ISSN 1392–1207. MECHANIKA. 2015 Volume 21(5): 419–423

Mechanical properties of shaft surfacing with micro-jet cooling

T. Wegrzyn*, J. Piwnik, B. Lazarz*, W. Tarasiuk****
**Silesian University of Technology, Faculty of Technical Materials, str. Krasińskiego 8, 40-019 Katowice, Poland, E-mail: tomasz.wegrzyn@polsl.pl; bogdan.lazarz@polsl.pl*
***Bialystok University of Technology, Mechanical Faculty, str. Wiejska 45C, 15-351 Bialystok, Poland, E-mail: j.piwnik@pb.edu.pl, w.tarasiuk@pb.edu.pl*

crossref http://dx.doi.org/10.5755/j01.mech.21.5.9545

1. Introduction

Welding surfacing process is very often used to apply a hardness or wear-resistant layer of base metal. It is very important method of extending the life of machines, tools, and construction equipment. Welding surfacing process is used to apply hardness and wear resistance. Main goal of that paper was describing possibilities of surfacing welding process with micro-jet cooling. Metallographic structure was analyzed in terms of micro-jet parameters. For getting various amount of martensite in this welding method it is necessary to determine the main parameters of the process such as: number of jets, i.e.:

- diameter of stream of the micro-jet injector;
- type of micro-jet gases;
- micro-jet gas pressure.

Welding with micro-jet technology was carefully tested for low alloy welding [1-13].

In the steel weld structure the best mechanical properties of weld correspond with chemical composition. Low amount of C (below 0.07%), Mn (below 0.7%), Si (below 0.4%), P (below 0.013%), S (below 0.014%), in WMD (weld metal deposit) correspond with good mechanical properties of welds, because of beneficial structure. Especially high amount of acicular ferrite (AF) in WMD is the structure that guaranties good impact toughness of welds. Having the most optimal chemical composition in weld it is only possible to get maximal 55% of AF in weld, but no more. It is why it was necessary to develop completely new welding technology to maximize of acicular ferrite (AF) content. Micro-jet technology gives chance to obtain artificially high amount of AF in low alloy weld (even on the level of 75%) [18-22]. Micro-jet technology also gives chance to obtain much higher amount of martensite after shaft surfacing [23-23]. The micro-jet technology was tested for steel welding with various micro-jet cooling conditions. A proper shaft regeneration has main influence on shaft exploitation [24-29]. Goal of that paper was to describe possibilities of innovative technology: shaft surfacing process together with micro-jet cooling.

2. Experimental procedure

To obtain various amount of martensite in surface weld it was installed cooling micro-jet injector (only with one steam diameter of 40 μm and 50 μm) after welding head (Fig. 1). To analyze the surfacing with micro-jet cooling, there were chosen shafts of structural steel for carburizing 18H2N2 (18CrNi8) with a diameter of 28 mm.

Montage of shaft, welding head and micro-jet injector illustrates Fig. 1.

Fig. 1 Position for superficial welding with micro-jet cooling: *1* – welding head; *2* – micro-jet cooling injector, *3* – weld overlay machine shaft, *4* – handle, *5* – micro-jet gas pipe [21]

Surface weld was prepared by welding with micro-jet cooling with varied parameters. Various micro-jet cooling gases (nitrogen, argon, helium) were tested in cooling process just after surface welding. There was not changing another important micro-jet parameter such as gas pressure (always on the level of 0.4 MPa). The main data about parameters of welding were shown in Table 1.

Table 1

Parameters of welding process

No.	Parameter	Value
1.	Diameter of wire	1.2 mm
2.	Standard current	220 A
3.	Voltage	24 V
4.	Shielding welding gas	Ar
5.	Kind of tested micro-jet cooling gas	1 – Ar; 2 – He; 3 – N_2
6.	Micro-jet gas pressure	always 0.4 MPa
7.	Micro-jet diameter	40 μm and 50 μm

Argon, nitrogen and helium were chosen for micro-jet cooling (with various diameter of 40 μm and 50 μm of micro-stream). MIG surface welding (argon) technology (with micro-jet cooling) was only used in this article. Argon is chosen as a shielded gas because of not oxidizing potential. Surface weld was prepared by welding with micro-jet cooling with varied parameters. After welding process surface was precisely grinded (Fig. 2).

Fig. 2 The superficial deposit made by using welding with micro-jet cooling [21]

3. Results and discussion

There were tested and compared various surface welds of standard MIG welding with new technology: MIG welding with micro-jet cooling. A goal of the study was to examine the varying structure of the typical surfacing shaft after welding. All tested welding processes were realized with varied micro-jet gases: argon, helium, nitrogen. A typical weld metal deposit had similar chemical composition in all tested cases. Micro-jet gas could have only influence on more or less intensively cooling conditions, but does not have greater influence on chemical WMD composition (except nitrogen amount in MWD), Table 2.

