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SHAFT WEAR AFTER SURFACING WITH MICRO-JET COOLING

ZUŻYCIE ŚCIERNE WAŁÓW PO NAPAWANIU Z CHŁODZENIEM MIKRO-STRUGOWYM

A paper presents a piece of information about innovate surfacing technology with micro-jet cooling. There are put down information about parameters of shaft surfacing with micro-jet cooling process. There were given information about influence of various micro-jet gases on metallographic structure of machine shaft after surfacing. There were analyzed tribological properties of welds. 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. Surfacing is also known as wearfacing, is often used to build up shafts, gears or cutting edges. Regenerated surface properties of various machine elements do not provide good tribological properties. 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

W artykule przedstawiono informację na temat innowacyjnej technologii nawania z chłodzeniem mikro-strugowym. Przedstawiono informacje na temat parametrów napawania wału maszynowego z chłodzeniem mikro-strugowym. Podano informację na temat doboru różnych gazów stosowanych w chłodzeniu mikro-strugowym i ich wpływ na strukturę metalograficzną napawanego wału. Analizowano właściwości tribologicznych spoin. Powierzchniowy proces spawania jest bardzo często używany do podniesienia twardości i odporności na zużycie warstwy metali. Jest to także bardzo ważna metoda pozwalająca na przedłużenie czasu eksploatacji elementów maszyn i elementów konstrukcji. Napawanie powierzchniowe jest również stosowane w wytwarzaniu wałów, przekładni, krawędzi tnących, itp. Regenerowane powierzchnie różnych elementów maszyn nie zawsze posiadają dobre właściwości tribologiczne. W artykule analizowano wpływ chłodzenia mikro-strugowego na poprawę własności tribologicznych napawanych wałów maszynowych.

1. Introduction

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. The further reason of preparing that article was investigate possibilities of getting varied amount of martensite in surface weld of machine shafts after 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, diameter of stream of the micro-jet injector, type of micro-jet gases, micro-jet gas pressure. Micro-jet technology was mainly 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 0.01%), S (below 0.01%), in WMD (weld metal deposit) correspond with good mechanical properties of welds, because of beneficial structure. Also low-oxygen welding processes (approx. 400 ppm in WMD) have strong influence on metallographic structure. Especially high amount of acicular ferrite (AF) in WMD is the structure that guaranties goog impact toughness properties of welds. Having the most optimal chemical composition in weld it is only possible to get maximal 65% 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 weld (on the level of 75%) [18-22]. The micro-jet technology was tested for steel welding with various micro-jet cooling conditions. Still new materials are tested in worldwide laboratories. This goes hand in hand with the possibilities of welding methods of new materials with modern technologies [23-28]. Goal of that paper was to describe possibilities of

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shaft surfacing welding process with micro-jet cooling, that could be treated as a absolutely innovative technology.

2. Experimental procedure

To obtain various amount of martensite in shaft surface weld it was installed welding process with micro-jet injector (only with one steam diameter of 40 μm). 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 figure 1.

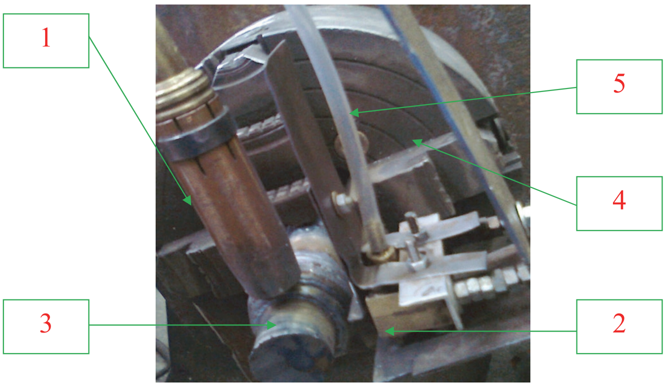

Fig. 1. Position for superficial welding with micro-jet cooling: 1 welding head, 2 micro-jet cooling injector, 3 weld overlay machine shaft, 4 handle, 5 micro-jet gas pipe [21]

Weld metal deposit 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 were also changing another micro-jet parameter: gas pressure (0.4 MPa and 0.5 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 Ar + 1.5% O_2 82% Ar + 18% CO_2
5.	Kind of tested micro-jet cooling gas	1 – Ar 2 – He 3 – N_2
6.	Micro-jet gas pressure	0.4 MPa, 0.5 MPa

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

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

3. Results and discusion

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 tables 3-5.

