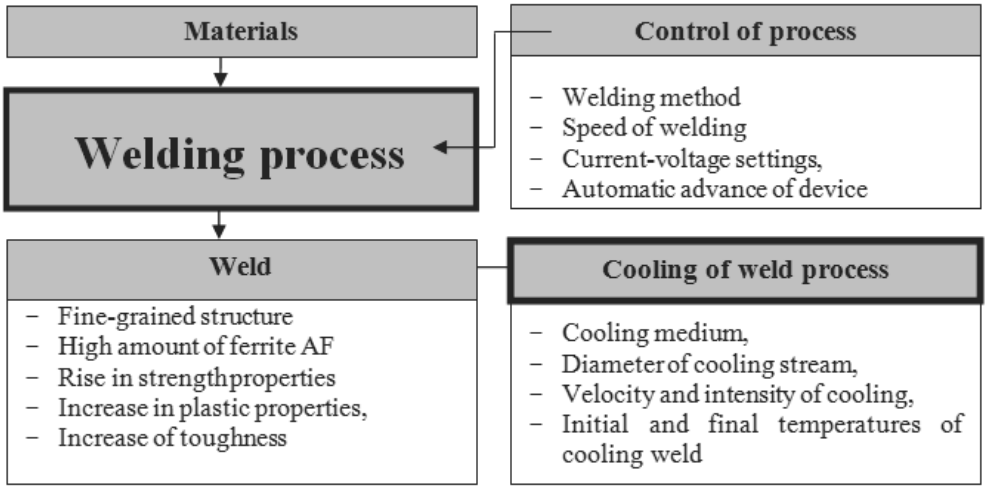


Fig. 3. A diagram of the welding process with weld metal cooling

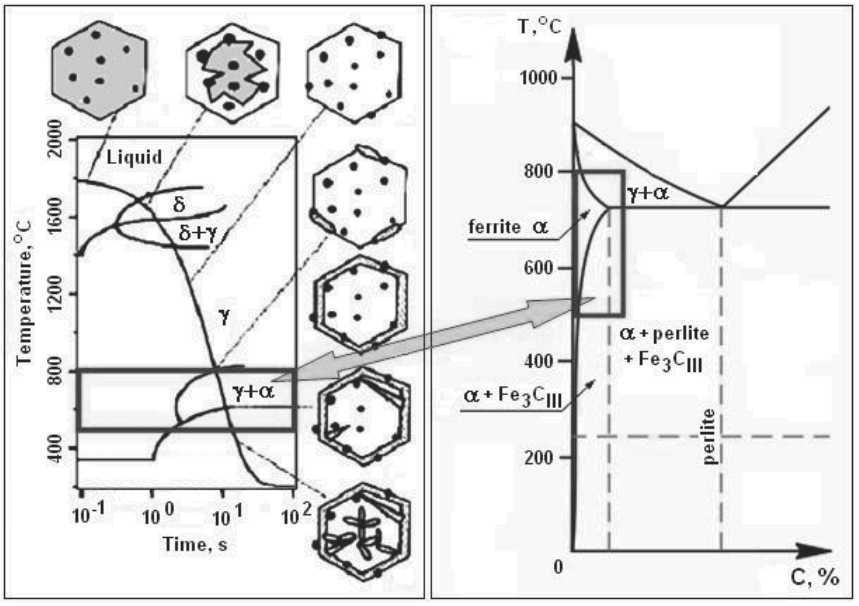


Fig. 4. Cooling TTT curve of weld metal with reference to Fe-C diagram, areas where weld metal cooling is done are clearly marked [25]

Table 1.
Parameters of welding process

No.	Parameter	Value
1.	Principal diameter of wire	4 mm
2.	Standard current	220 A
3.	Voltage	24 V
4.	Shielding welding gas	Ar
5.	Micro-jet welding cooling gas, gas pressure	Ar, 0.1 MPa
6.	Velocity of welding	150 mm/min

Table 2.
A typical chemical composition of the weld

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

The greater deformation of test sample without crack the better plastic properties test sample have. Depth crease without cracking is a measure of the plastic properties of the sample.

Tests were done with the standard (Fig. 5) [26]. Example of test piece after Erichsen cupping tests was presented in Fig. 6.