Table 2

Chemical composition of metal weld deposit

No.	Element	Amount
1.	C	0.15%
2.	Mn	0.4%
3.	Si	0.15%
4.	P	0.014%
5.	S	0.011%
6.	Cr	1.8%
7.	Ni	1.9%
8.	N	50-70 ppm

For standard MIG welding and welding with two main micro-jet gases: argon and helium amount of nitrogen was always on the level of 50 ppm. For welding with nitrogen as a third micro-jet gas amount of nitrogen was higher, on the level of 70 ppm. After chemical analyses the metallographic structure was given. Example of this structure was shown in Table 3.

Table 3

Martensite in weld (argon, helium and nitrogen used as a micro-jet gas)

Micro-jet diameter	Number of jets	Martensite aprox, % argon	Martensite aprox, % helium	Martensite aprox, % nitrogen
40 μm	1	50	50	50
40 μm	2	60	70	60
50 μm	1	60	60	60
50 μm	2	70	80	75

Heat transfer coefficient of tested micro-jet gases influences on cooling conditions of welds (table 3). This is due to the similar conductivity coefficients ($\lambda \cdot 105$), which for Ar and N_2, in the 273 K are not very various, respectively: 16.26 and 23.74 J/cm·s·K. Cooling conditions are rather similar when nitrogen and argon are chosen as a micro-jet gas. Helium gives much stronger cooling conditions due to the higher conductivity coefficients ($\lambda \cdot 105$), which for He is 143.4 J/cm·s·K. Micro-jet cooling does not have greater influence on chemical composition of weld. Only in case with helium micro-jet cooling there were observed traces of nitrides. There was firstly carried out metallographic structures for MIG surfacing with micro-jet cooling in terms on micro-jet parameters (Figs. 3-6).

Fig. 3 Martensite (aprox. 50%) in weld after welding without micro-jet cooling, 500x

Fig. 4 Martensite (aprox. 70%) in weld after welding with micro-jet cooling (argon as micro-jet gas), magn. 500x

Fig. 5 Martensite (aprox.75%) in weld after welding with micro jet cooling (nitrogen as micro-jet gas), magn. 500x

Fig. 6 Martensite (aprox. 80%) in weld after welding with micro-jet cooling (helium as micro-jet gas), magn. 500x

It is not so easy to count precisely martensite amount such as other typical weld phases: acicular ferrite, grain boundary ferrite, side plate ferrite for low alloy welding [14-27]. Martensite amount was only estimated. Nevertheless it is possible to present, that micro-jet technology is absolutely capable of structure steering (Table 3). Martensite amount is similar when nitrogen and argon are taken as micro-jet gases (Figs. 4, 5). Martensite amount is the highest when helium is taken as micro-jet gas (Fig. 7). After microscope observation a micro hardness was carried out (Figs. 7-10). Standard surface welding could not guaranty high hardness (Figs. 8).

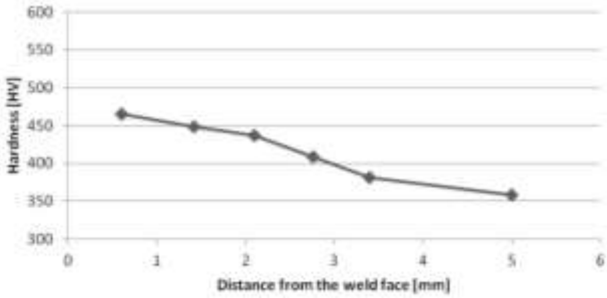

Fig. 7 Hardness of standard weld without micro-jet cooling

Surface weld hardness of the shaft was decreased in terms of the distance from weld face, the maximum value was much below 500 HV. Much higher hardness values were observed after welding with micro-jet cooling (Fig. 8).

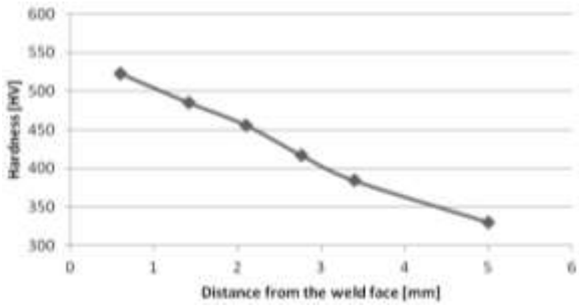

Fig. 8 Hardness of weld after micro-jet cooling, argon used as micro-jet gas

Shaft surface welding with micro-jet cooling (by argon) with one jet allowed to excide hardness under 500 HV. A little higher surface weld hardness values were observed after welding with nitrogen as a micro-jet gas (Fig. 9).

