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Define the Type of Tribological Wear of High Speed Steel Remelted with the Electric Arc with the Usage of the Confocal Microscope

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Abstract

The paper presents the possibility of the usage of the concfocal microscope for define the type of tribological wear present during the technical dry friction on the testing machine of the pin-on-disc T-01M. The pin was a remelted high-speed steel and the disc was made from sintered carbides. The surface layer of the high-speed steel was remelted with the electric arc with different parameters. The intensity of the electric arc current was changed, the scanning speed and the single, overlapping remeltings were used.

On the basis of the 3D, 2D view of the surface friction of the pin (made from the remelted high-speed steel), disc (made from the sintered carbides) and the surface roughness profile run along the marked line, the presence of the abrasive wear can be defined with the description of the elementary wear processes due to the abrasive and/or adhesive wear.

Keywords: Heat Treatment – Mechanical Features – Metallography, Confocal Microscope, High Speed Steel, Remelting, Electric Arc, Tribological Wear

1. Introduction

One of the method that leads to obtain the significant refinement the high-speed steel structure is remelting its surface layer with the laser or electric arc. Getting smaller crystals within the remelting zone usually leads to the increase of that steel hardness. However not always, the increase of the hardness is equivalent with the increase of the tool life made from that steel. Apart from the high hardness, the steel should have the high impact strength. In order to do that, after remelting of the steel, the conventional treatment is used – often consisting in high tempering. The steel structure before remelting is also important. Still the proper compilation of parameters of the heat treatment mentioned above can lead to the increase of the tool life. Most often the correctness of the heat treatment performed can be verified with the use of exploitation tests, for example tribological tests. As result of these tests we can calculate the intensity of tribological wear of the steel and what is more important define the types of the tribological wear during the friction and in the end define the influence of heat treatment parameters on their occurrence and participation.

2. Material and test methodology

The material for the tests was the high-speed steel HS 6-5-2 in the annealed condition. The surface layer of the steel was remelted with the electric arc with the usage of FALTIG

315AC/DC device used for welding with the GTAW method. The parameters of the device work are selected in order for the remelting of the surface layer of the steel could be present.

The single and overlapping remeltings were used (40% covering). The remelting process was done in the Department of Foundry and Welding of Rzeszow University of Technology. The tribological research within the technical dry friction conditions was done on a test machine of the type pin-on-disc T-01M. The following parameters of the friction process were used: anti-sample (disc) made from the sintered carbides of the hardness about 1500 HV, friction unit load – 49 N, path of friction 2000 m (7000 seconds). The metallographic tests LM were made on the confocal microscope µsurf explorer NanoFocus AG.

3. Results

Samples from the high-speed steel HS 6-5-2 size 10x10x25 mm were remelted from the head with the electric arc. Then from such remelted cuboids, the samples size 4x4x25mm were cut for the tribological tests (Fig. 1) within the conditions of technical dry friction, on a test machine of the type pin-on-disc T-01M (Fig. 2, 3).

a) b)

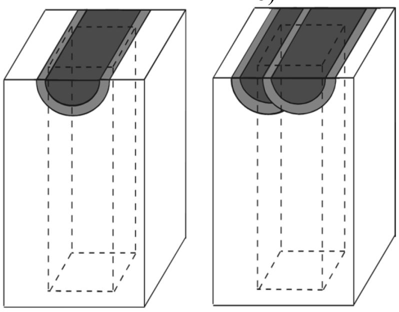


Fig. 1. The way of sample cutting for the tribological test, a) samples with single remelting, b) samples with overlapping remeltings

After the process of friction is finished, the friction surface of the pin and disc were observed on a confocal microscope µsurf explorer NanoFocus AG using the magnification of 50x, receiving the observation field 320x320 µm. There was a resolution within the axis: Z: 4 nm, XY: 0.7 µm received for such a field.

The occurrence of the abrasive wear depends on the type of the structure and properties of the materials cooperating with one another. In most cases, the resistance to the abrasive wear increases together with the increase of the material hardness, the cooperating elements are made of. There is a 3D view of the friction surface of the pin made from the remelted high-speed steel HS 6-5-2 presented in the Fig. 4, and the friction surface of the disc made from the sintered carbides, after the process of the technical dry friction on a test machine T-01M. There is a abrasive wear visible, causing the material loss in the surface layer by separation of the particles due to the micro-machining cutting, scratching or grooving.