TABLE 3

Martensite in weld (argon used as a micro-jet gas)

Micro-jet gas pressure	**Number of jets**	**Martensite aprox, %**	**nitrides**
0.4 MPa	0	50	-
0.4 MPa	1	60	-
0.5 MPa	0	60	-
0.5 MPa	1	70	-

TABLE 4

Martensite in weld (helium used as a micro-jet gas)

Micro-jet gas presure	**Number ofjets**	**Martensite aprox, %**	**nitrides**
0.4 MPa	0	50	-
0.4 MPa	1	70	-
0.5 MPa	0	60	-
0.5 MPa	1	80	-

TABLE 5

Martensite in weld (nitrogen used as a micro-jet gas)

Micro-jet gas presure	**Number of jets**	**Martensite aprox, %**	**nitrides**
0.4 MPa	0	50	-
0.4 MPa	1	60	traces
0.5 MPa	0	60	-
0.5 MPa	1	70	traces

Heat transfer coefficient of tested micro-jet gases influences on cooling conditions of welds (tables 3-5). 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 (fig 3).

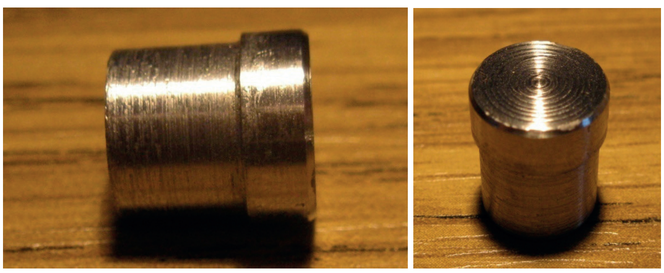

Fig. 3. A view of the test sample for microscope observation and for the Amsler test [21]

In all cases martensite was the main phase that only was varied in terms of various micro-jet gases; it is shown in figures 4-7.

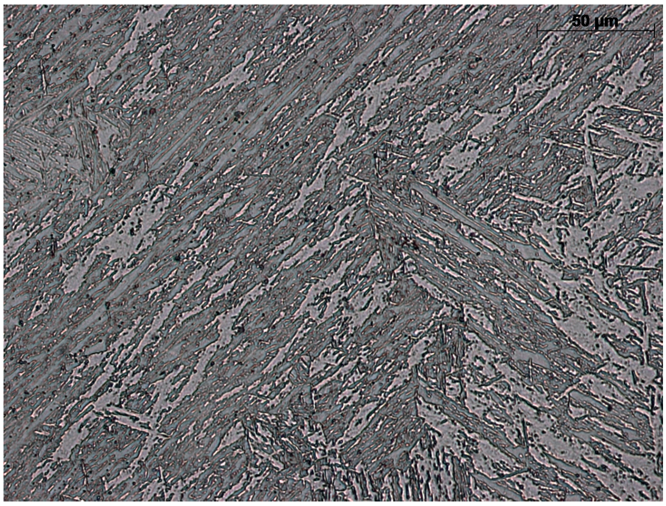

Fig. 4. Martensite (aprox. 50%) in weld after welding without micro-jet cooling, 500x

Fig. 5. Martensite (aprox. 70%) in weld after welding with micro-jet cooling (argon as micro-jet gas), magn. 500x

Fig. 6. Martensite (aprox. 70%) in weld after welding with micro-jet cooling (nitrogen as micro-jet gas), magn. 500x