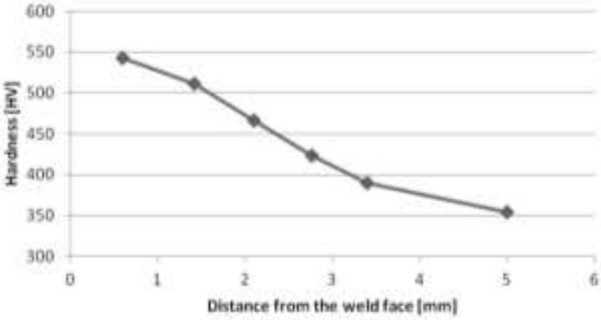

Fig. 9 Hardness of weld after with micro-jet cooling, nitrogen used as micro-jet gas

Surface shaft welding with micro-jet cooling (by helium) allowed to excide hardness under 550 HV, (Fig. 10).

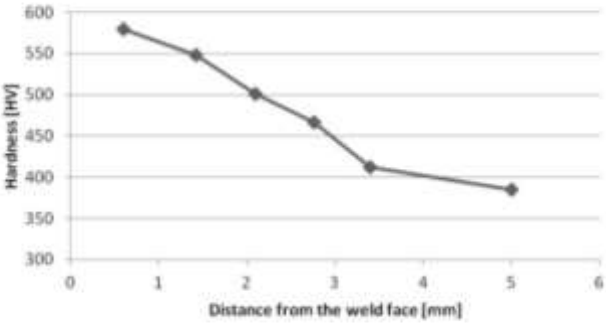

Fig. 10 Hardness of weld after micro-jet cooling, helium used as a micro-jet gas

The micro-hardness inside the martensitic regions after welding with micro-jet cooling are higher than in standard weld, i.e. between 580 HV than 475 HV compared to 470 HV. The tribological properties of steel after thermo treating and micro-jet welding processes were obtained on the new elaborated research T-11 band [28]. In the case studies, the T-11 tester was used to determine average: friction coefficient μ, and frictional force Tav. Each sample was tested five times. The time test was t = 800 s. Results of T-11 tests are shown on Figs. 11-12.

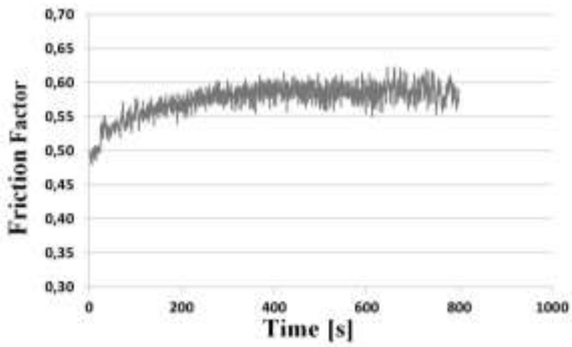

Fig. 11 A plot of the coefficient of friction between the time at which the strength was increased for sample made from deposit without micro-jet cooling

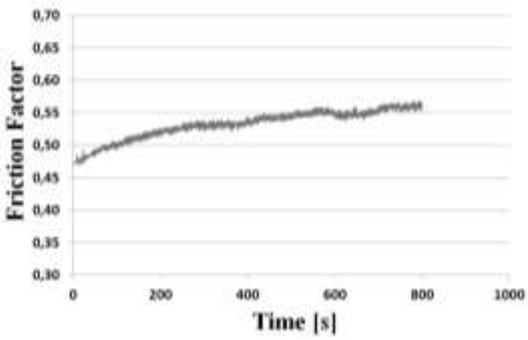

Fig. 12 A plot of the coefficient of friction between the time at which the strength was increased for sample made from deposit with micro-jet cooling

The tribological tests show that micro-jets cooling affects the properties of the welds. Table 4 summarizes the results of tribological tests.

Based on the results stated in Table 4, it was found that the highest resistance to abrasive wear has the sample taken after welding with micro-jet cooling. Favourable micro-jet gases are nitrogen or helium.

4. Conclusion

The micro-jet surfacing technology was tested for surface welding with various micro-jet gases (nitrogen, argon, helium) and another micro-jet parameter (micro-jet gas pressure). Micro-jet technology could be treated as a very beneficial process during shaft surfacing.

