

D. HADRYŚ*[#], T. WĘGRZYN**[#], J. PIWNIK***[#]

THE EFFECT OF DIFFERENT MICRO-JET STREAMS NUMBER ON PLASTIC PROPERTIES OF WELDS

WPLYW RÓŻNEJ LICZBY STRUG MIKROJETOWYCH NA WŁAŚCIWOŚCI PLASTYCZNE SPOIN

The main goal of that paper was analysing of plastic properties of welds made with micro-jet cooling. New technology of micro-jet welding could be regarded as a new way to improve plastic properties of welds. It allows to obtain welds with better properties in comparison to ordinary welding method. Moreover, it is possible to steering of weld structure and properties of the weld. During research Erichsen cupping tests and bending tests were carried out for welds made by MIG method with micro-jet cooling. Argon was cooling medium. Different numbers of micro-jet streams were used to weld cooling. Different plastic properties were obtained for different numbers of micro-jet streams. In this research welds made by new method of welding (welding with micro-jet cooling) were compared with welds made by ordinary welding method.

Keywords: welding, micro-jet cooling, plastic properties, Erichsen cupping test, bending tests

Głównym celem niniejszego artykułu jest przeanalizowanie własności plastycznych spoin wykonanych z chłodzeniem mikrojetowym. Ta nowa technologia spawania może być traktowana jako nowy sposób na poprawę własności plastycznych spoin. Umożliwia to uzyskanie spoiny o lepszych właściwościach w porównaniu z typowymi sposobami spawania. Ponadto, możliwe jest sterowanie strukturą i właściwościami spoiny. Dla spoin wykonanych metodą MIG z chłodzeniem mikrojetowym oraz zwykłych spoin wykonano próby tłoczności metodą Erichsena oraz badania przeginalnia. Jako czynnik chłodzący zastosowano argon. Spawanie z chłodzeniem mikrojetowym z różnymi liczbami mikro strug medium chłodzącego zostało użyte do przygotowania próbek. Różne właściwości plastyczne uzyskano dla różnej liczby mikro strug

1. Introduction

In case of steel constructions a few things are very important. One of them are plastic properties of the construction. Properties of the construction it means properties of material of components and properties of connection between components. In case of welded constructions plastic properties of welds are also very important, for example shock, overload [1, 2]. Plastic properties of welds depend on a few things (welding method, parameters of welding process, welding binder, ect.). Moreover, construction durability and safety maintenance under different conditions depend on plastic properties.

In case of welded steel constructions plastic properties depend on structure of weld metal deposit (WMD). Beneficial phase is acicular ferrite (AF). High content of AF is a guarantee of high plastic properties. Safety maintenance of welded construction is effect of proper values of these parameters [3÷8]. Welding with micro-jet cooling is a new interesting way to improve plastic properties of welds. High amount of AF in WMD appears during welding with micro-jet cooling. Amount of AF is higher than in ordinary welding method (e. g. MIG). This fact influences positively on improve plastic properties of weld. This

paper describes the influence of welding with micro-jet cooling on plastic properties of the weld in comparison to weld made by ordinary welding method. Additionally, comparison was done for different number of micro-jet streams. Cooling medium was gas (argon). Fact of material heating and cooling influence on structure and properties [9÷14]. Erichsen cupping tests and bending tests were carried out. Figures 1 and 2 present apparatus for welding with micro-jet cooling.