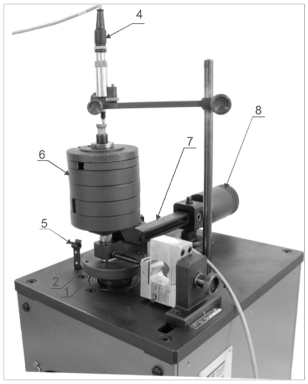


Fig. 2. Tribological test machine of the type pin-on-disc T-01M; 1- pin, 2 – turning attachment with the disc, 3 – strain gauge for measuring the friction force, 4 – inductive sensor for measuring the linear wear of the pin, 5 – temperature sensor handle, 6 – weights of the friction joint, 7 – lever, 8 – counterweight

a) b)

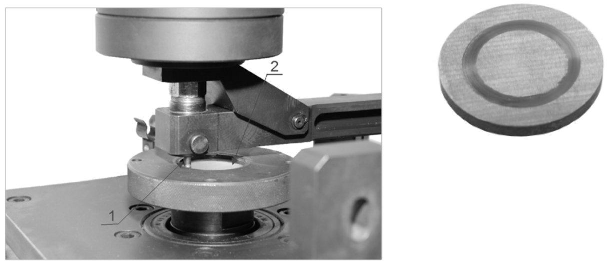
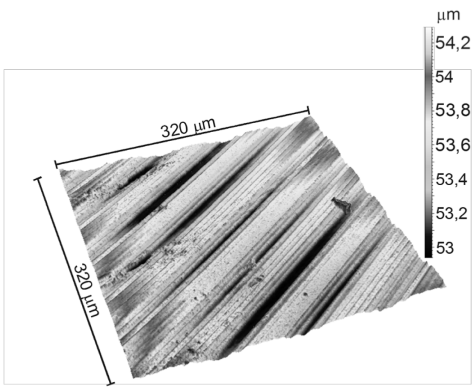


Fig. 3. a) the friction joint of the tribological test machine T-01M, b) the disc view after the tribological test; 1 - pin, 2 - disc

The most common tribological wear, present during the technical dry friction, on a test machine of the type pin-on-disc T-01M of the remelted high-speed steel from the sintered carbides is the abrasive and adhesive wear.

a)



b)

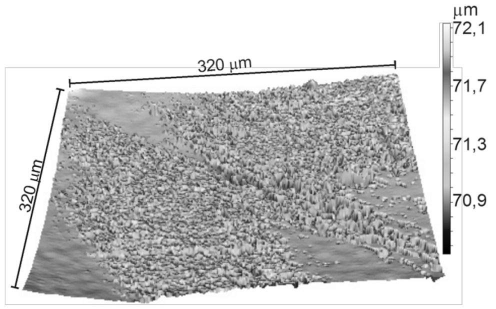
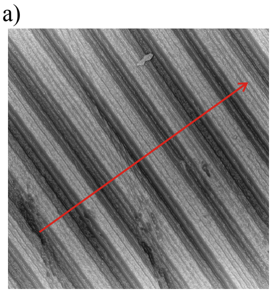


Fig. 4. 3D view, received from the confocal microscope: a) of the friction surface of the pin made from the remelted high-speed steel HS 6-5-2, b) of the friction surface made from the sintered carbides, after the process of technical dry friction on a test machine T-01M. The visible abrasive wear causing the material loss in the surface layer, by separation of the particles due to the micro-machining cutting, scratching or grooving

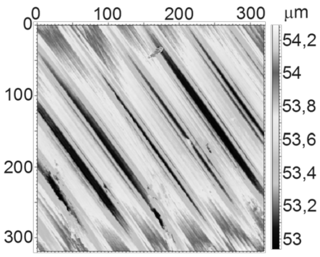
The geometrical parameters of the surface deciding about the intensity of the tribological wear have a huge meaning.

