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Wear Resistance of Steel 20MnCr5 After Surfacing with Micro-jet Cooling

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Abstract

This paper presents results of experimental research concerning the impact of an innovative method of micro-jet cooling on the padding weld performed with MIG welding. Micro-jet cooling is a novel method patented in 2011. It enables to steer the parameters of weld cooling in a precise manner. In addition, various elements which may e.g. enhance hardness or alter tribological properties can be entered into its top surface, depending on the applied cooling gas. The material under study was steel 20MnCr5, which was subject to the welding process with micro-jet cooling and without cooling. Nitrogen was used as a cooling gas. The main parameter of weld assessment was wear intensity. The tests were conducted in a tribological pin-on-disc type position. The following results exhibit growth at approximately 5% in wear resistance of padding welds with micro-jet cooling.

Keywords: Tribological properties, Welding, Micro-jet, Steel 20MnCr5

1. Introduction

Modern industry requires materials of strictly defined properties which are adjusted to work and load conditions. Frequently, the elements of machines are exposed to intensive frictional or erosive processes. Such examples involve: transport of loose materials, production of silicate goods, densification of loose materials, e.g. briquette production [2, 3]. The used materials must have high wear resistance adjusted to the existing loads [8].

The working elements of machines operating in hard conditions are subject to intensified wear not on their full surface, but merely in specific characteristic places. These are mostly places where the biggest pressure occurs or materials causing accelerated wear get into contact (e.g. sand grains of sharp edges) [4, 5].

Local defects in the elements of machines can be supplemented by applying e.g. the welding process. In order to improve the tribological properties of welded surfaces, this process is combined with micro-jet cooling. It causes changes in the microstructure of the top surface. With regard to the applied cooling gas, broken martensite can be obtained [1, 7].

Other methods enabling to regenerate worn surfaces involve e.g. laser alloying, the application of ceramic coating etc. [6, 8].

2. Experimental procedure

The research incorporated steel 20MnCr5 intended for carburizing and heat improvement. It is characterised by very good mechanical properties and hardness after a proper thermo-chemical heat treatment, exceeding 60 HRC [9]. It is applied on parts of machines prone to changeable loads and intensive wear. It is used in, among others, matrix sheeting for producing silicate goods (Fig. 1) [4].

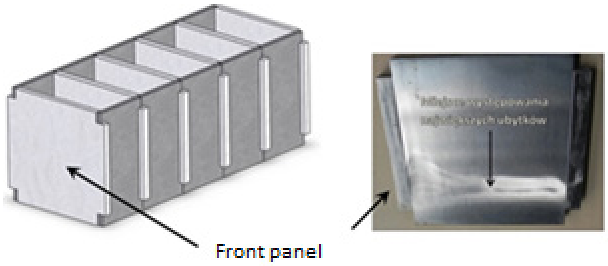

Fig. 1. Matrix for producing a silicate brick; worn front panel

In order to preserve conditions approximate to those existing in the real process of regeneration, the panel, from which the samples were extracted, underwent carburization, hardening and tempering. Table 1 presents the parameters of the process.

Table 1.
Parameters of the thermo-chemical heat treatment of 20MnCr5 steel

Type of treatment	carburization	hardening	tempering
Temperature [°C]	910°C	820°C	240°C

Upon the thermo-chemical heat treatment, the frontal area of the sample was welded with the MIG method without cooling and with micro-jet cooling. The gas used in the cooling process was nitrogen. Table 2 presents the parameters of the process.

Table 2.
Parameters of the welding process

No	Parameter	Value
1.	Diameter of wire	1 mm
2.	Standard current	200 A
3.	Micro-jet cooling gas	N_2
4.	Micro-jet gas pressure	0.4 MPa
5.	Micro-jet diameter	40μm

Upon welding, the surface underwent grinding in order to remove roughness. The removed layer while grinding equalled up to 0.2 mm (Fig. 2). In order to indicate wear intensity of the welded plate, samples in the shape of a square at the size of 4x4 mm were extracted (by electro-hollowing).

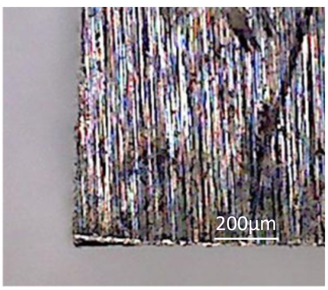

Fig. 2. Surface of the sample upon grinding

The resultant samples were studied via the T-11 pin-on-disc tester (Fig. 3).