Table 4

The tribological test results

Properties	Sample of surface weld without micro-jet cooling	Sample of surface weld with argon micro-jet cooling	Sample of surface weld with helium micro-jet cooling	Sample of surface weld with nitrogen micro-jet cooling
Hardness	47 HRC	51 HRC	51 HRC	52 HRC
Average friction force, N	23.4 N	21.72 N	20.96 N	20.21 N
Unit pressure	1.25 N/mm^2	1.25 N/mm^2	1.25 N/mm^2	1.25 N/mm^2
Test time	800 s	800 s	800 s	800 s
Average coefficient of friction	0.575	0.532	0.512	0.503
Weight loss, g	0.0027 g	0.0015 g	0.0012 g	0.0010 g

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

- micro-jet-cooling could be treated as important element of MIG welding process;
- it is possible to steer the metallographic structure (martensite, nitrides);
- it is possible to steer the weld harness by various micro-jet parameters;
- there is not great difference between the influence of argon and nitrogen on cooling conditions;
- helium used for micro-jet cooling (instead of argon and nitrogen) is responsible of the highest hardness in all tested;
- there were observed traces of nitrides when nitrogen was used for micro-jet cooling (instead of argon when nitrides were not observed);
- the highest resistance to abrasive wear has the sample taken after welding with micro-jet cooling.

References

1. **Węgrzyn, T.; Piwnik, J.; Hadryś, D.; Wieszała, R.** 2011. Car body welding with micro-jet cooling, JAMME 49(1): 90-94.
2. **Lisiecki, A.** Welding of titanium alloy by Disk laser, Proc. of SPIE Vol. 8703, Laser Technology 2012: Applications of Lasers, 87030T (January 22, 2013). http://dx.doi.org/10.1117/12.2013431.
3. **Węgrzyn, T.; Hadryś, D.; Miros, M.** 2010. Optimization of operational properties of steel welded structures, Maintenance and Reliability 3: 30-33.
4. **Węgrzyn, T.; Mirosławski, J.; Silva, A.; Pinto, D.; Miros, M.** 2010. Oxide inclusions in steel welds of car body, Materials Science Forum 636-637: 585-591. http://dx.doi.org/10.4028/www.scientific.net/MSF.636-637.585.
5. **Goyal, V.K.; Ghosh, P.K.; Saini, J.S.** 2008. 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. http://dx.doi.org/10.1007/s11661-008-9637-8.
6. **Lisiecki, A.** 2012. Diode laser welding of high yield steel, Proceedings of SPIE Vol. 8703, Laser Technology 2012: Applications of Lasers, 87030S. http://dx.doi.org/10.1117/12.2013429.
7. **Lisiecki, A.** 2014. Experimental and numerical study of heat conditions during diode laser gas nitriding of titanium alloy, Advanced Materials Research 1036: 320-325. http://dx.doi.org/10.4028/www.scientific.net/AMR.1036.320.
8. **Słania, J.** 2005. Influence of phase transformations in the temperature ranges of 1250-1000ºC and 650-350ºC on the ferrite content in austenitic welds made with T 23 12 LRM3 tubular electrode, Archives of Metallurgy and Materials 50(3): 757-767.
9. **Węgrzyn, T.** 2002. Mathematical equations of the influence of molybdenum and nitrogen in welds, Conference of International Society of Offshore and Polar Engineers ISOPE´2002, Kita Kyushu, Japan 2002, Copyright by International Society of Offshore and Polar Engineers, vol. IV, ISBN 1-880653-58-3, Cupertino