Table 3.
Chemical composition of S355J2G3 steel

No.	Element	Amount
1.	C	0.17%
2.	Mn	1.2%
3.	Si	0.4%
4.	P	0.017%
5.	S	0.017%
6.	Cr	0.3%
7.	Ni	0.2%
8.	As	0.06%
9.	Cu	0.3

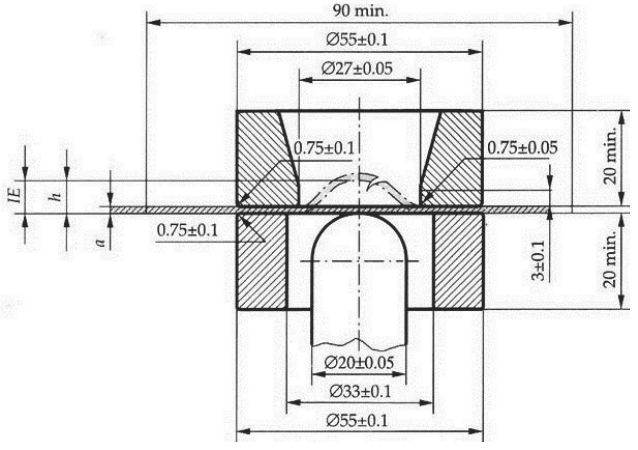
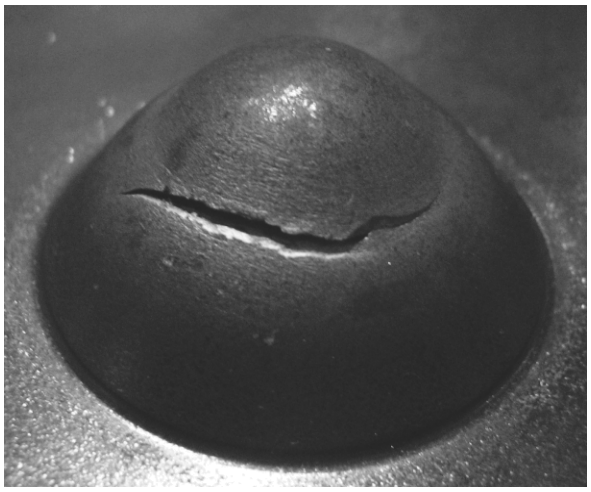


Fig. 5. Idea of Erichsen cupping tests: a - thickness of test piece, h-depth of the indentation during the test, IE - Erichsen cupping index [26]

a)



b)

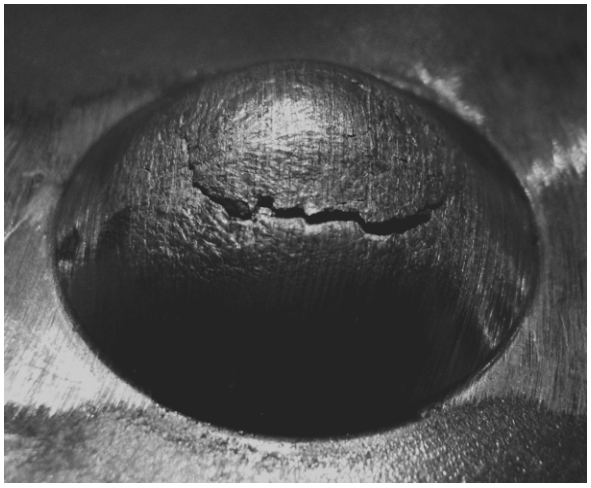


Fig. 6. Example of test piece after Erichsen cupping tests, a) test sample without weld, b) test sample with weld

The second research was bending test. In order to determine changes in the plastic properties comparison of bend for pieces with weld was done. The test consists in repeated flexing of the samples on both sides until the appearance of cracks.

The higher number of bends of test sample without crack the better plastic properties test sample have. Number of bends without breaking is a measure of the plastic properties of the sample.

Tests were done with the standard (Fig. 7) [27]. The way of the calculation of the successive bends sample was shown in Fig. 8.

During the bending test bends of sample were counting. In the same time test samples were observed for material discontinuities. When discontinuities were appeared number of bend was saved. Next test was continued and test samples were observed for cracks. When crack was appeared number of bend was saved.

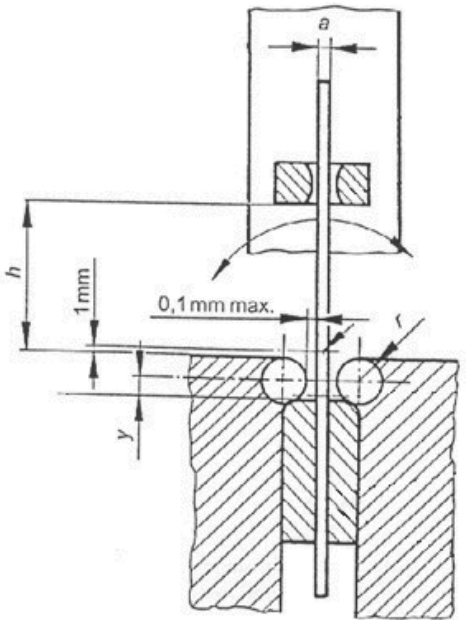


Fig. 7. Idea of bending tests [27], a - thickness of test piece, h - distance from the track to the sample clip, r - radius of support, y - the closest point of contact with the sample clip to test piece