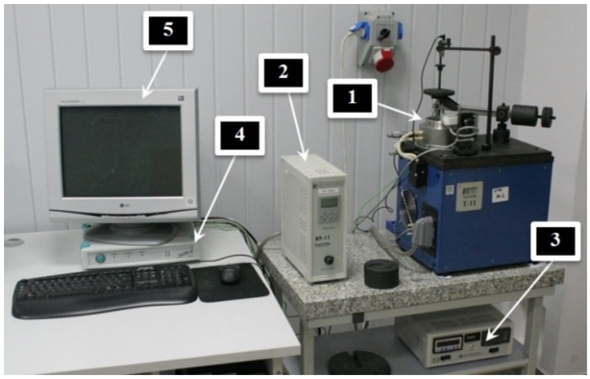

Fig. 3. Scheme of the T-11 position for the tribological pin-on-disc-type test:1 - sensors and transducers, 2 - controller BT-11, 3 - controller BT-03, 4 - digital amplifier 8 Spider, 5 - a set of computers

It allows for indicating basic wear parameters (wear force, wear coefficient, wear intensity). The counter-sample constituted a silicate disc (Fig. 4b). It was made of a densified calcareous and sand mixture of 0 ÷ 0.6 mm granularity. The application of this type of frictional vapour imitates conditions of intensive dry friction which occurs, among others, in dry material carriers (e.g. aggregate, corn grains) and the densifying process of dry materials (e.g. production of silicate bricks, pavement blocks). The unit pressure of the sample vs. the counter-sample was identical in every test and equalled $p = 0.75\ MPa$. The duration time of the test was 20 min. It was not used lubrication. The test was performed at 20 degrees Celsius.

The assigned parameters during the test were:

✓ wear intensity

$$I = \frac{M_1 - M_2}{SF} \left[\frac{mg}{m^3}\right], \quad (1)$$

where: M_1 and M_2 – mass of the sample before and after the friction test [mg],
S – path of friction [m],
F – cross-sectional area of the sample [m^2].

$$S = \pi \cdot R_T \cdot t \cdot n[m] \quad (2)$$

where: R_T – radius of friction [m], t – test time [min], n – silicate sample rotation speed.

✓ friction coefficient

$$\mu = \frac{T}{P},$$

where: T – friction force, P – load.

✓ friction force.

The force value was registered by means of a sensor placed in the tester.

Fig. 4 presents the sample and the counter-sample.

a) b)

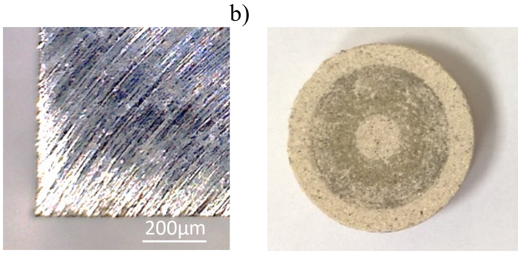

Fig. 4. View of: a) the sample, b) the counter-sample

Due to the shape of the sample, a special head was used for mounting the sample (Fig. 5).

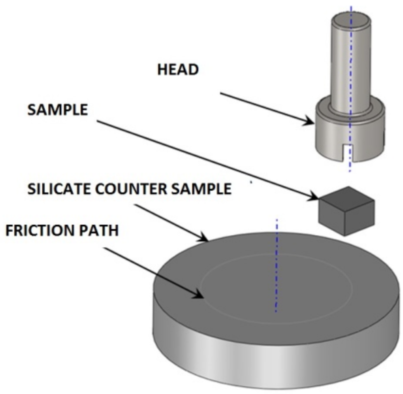

Fig. 5. Diagram of the steel and silicate counter-sample

In order to compare the impact of micro-jet cooling on the intensity of friction wear, the test also involved samples after the thermo-chemical heat treatment and welding without micro-jet cooling.

3. Results and Discussion

The obtained results constitute an average out of 5 tests conducted on 5 samples that were put to the same welding procedure and the same thermo-chemical heat treatment. These results are included in table 3.

Table 3.
Compilation of results obtained in the research at the T-11 position

Research material	I_{av} [mg/m^3]	μ_{av}	T_{av} [N]
steel after micro-jet welding processes	164.3	0.49	6.43
steel after welding processes	173.9	0.46	6.01

The difference in wear intensity equals ca. 5% to the benefit of welding with micro-jet cooling. The obtained mean values together with a standard deviation were shown in fig. 6.

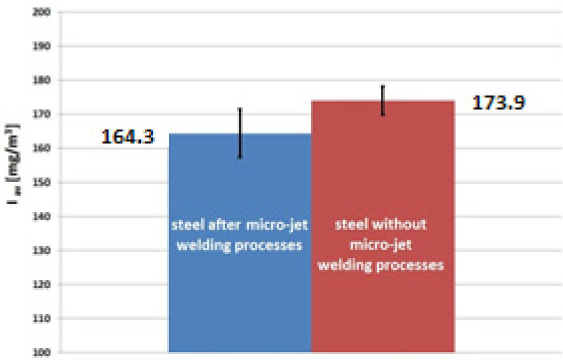

Fig. 6. Compilation of results for steel after padding with micro-jet cooling and without cooling

4. Conclusion

The application of nitrogen in micro-jet cooling of the padding weld in the welding process of steel 20MnCr5 beneficially affects resistance to friction wear. Compared to the weld made without micro-jet cooling, this difference makes ca. 5%.

By using welding as a method of regenerating elements of machines, it is worth applying micro-jet cooling.

In the future, the problem will be examined in more detail.

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