Fig. 1. Apparatus for welding with micro-jet cooling

* HIGHER SCHOOL OF LABOUR SAFETY MANAGEMENT, 8 BANKOWA STR., 40-007 KATOWICE, POLAND

** SILESIA UNIVERSITY OF TECHNOLOGY, 8 KRASIŃSKIEGO STR., 40-019 KATOWICE, POLAND

*** BIAŁYSTOK UNIVERSITY OF TECHNOLOGY, 45C WIEJSKA STR., BIAŁYSTOK, POLAND

[#] Corresponding author: dhadryś@wszop.edu.pl

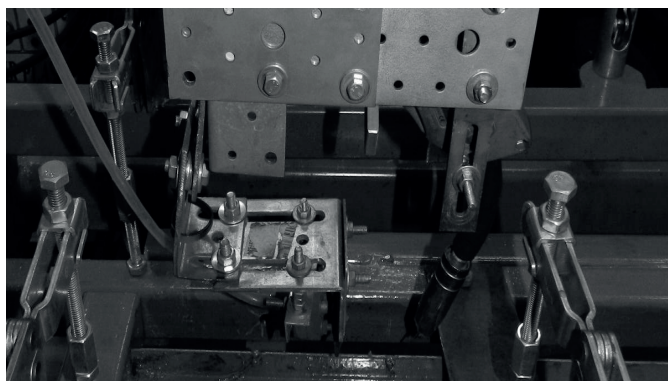


Fig. 2. Montage of welding head and micro-jet injector

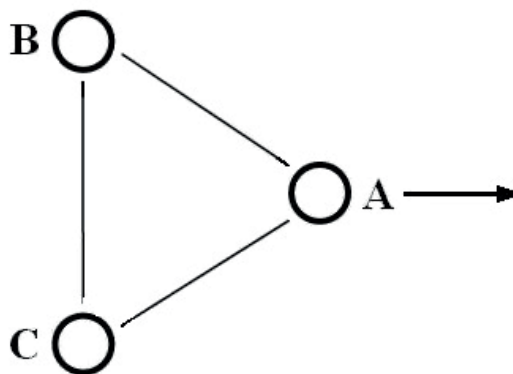


Fig. 3. Micro-jet cooling jets location; arrow indicates the direction of movement

2. Experimental procedure

Two kinds of samples were made for investigations: samples for Erichsen cupping tests and samples for bending tests. For both kinds of investigations following type of samples were made:

- samples without weld,
- samples with weld made by MIG method,
- samples welded with MIG method with micro-jet cooling with one jet,
- samples welded with MIG method with micro-jet cooling with two jets,
- samples welded with MIG method with micro-jet cooling with three jets.

Argon was chosen as shielding welding gas and as a gas (cooling medium) for micro-jet cooling. The diameter of stream in micro-jet injector was always 40 μm. Samples were welded with different number of micro-jet stream (one, two and three). The main data about parameters of welding were shown in table 1. Figure 3 shows arrangement of jets.

TABLE 1

Parameters of welding process

No.	Parameter	Value
1.	Diameter of wire	4 [mm]
2.	Standard current, Voltage	220 [A], 24 [V]
4.	Shielding welding gas	Ar
5.	Micro-jet cooling gas	Ar
6.	Cooling gas pressure	0.4 [MPa]
7.	Diameter of micro-jet cooling stream	40 [μm]
8.	Number of tested micro-jet cooling jet	1 (A) 2 (B + C) 3 (A + B + C) Situating in equilateral triangle with sides 6 mm (fig. 3)

A typical weld metal deposit had chemical composition which was shown in table 2. One type of low alloy S355J2G3 steel was used in investigations. The thickness of the test sample always was 3 mm.

TABLE 2

A typical chemical composition of 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]

First investigation was Erichsen cupping tests. In order to determine changes in the plastic properties comparison of depth of the indentation for weld was done. Tests were done with the standard [15]. Investigation points were situated in place of weld. Idea of Erichsen cupping tests was shown in figure 4.

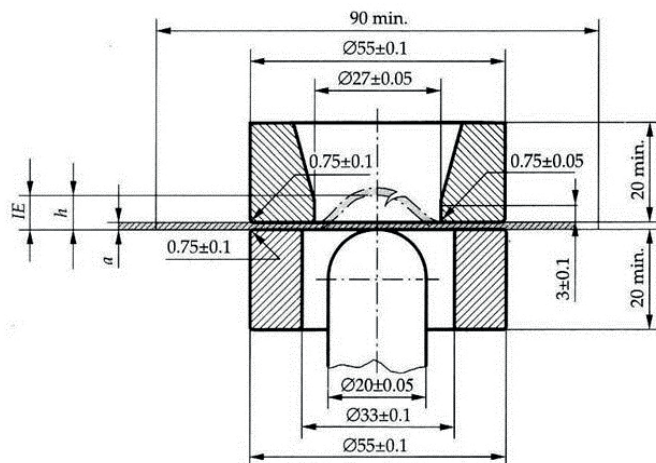


Fig. 4. Idea of Erichsen cupping tests [15], a – thickness of sample, h – depth of the indentation during the test, IE - Erichsen cupping index

Second investigation was bending test. In order to determine changes in the plastic properties comparison of bend for samples without and with weld was done. Tests were done with the standard [16]. Places of bending were situated in place of weld. Figures 5 and 6 describe methodology of bending test.