The Fig. 5 presents the view of the friction surface of the pin made from the remelted high-speed steel HS 6-5-2 with the marked profile measurement line and the surface roughness profile led along the marked line and appropriately on the Fig. 7 for the discs from the sintered carbides after the technical dry friction on a test machine T-01M.

a)



b)



c)

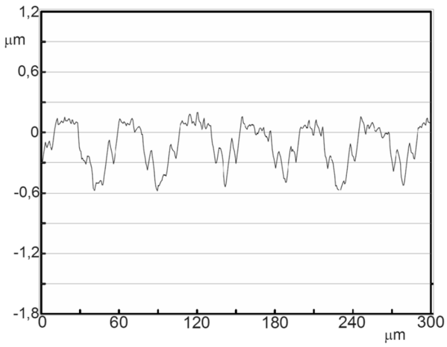


Fig. 5. Views received from the confocal microscope, of the friction surface of the pin made from the remelted high-speed steel HS 6-5-2 after the technical dry friction on a test machine T-01M; a) the view of the friction surface of the steel with the marked profile measurement line, b) 2D view of the steel friction surface, c) surface roughness profile led along the marked line

There is a criterion, which is the quotient of the surface cross-section of the crack hollow S_3 and material upsetting around the crack S_1+S_2 (Fig. 6) used for the elementary wear processes[1] due to the abrasion.

Machining is present in the case where the quotient

$$\frac{S_1+S_2}{S_3}=0 \tag{1}$$

that is the surface of the material upsetting $S_1+S_2=0$.
In case, where:

$$\frac{S_1+S_2}{S_3}=1 \tag{2}$$

then there is only plastic deformation that is grooving .
Because, in the presented in the Fig. 6 case, the quotient of the surface field

$$\frac{S_1+S_2}{S_3}=0{,}35 \tag{3}$$

so in that case of the abrasive wear we are dealing with the micromachining – there is a plastic deformation and scratching of the surface.

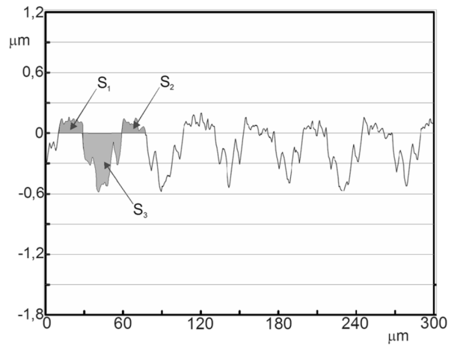
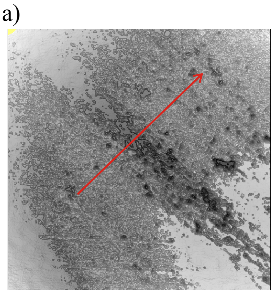
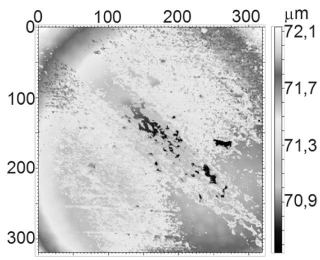


Fig. 6. The surface roughness profile of the pin made from the remelted high-speed steel HS 6-5-2 after the process of technical dry friction on a test machine T-01M with the cross-section surfaces marked, the crack hollows S_3 and material upsetting around the crack S_1+S_2

a)



b)



[1] Elementary wear processes - the processes of the destructive changes of the surface caused the friction in the micro-areas of the surface of solid state

c)

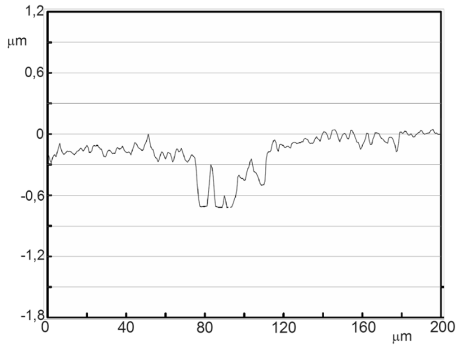
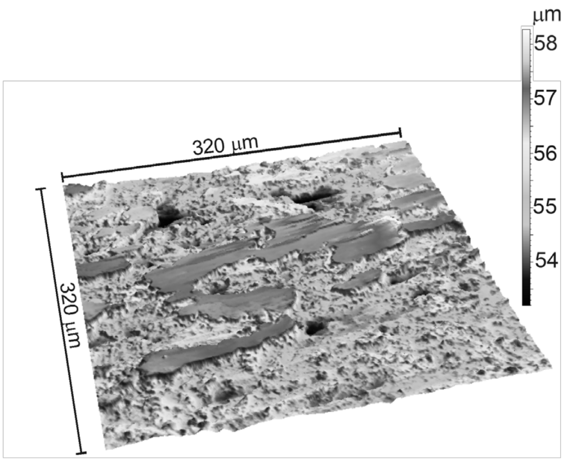