– California – USA 2002.
10. **Węgrzyn, T.** 2011. Proposal of welding methods in terms of the amount of oxygen, Archives of Materials Science and Engineering 47(1): 57-61.
11. **Węgrzyn T.** 1999. The classification of metal weld deposits in terms of the amount of oxygen, Proceedings of the Conference of International Society of Offshore and Polar Engineers ISOPE'99, Brest, France 1999, International Society of Offshore and Polar Engineers, vol. IV, Cupertino – California, USA, 212-216.
12. **Lukaszkowicz, K.; Kriz, A.; Sondor, J.** 2011. Structure and adhesion of thin coatings deposited by PVD technology on the X6CrNiMoTi17-12-2 and X40 CrMoV5-1 steel substrates, Archives of Materials Science and Engineering 51: 40-47.
13. **Węgrzyn, T.; Piwnik; J.; Hadryś, D.** 2013. Oxygen in steel WMD after welding with micro-jet cooling, Archives of Metallurgy and Materials, 58(4): 1067-1070. http://dx.doi.org/10.2478/amm-2013-0127.
14. **Sozańska, M.; Maciejny, A.; Dagbert, C.; Galland, J.; Hyspecka, L.** 1999. Use of quantitive metallography in the evaluation of hydrogen action during martensitic transformations, Materials Science and Engineering A 237-275: 485-490.
15. **Wegrzyn, T.; Piwnik, J.; Łazarz, B.; Plata, M.** 2012. Micro-jet cooling gases for low alloy steel welding, Archives of Materials Science and Engineering 58(1): 40-44.
16. **Węgrzyn, T.; Piwnik, J.; Łazarz, B.; Hadys, D.; Wieszala, R.** 2012. Parameters of welding with micro-jet cooling, Archives of Materials Science and Engineering 54(2): 86-92.
17. **Konieczny, Ł.; Burdzik, R.; Figlus, T.** 2013. The possibility to control and adjust the suspensions of vehicles, J. Mikulski (Ed.): Activities of Transport Telematics, CCIS 395: 378-383.
18. **Węgrzyn, T.; Piwnik, J.; Łazarz, B.; Sieteski, D.** 2013. Innovative surface welding with micro-jet cooling, Archives of Materials Science and Engineering 61(1): 38-44.
19. **Piwnik, J.; Hadryś, D.; Skorulski, G.** 2013. Plastic Properties of weld after micro-jet cooling, Archives of Materials Science and Engineering 59(1): 20-25.
20. **Schits, P**. 2013. Master's Degree Teses, Technical University of Silesie, Katowice.
21. **Szczucka-Lasota, B.; Formanek, B.; Hernas, A.** 2005. Growth of corrosion products on thermally sprayed coatings with FeAl intermetallic phases in aggressive environments, Journal of Materials Processing Technology 164-165: 930-934. http://dx.doi.org/10.1016/j.jmatprotec.2005.02.244.
22. **Burdzik, R.; Konieczny, Ł.; Stanik, Z.; Folęga, P.; Smalcerz, A.; Lisiecki, A.** 2014. Analysis of impact of chosen parameters on the wear of camshaft, Archives of Metallurgy and Materials 59(3): 957-963. http://dx.doi.org/10.2478/amm-2014-0161.
23. **Formanek, B.; Szymański, K.; Szczucka-Lasota, B.** 2005. New generation of protective coatings intended for the power industry, Journal of Materials Processing Technology 164-165: 850-855. http://dx.doi.org/10.1016/j.jmatprotec.2005.02.098.
24. **Burdzik, R.** 2013. Research on the influence of engine rotational speed to the vibration penetration into the driver via feet-multidimensional analysis, Journal of Vibroengineering 15(4): 2114-2123.
25. **Burdzik, R.** 2014. Identification of structure and directional distribution of vibration transferred to car-body from road roughness, submitted to Journal of Vibroengineering 16(1): 324-333.
26. **Folęga, P.; Siwiec, G.** 2014. Numerical analysis of selected materials for flexsplines, Archives of Metallurgy and Materials 57(1): 185-191.
27. **Lisiecki, A.** 2014. Mechanism of Laser Surface Modification of the Ti-6Al-4V Alloy in nitrogen atmosphere using a High Power Diode Laser, Advanced Materials Research 1036: 411-416. http://dx.doi.org/10.4028/www.scientific.net/AMR. 1036. 411.
28. **Tarasiuk, W.; Szczucka-Lasota, B.; Piwnik, J.; Majewski, W.** 2014. Tribological properties of super field weld with micro-jet process, Advanced Materials Research 1036: 452-457. http://dx.doi.org/10.4028/www.scientific.net/ AMR.1036. 452.
29. **Szczucka-Lasota, B.; Majewski, W.** 2014. Oxidation Resistance of Coating Obtained by Innovative Methods for Energy Boilers, Advanced Materials Research 1036: 152-157. http://dx.doi.org/10.4028/www.scientific.net/ AMR.1036. 152.

T. Wegrzyn, J. Piwnik, B. Lazarz, W. Tarasiuk

MECHANICAL PROPERTIES OF SHAFT SURFACING WITH MICRO-JET COOLING

S u m m a r y

An article presents information about innovate welding technology (surfacing) with micro-jet cooling. There are given main information about parameters of shaft surfacing with micro-jet cooling process. There were also put down information about influence of various micro-jet gases on metallographic structure of machine shaft after surfacing. There were tested tribological properties of welds. The tribological interactions of a solid shaft surfaces were tested after welding with micro-jet cooling.

Keywords: welding surfacing, micro-jet cooling, metallographic structure, wearing.

Received January 20, 2015
Accepted April 21, 2015