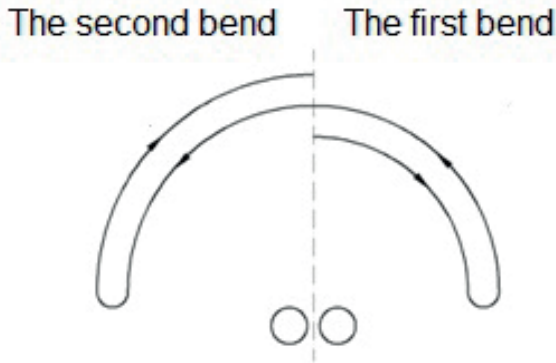


Fig. 5. The way of the calculation of the successive bends of sample [16]

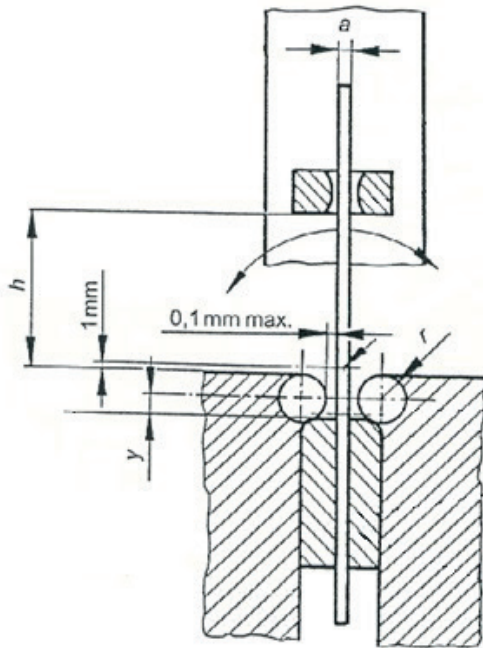


Fig. 6. Idea of bending tests [16], a – thickness of sample, h – distance from the track to the sample clip, r – radius of support, y – the closest point of contact with the sample clip to sample

3. Results and discussion

Figure 7 shows example of samples after Erichsen cupping tests and figure 8 shows the results obtained in that investigations. For all kind of test sample five trials were done. The results are the average of five trials. The higher value of Erichsen cupping index was observed for samples without weld. It was about 13.2 mm. For welded samples that values were smaller than for samples without weld. For samples welded by MIG method this value was about 10.1 mm. Samples welded with MIG method and micro-jet cooling with one jet achieved value about 12.1 mm. Samples welded

with MIG method and micro-jet cooling with two jets achieved value about 13,0 mm. Samples welded with MIG method and micro-jet cooling with three jets achieved value about 12,2 mm. It could be observed that welding with micro-jet cooling improves results in comparison to ordinary welding method, but very important thing is number of jets. In this case the best results were achieved for welding with micro-jet cooling with two jets. It should be told that for all cases with micro-jet cooling results were better than for ordinary MIG welding method.

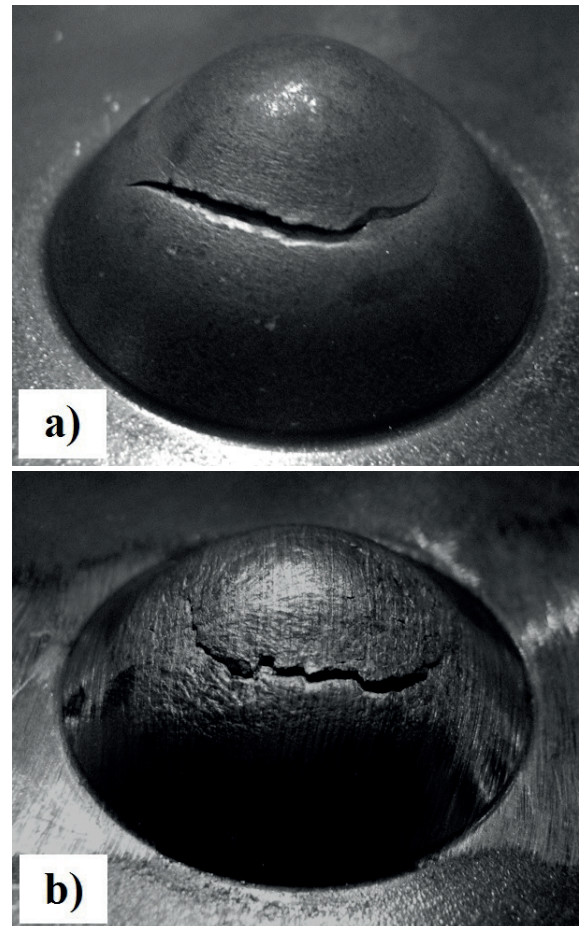


Fig. 7. Example of sample after Erichsen cupping tests; a) – sample without weld, b) – sample with weld