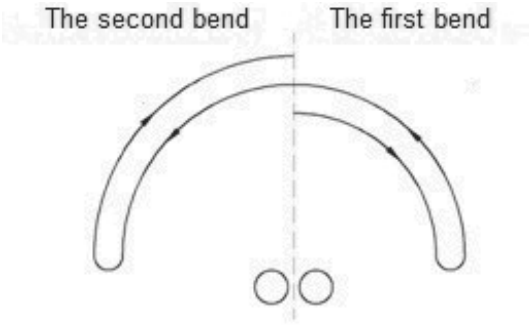


Fig. 8. The way of the calculation of the successive bends sample [27]

3. Results and discussion

Fig. 9 shows the results obtained in Erichsen cupping tests. The results are the average of five trials.

The higher value of Erichsen cupping index was observed for test pieces without weld. It was about 13.3 mm. For test pieces welded by MIG method this value was about 10.1 mm. Test pieces with weld made by MIG method with micro-jet cooling achieved value about 12.1 mm.

Results obtained in Erichsen cupping tests show that welds made with micro-jet cooling have better plastic properties than welds made by ordinary welding method.

Tables 4 and 5 show the results obtained during bending tests. For all kind of test sample five trials were done.

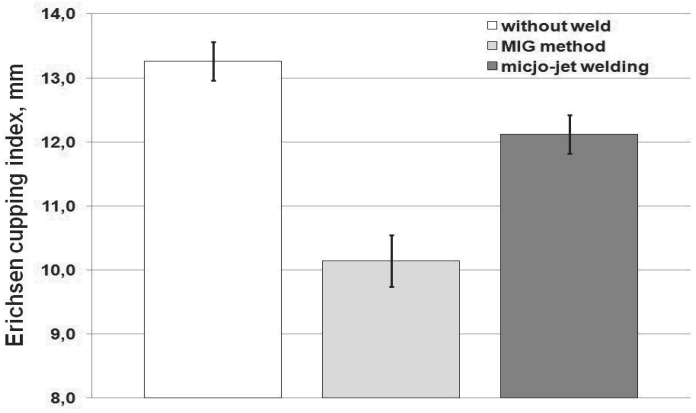


Fig. 9. Results of Erichsen cupping tests

Table 4.
Results of bending tests - Number of bends to the first material discontinuities

No.	Kind of sample	Number of bends to the appearance of the first material discontinuities				
		Test number				
		1	2	3	4	5
1.	Without weld	3	1	2	2	2
2.	Welded with MIG method	1	1	2	1	2
3.	Welded with MIG method and micro-jet cooling	2	2	1	2	2

The highest value of bends number was observed for test samples without weld. This situation was for number of bends to the first material discontinuities and for number of bends to cracks of test sample. Smaller values were observed for test samples with weld. For welded samples better plastic properties were saved for samples which were made by MIG welding with micro-jet cooling.

Table 5.
Results of bending tests - Number of bends to cracks of test sample

No.	Kind of sample	Number of bends to cracks of sample				
		Test number				
		1	2	3	4	5
1.	Without weld	5	3	3	3	4
2.	Welded with MIG method	2	3	4	2	3
3.	Welded with MIG method and micro-jet cooling	4	3	3	3	2

4. Conclusions

Erichsen cupping tests and bending tests were carried out for welds made by MIG method with micro-jet cooling and ordinary welding method. On the basis of investigation it is possible to deduce that:

- results obtained in Erichsen cupping tests show that welds made with micro-jet cooling have better plastic properties than welds made by ordinary welding method,
- results obtained in bending tests show that welds made with micro-jet cooling have better plastic properties than welds made by ordinary welding method,
- micro-jet-cooling could be treated as a 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,
- because of using micro-jet after welding it could be possible to steer the metallographic structure,
- high amount of acicular ferrite influences positively on plastic properties.

References

[1] T. Węgrzyn, T. Śliwiński, D. Sieteski, D. Hadryś, Methods for welding of the vehicle body, Instrumentation Research and Teaching 3 (2011) 53-60 (in Polish).
[2] M. Miros, D. Hadryś, T. Węgrzyn, A. Silva, Effect of Welding methods in the repair of model elements energy-absorbing steel body, Instrumentation Research and Teaching 3 (2011) 109-114 (in Polish).
[3] T. Węgrzyn, M. Miros, Fatigue strength of welds in car body frames, Apparatus Research and Teaching 2 (2010) 65-68.
[4] T. Węgrzyn, R. Szopa, M. Miros, Non-metallic inclusions in the weld metal deposit of shielded electrodes used for welding of low-carbon and low-alloy steel, Welding International 23/1 (2009) 54-59.