Fig. 7. Views received from the confocal microscope, friction surface of the disc made from the sintered carbides after the process of technical dry friction on a test machine T-01M; a) the view of the friction surface of the disc with the marked profile measurement line, b) 2D view of the friction surface of the disc, c) the surface roughness profile led along the marked line

The adhesive wear is present during the sliding friction with small friction speed and huge individual pressure. It consists on creating of the local graftings of the friction surface and their destruction together with the metal (alloy) particles separation or its smearing on the friction surface. There is 3D view presented in the Fig. 8a, received from the confocal microscope, friction surface of the pin made from the remelted high speed steel HS 6-5-2 and the Fig. 8b of the friction surface of the disc from the sintered carbides after the process of technical dry friction on a test machine T-01M. There is a typical adhesive wear visible.

a)



b)

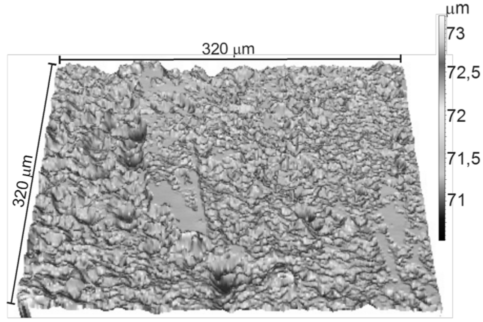
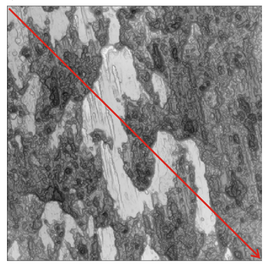


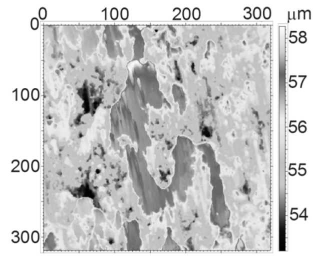
Fig. 8. 3D view, received from the confocal microscope; a) friction surface of the pin made from the remelted high-speed steel HS 6-5-2, b) friction surface of the disc made from the sintered carbides, after the process of technical dry friction on a test machine T-01M. The visible adhesive wear characterized by creation of the local metal graftings of the friction surfaces and damage of these connections with the metal particles separation or its smearing on the friction surface

The adhesive wear of the machine items is done with the following sliding speeds to 0.2 m/s and nominal pressure to 11 MPa. Cutting the adhesive graftings causes the existence, on the reinforced material border, the crater on the surface and the material carrying on the second surface creating the growths that can have irregular shapes and sharp edges. Fig. 9 presents the view of the friction surface with the adhesive graftings with the marked line of the profile measurement and the surface roughness profile led along the marked line for the pin made from the remelted high-speed steel HS 6-5-2 and the Fig. 10 for the discs made from the sintered carbides after the process of the technical dry friction on a test machine T-01M.

a)



b)



c)

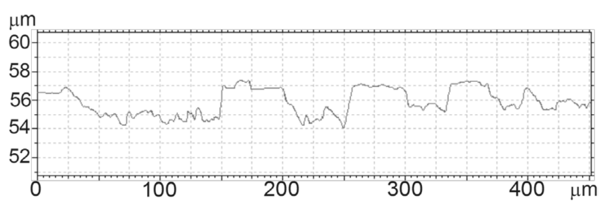
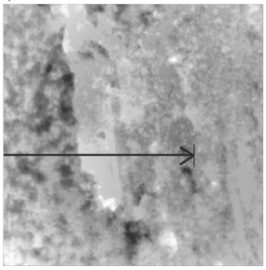
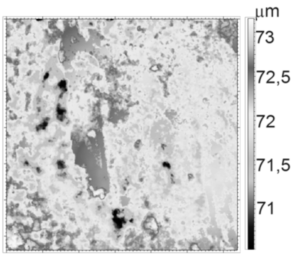