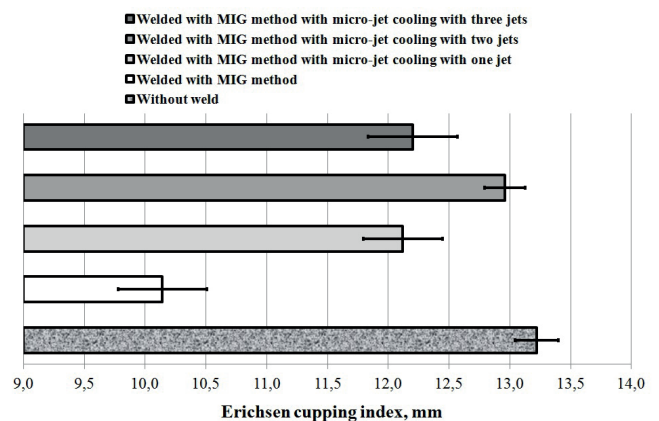


Fig. 8. Results of Erichsen cupping tests

First part of this investigation was from first bend to number of bend to appearance first material discontinuities. The best results were achieved for test sample without weld and for cases of welding with micro-jet cooling with two and three jets. The worse result were achieved for samples which were made with ordinary MIG welding method without micro-jet cooling. Use of micro-jet cooling for welding influences positively on results of bending test, during first part of that investigations.

Second part of this investigation was from number of bend to the appearance of the first material discontinuities to number of bends to cracks of sample. In this case the situation is little different. The best results were observed for not welded sample. The worse result were observed for test samples welded with using standard MIG method without micro-jet cooling. Application of micro-jet cooling for welding influences positively on results of bending test, during second part of that investigations. It could be observed that welding with micro-jet cooling improves results in comparison to ordinary welding method. In that cases results are similar to result for non welded samples.

Figures 9 and 10 show the results obtained in bending tests. For all kind of test sample five trials were done.

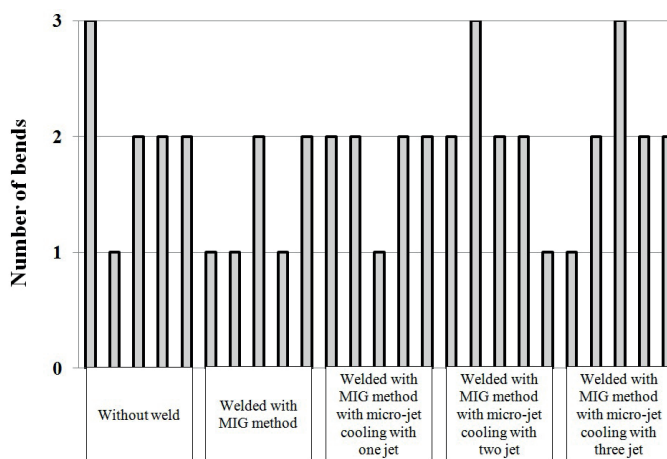


Fig. 9. Results of bending tests, part 1

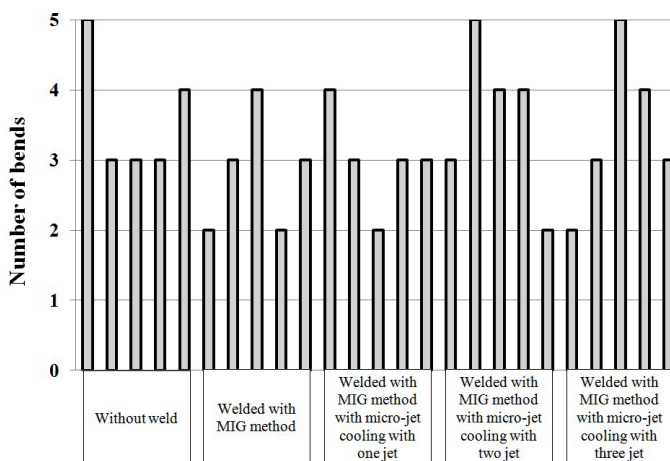


Fig. 10. Results of bending tests, part 2

During the study it was found that very important is number of nozzles that produce streams of cooling medium. Too large number of jets degrades performance of micro-jet cooling. The reason for this may be an interaction between streams of coolant and interrelation disruption the flow of coolant.