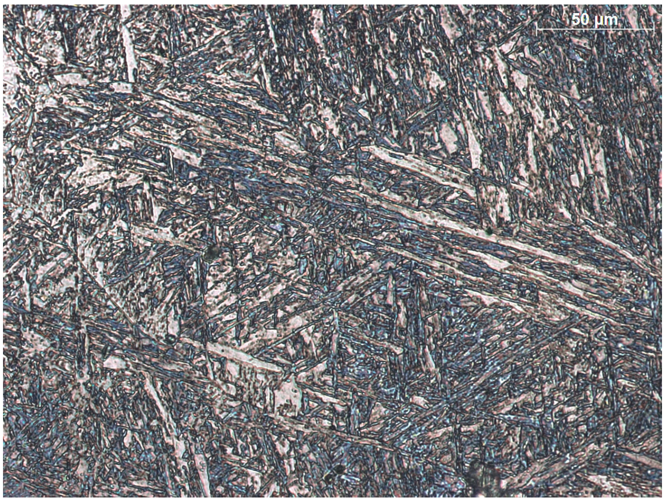

Fig. 7. Martensite (aprox. 80%) in weld after welding with micro-jet cooling (helium as micro-jet gas), magn. 500x

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 [16]. Martensite amount was only estimated. Nevertheless it is possible to present, that micro-jet technology is absolutely capable of structure steering (tables 3, 4, 5). Martensite amount is similar when nitrogen and argon are taken as micro-jet gases (fig. 5, 6). Martensite amount is the highest when helium is taken as micro-jet gas (fig. 7). After microscope observation a micro hardness was carried out (fig. 8-11). Standard surface welding could not guaranty high hardness (fig. 8).

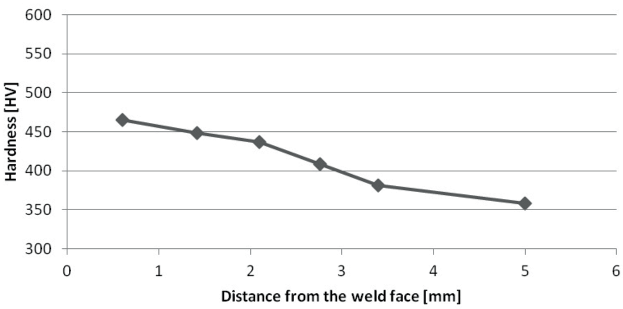

Fig. 8. Hardness of standard weld without micro-jet cooling

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. 7).

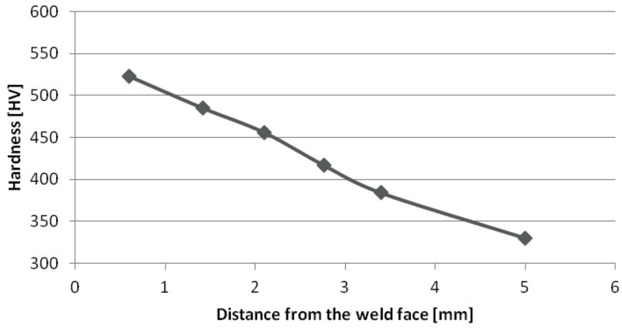

Fig. 9. Hardness of weld after micro-jet cooling, argon used as micro-jet gas

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. 8).

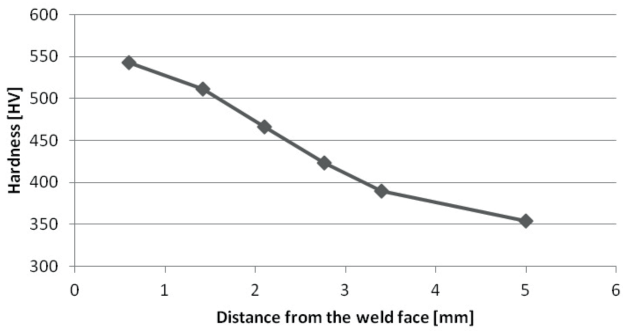

Fig. 10. Hardness of weld after with micro-jet cooling, nitrogen used as micro-jet gas

Surface shaft welding with micro-jet cooling (by helium) allowed to excide hardness under 550 HV, (fig. 9).