Fig. 9. Views received from the confocal microscope, friction surface of the pin made from the remelted high-speed steel HS 6-5-2 after the technical dry friction on a test machine T-01M; a) view of the friction surface of the steel with the with the marked profile measurement line, b) 2D view of the steel friction surface, c) the surface roughness profile led along the marked line

a)



b)



c)

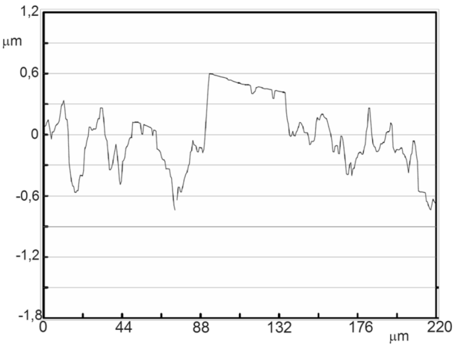


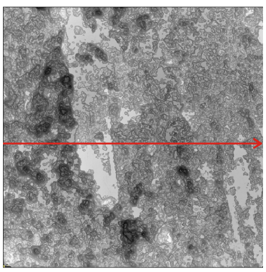
Fig. 10. Views received from the confocal microscope, of the friction surface of the disc made from the sintered carbides after the process of technical dry friction on a test machine T-01M; a)the friction surface view of the disc with the marked line along the profile measurement line, b) 2D view of the friction surface of the disc, c) surface roughness profile led along the marked line

For the tested samples there are geometrical parameters of the surface, calculated from the roughness profile (R), defined, which decide about the intensity of the tribological wear (by PN-EN ISO 4287):

Rp – maximum profile peak height
Rv –maximum profile valley depth
Rz – average maximum height of the profile
Rc –mean height of profile irregularities
Rt –maximum height of the profile
Ra –roughness average
Rq –root mean square (RMS) roughness
Rsk – skewness
Rku – kurtosis.

Table 1 presents the parameters of the amplitude of the roughness profile set along the marked line (Fig. 11) for the friction surface of the disc made from the sintered carbides after the process of technical dry friction on a test machine T-01M.

a)



b)

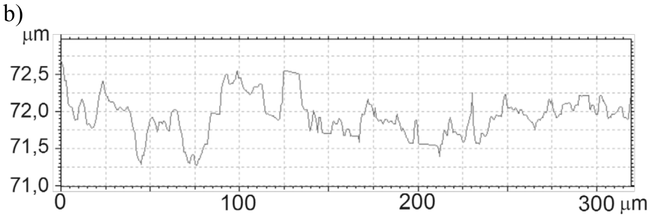


Fig. 11. The friction surface of the disc made from the sintered carbides after the process of technical dry friction on a test machine T-01M; a) view of the friction surface with the marked profile measurement line, b) surface roughness profile led along the marked line

Table 1.
Parameters of the profile amplitude along the marked line of the friction surface of the disc made from the sintered carbides after the process of technical dry friction on a test machine T-01M

Parameters of amplitude of the roughness profile (PN-EN ISO 4287)		
Rp	0.46	µm
Rv	0.37	
Rz	0.82	
Rc	0.54	
Rt	1.02	
Ra	0.16	
Rq	0.12	
Rsk	0.33	-
Rku	2.85	-

4. Conclusions

Using the confocal microscope in testing the samples, after tribological tests in the conditions of technical dry friction we can receive the 3D, 2D views of the friction surface together with the surface roughness profile led along the marked line, that helps to define the abrasion wear presence with defining the elementary wear processes due to the abrasion and/or adhesive usage.

It appears from all tests and research done by the author of that work, that remeltings overlapping causes the increase of the tribological wear intensity comparing to single remeltings. It is connected with the heat influence of the overlapping paths one by one [8, 9].

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