[5] T. Węgrzyn, D. Hadryś, M. Miros, Optimization of operational properties of steel welded Structures, Maintenance and Reliability 3 (2010) 30-33.
[6] T. Węgrzyn, J. Mirosławski, A. Silva, D. Pinto, M. Miros, Oxide inclusions in steel welds of car body, Materials Science Forum 636-637 (2010) 585-591.
[7] T. Węgrzyn, Mathematical equations of the influence of molybdenum and nitrogen in welds, Proceedings of the Conference „International Society of Offshore and Polar Engineers" ISOPE'2002, Kita Kyushu, 2002, 263-267.
[8] T. Węgrzyn, Proposal of welding methods in terms of the amount of oxygen, Archives of Materials Science and Engineering 47/1 (2011) 57-61.
[9] T. Węgrzyn, The classification of metal weld deposits in terms of the amount of oxygen, Proceedings of the Conference „International Society of Offshore and Polar Engineers" ISOPE'1999, Brest, 1999, 212-216.
[10] A. Dobrzańska-Danikiewicz, T. Tański, J. Domagała-Dubiel, Unique properties, development perspectives and expected applications of laser treated casting magnesium alloys. Archives of Civil and Mechanical Engineering 12/ (2012) 318-326.
[11] A. Dobrzańska-Danikiewicz, E. Hajduczek, M. Polok-Rubiniec, M. Przybył, K. Adamaszek, Evaluation of selected steel thermochemical treatment technologies using foresight methods, Journal of Achievements in Materials and Manufacturing Engineering 46/2 (2011) 115-146.
[12] A. Dobrzańska-Danikiewicz, E-foresight of materials surface engineering, Archives of Materials Science Engineering 44/1 (2010) 43-50.
[13] L.A. Dobrzański, E. Jonda, K. Lukaszkowicz, A. Kriz, Structure and tribological behavior of surface layer of laser modiefied X40CrMoV5-1, Journal of Achievements in Materials and Manufacturing Engineering 18/1-2 (2006) 343-346.
[14] K. Lukaszkowicz, L.A. Dobrzański, M. Pancielejko, Mechanical properties of the PVD gradient coatings deposited onto the hot work tool steel X40CrMoV5-1, Journal of Achievements in Materials and Manufacturing Engineering 24/2 (2007) 115-118.
[15] A. Dobrzańska-Danikiewicz, K. Lukaszkowicz, Technology validation of coatings deposition onto brass substrate, Archives of Materials Science 46/1 (2010) 5-38.
[16] T. Wegrzyn, J. Piwnik, P. Baranowski, A. Silva, M. Plata, Micro-jet welding for low oxygen process, Proceedings of the International Conference "Innovation and Development" ICEUBI'2011, Covilha, 2011.
[17] T. Węgrzyn, J. Piwnik, R. Burdzik, G. Wojnar, D. Hadryś, New welding technologies for car body frame welding; Proceedings of the Conference "Iron and Steelmaking", Czarna, 2012.
[18] T. Węgrzyn, J. Piwnik, R. Wieszała, D. Hadryś, Control over the steel welding structure parameters by micro-jet cooling, Archives of Metallurgy and Materials 57/3 (2012) 679-685.
[19] T. Węgrzyn, J. Piwnik, D. Hadryś, R. Wieszała, Car body welding with micro-jet cooling, Journal of Achievements in Materials and Manufacturing Engineering 49/1 (2011) 90-94.
[20] T. Węgrzyn, J. Piwnik, B. Łazarz, D. Hadryś, R. Wieszała, Parameters of welding with micro-jet cooling, Archives of Materials Science and Engineering 54/2 (2012) 86-92.
[21] J. Piwnik, T. Węgrzyn, R. Wieszała, D. Hadryś, Welding of the carbody structure using microjet cooling, Proceedings of the IV International Conference "Transport Problems", Katowice-Ślemień, 2012.
[22] T. Węgrzyn, J. Piwnik, B. Łazarz, M. Plata, Micro-jet cooling gases for low alloy steel welding, Proceedings of the Conference "Iron and Steelmaking", Czarna, 2012.
[23] T. Wegrzyn, J. Piwnik, A. Silva, M. Plata, P. Baranowski, Welding with micro-jet cooling for low oxygen process, Proceedings of the International Conference ICEUBI, Covilha, 2011.
[24] T. Węgrzyn, J. Piwnik, Low alloy welding with micro-jet cooling, Archives of Metallurgy and Materials 57/2 (2012) 539-543.
[25] S.B. Sudarsanam, The mechanism of acicular ferrite, Current opinion in Solid state and Materials Science 8 (2004) 267-287.
[26] PN-EN ISO 20482:2004. Metallic materials - Sheet and strip - Erichsen Cupping test method (in Polish).
[27] PN-EN ISO 7799:2002. Metallic materials - Sheet and strip thickness of 3 mm - Trying to bending (in Polish).