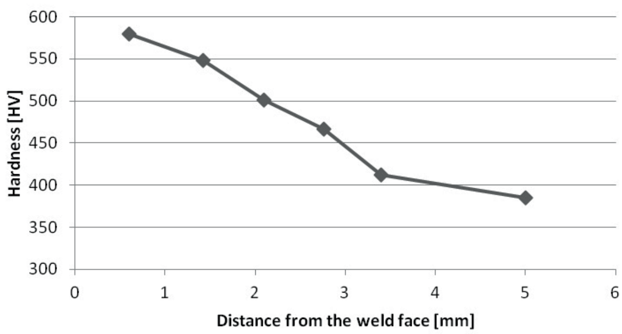

Fig. 11. Hardness of weld after micro-jet cooling, helium used as a micro-jet gas

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.

TABLE 6

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	45 HRC	50 HRC	52 HRC	52 HRC
Force critical	300 N	300 N	300 N	300 N
Critical unit pressure	9,74 N/mm2	9,74 N/mm2	9,74 N/mm2	9,74 N/mm2
Blurring time	10 s	20 s	25 s	25 s
Coefficient of friction	0,548	0,529	0,397	0,380
Weight loss [g]	0,0160 g	0,0013 g	0,0009 g	0,0006 g

Finally tribological tests were done using Amsler machine. Results of Amsler tests are shows on figures 12-13.

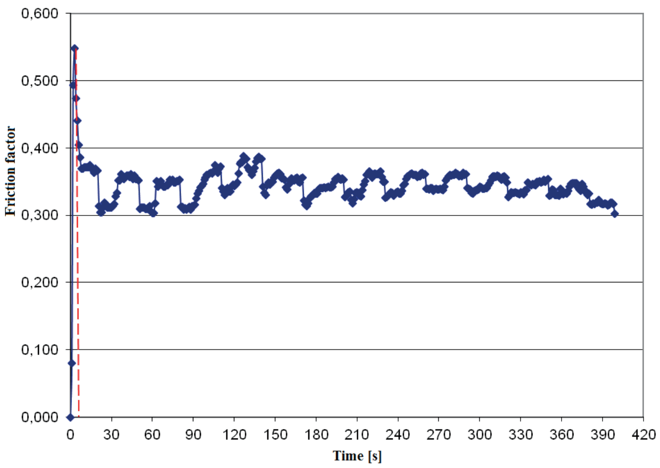

Fig. 12. A plot of the coefficient of friction between the time at which the strength was increased for sample made from deposit without micro-jet cooling [22]

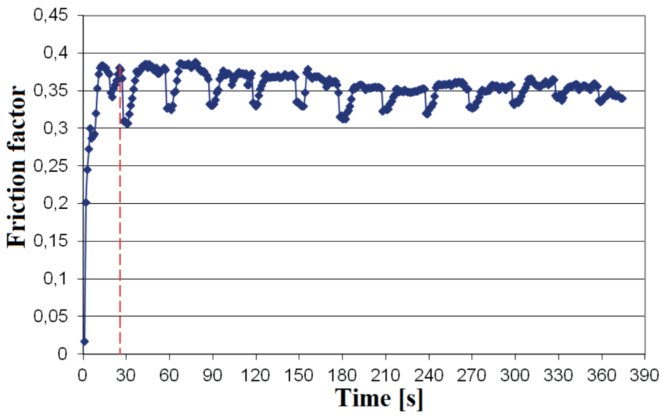

Fig. 13. A plot of the coefficient of friction between the time at which the strength was increased for sample made from deposit with micro-jet cooling [22]

The tribological tests show that micro-jets cooling affects the properties of the welds. Table 49 summarizes the results of tribological tests (table 6).

Based on the results stated in table 6, it was found that the highest resistance to abrasive wear has the sample taken after welding with micro-jet cooling. Favorable micro-jet gases are nitrogen or helium.

4. Conclusions

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.

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

- micro-jet-cooling could be treated as a 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.

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