4. Conclusions

This work introduced Erichsen cupping tests and bending tests as a measure of the plastic properties for welded samples. An innovative welding process with micro-jet cooling influences positively on plastic properties of the weld. It could have influence on another aspect in welding. The investigations of Erichsen cupping tests and bending tests have been carry out. On the basis of this investigations it is possible to deduce that:

- micro-jet cooling could be treated as an important element of MIG welding process,
- micro-jet technology in welding could improve plastic parameters of welds,
- different number of micro-jet cooling jet influences on weld parameters, but too large number of jets is not the best solution,
- the best results for Erichsen cupping tests were achieved with use of two micro-jet cooling jets,
- the best results for bending tests were achieved with use of two micro-jet cooling jets.

REFERENCES

- [1] R. Burdzik, Ł. Konieczny, Research on structure, propagation and exposure to general vibration in passenger car for different damping parameters, *Journal of Vibroengineering* **15**, (4), (2013).
- [2] Ł. Konieczny, R. Burdzik, B. Bogusław, Application of the vibration test in the evaluation of the technical condition of shock absorbers built into the vehicle, *Journal of Vibroengineering* **15**, 4 (2013).
- [3] T. Węgrzyn, J. Piwnik, Low alloy welding with micro-jet cooling, *Archives of Metallurgy and Materials* **57**, 2 (2012).
- [4] T. Węgrzyn, J. Mirosławski, A. Silva, D. Pinto, M. Miros, Oxide inclusions in steel welds of car body, *Materials Science Forum*. **636-637**, (2010).
- [5] T. Węgrzyn, The influence of nickel and nitrogen on impact toughness properties of low alloy basic electrode steel deposits. Conference of International Society of Offshore and Polar Engineers ISOPE'2001, Stavanger, VOL IV Book Series: International Offshore and Polar Engineering Conference Proceedings, Published, (2001).
- [6] T. Węgrzyn, The Classification of Metal Weld Deposits in Terms of the Amount of Nitrogen. Conference of International Society of Offshore and Polar Engineers ISOPE'2000, Seattle, USA 2000, Copyright by International Society of Offshore and Polar Engineers, vol. IV, ISBN 1-880653-50-8, Cupertino – California – USA (2000).
- [7] T. Węgrzyn, The Classification of Metal Weld Deposits in Terms of the Amount of Oxygen. Conference of International Society of Offshore and Polar Engineers ISOPE'99, Brest,

- France 1999, Copyright by International Society of Offshore and Polar Engineers, ISBN 1-880653-43-5, vol. IV Cupertino – California – USA (1999).
- [8] J. Piwnik, D. Hadryś, G. Skorulski, Plastic properties of weld after micro-jet cooling; *Journal of Achievements in Material and Manufacturing Engineering*, Vol. 59, Issue 1, (July 2013).
- [9] A. Grajcar, W. Borek, The thermo-mechanical processing of high-manganese austenitic TWIP-type steels, *Archives of Civil and Mechanical Engineering* 8 (4) (2008).
- [10] L.A. Dobrzański, A. Grajcar, W. Borek, Microstructure evolution of C-Mn-Si-Al-Nb high-manganese steel during the thermomechanical processing, *Materials Science Forum* 638 (2010).
- [11] J. Adamiec, A. Grabowski, A. Lisiecki, Joining of an Ni-Al alloy by means of laser beam welding. *Proc. SPIE* 5229, *Laser Technology VII: Applications of Lasers*, 215 (October 6, 2003).
- [12] A. Grabowski, G. Moskal, Laser surface treatment of aluminium matrix composites, *Proc. SPIE* 8703, *Laser Technology 2012: Applications of Lasers*, 87030J (January 22, 2013).
- [13] A. Lisiecki, Welding of titanium alloy by Disk laser. *Proc. of SPIE* Vol. **8703**, *Laser Technology 2012: Applications of Lasers*, 87030T (January 22, 2013), DOI: 10.1117/12.2013431.
- [14] J. Górka, Analysis of simulated welding thermal cycles S700MC using a thermal imaging camera, *Advance Material Research ISI Proceedings*, vol. **837**/2014.
- [15] PN-EN ISO 20482:2004. Metale - Blachy i taśmy - Próba tężności metodą Erichsena.
- [16] PN-EN ISO 7799:2002. Metale - Blachy i taśmy grubości do 3 mm - Próba przeginięcia.

Received: 20 April 2014.

