THE WEAR RESISTANCE OF DIFFERENT COATINGS USED FOR CAMSHAFT IMPROVEMENTS IN EHD LUBRICATION CONDITIONS

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Abstract: *This paper presents two types of deposited coatings, one by atmospheric plasma spray method made up of Al_2O_3-TiO_2 ceramic powder and a second by electric arc deposition made up of 40Cr130 metal wire, both on an 18MnCr11 alloy steel. Using CETR UMT-2 tribometre, wear tests were performed on the two samples with different coatings. In both tests a mixed lubrication regime was used to lower the friction coefficient between the sliding surfaces and improve the contact wear. The pressure distribution in the lubricating film depends on surface roughness so the lubrication regime is an important factor to lower the wear between the surfaces in contact. The heat generated by the friction is dissipated more efficiently if a lubricant is present between the samples. There are also elastic and plastic contacts between surface asperities so an EHD lubrication is present. Highlighting and interpretation of the wear caused by the tests was made using SEM imagery elementary chemical analyses and profilometry on the samples.*

Keywords: *Al_2O_3-TiO_2, 40Cr130, SEM, tribometer CETR UMT-2*

1. Introduction

The incorrect operation of the camshaft affects not only the normal engine service, but also its economic indices.[1] The elements of the gas distribution mechanism are especially submitted to mechanical wear. The main types of wear characteristic to the camshaft are: abrasive wear, adhesive wear and fatigue wear.[2]

The materials used for the manufacturing of camshafts must ensure, after processing and thermal treatments, a good rigidity and high resistance to wear for the cam and spindle surfaces.[3]

To improve the wear resistance of the surfaces in contact different types of coatings can be deposited on the base material from which the camshaft is made. [4] There are different methods to achieve high quality coatings. In this paper are presented two types of coatings obtained by two different methods: atmospheric plasma spraying and electric arc deposition. [5] The materials usually used for plasma jet deposition are different types of powders as Al alloys and oxides, Si or W carbides, Ni-Cr-Ti alloys which can compose carbides or nitrides, inter metallic compounds, ceramic materials with B or Si oxides or nitrides, borides or carbides. For the electric arc deposition method the usually used materials are metallic alloys in the form of wires.[6]

The electric arc deposition method unlike other methods (D-gun, flame spraying, laser alloying) induces a lower structural change to the base material due to its low deposition process temperature and has a better adhesion to it.[7]

These methods also give the opportunity to apply different thicknesses and surfaces qualities for the obtained coatings according to the work conditions of the part.

2. Materials, methods and instrumentation

For the conducted tests in this paper two samples were used. They had the same 18MnCr11 alloy steel base material but with different coatings.

The coating for the first sample was made by atmospheric plasma jet spraying using the Sulzer Metco SPRAYWIZARD-9MCE installation. The powder used for the top coating is Al_2O_3-TiO_2 and for the bond coating, between the base material and top coating, NiMoAl (90-5-5). The bond coating was deposited by electric arc method.

These materials were chosen due to their good adherence and strength.

The second sample was made by electric arc deposition with the Sulzer Metco Smart Arc 350 installation. The material used was 40Cr130 in wire form. This material was used due to its good resistance to adhesion, abrasive and fatigue wear.

The deposition parameters for the atmospheric plasma jet installation are presented in Table 1. The deposition parameters for the intermediary layer are shown in Table 2.

Table 1: Technical parameters

APS powder used	**Al_2O_3-TiO_2**
Cooling water debit	8.7 bar
Velocity of rotation	55 rot/min
Electrode voltage (U)	60 V
The intensity of the gas plasma (A)	600 A
Composition of plasma	46.1%Ar/13.51%H2
Spraying distance	120 mm

Table 2: Technical parameters

Smart Arc 350	**Ni Mo Al**
U	31 V
I	200 A
Air pressure	60 PSI

In Table 3 are presented the deposition parameters for the sample with the 40Cr130 coating deposited in electric arc.

Table 3: Technical parameters

Smart Arc 350	**40Cr130**
U	28V
I	252A
Air pressure	60PSI

Both samples were mounted one by one on the device shown in Fig. 1. The tests were performed in oil-lubricated conditions, using a SAE 5W-30 Audi Original oil (51.7 mm2/s viscosity at 40°C according to ASTM D-445).

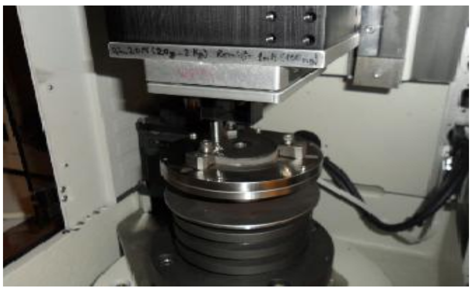


Figure 1: *The way how the sampled is mounted on the CETR UMT-2 tribometre*

To highlight the results analysis were performed using electron microscopy with QUANTA 200 3D DUAL BEAM electron microscope. After each the test cycle, samples were removed and cleaned with special solution in an ultrasonic bath.

3. Experimental results

The tests were performed using the CETR UMT-2 tribometer with pin-disk system. The pin used for the test had a diameter of 6.3 mm. The samples used for the test were discs. At a radius of 10 mm from the centre of the disc a normal pressure force of Fz = 10 N was applied through the pin for a period of 10 minutes. Tests were performed under oil lubricated conditions. The surface roughness was measured after the abrasion test to estimate the wear due to the friction [2].

3.1 The analyses performed on the sample with Al_2O_3-TiO_2 coating subjected to oil lubricated friction

Fig. 2 shows that the width of the impression left on the sample due to friction is between 236 μm - 270 μm, without changes in the superficial layer, as shown in Figures 3.a and b.

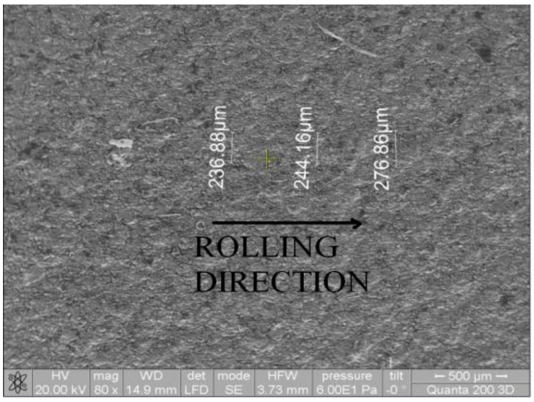
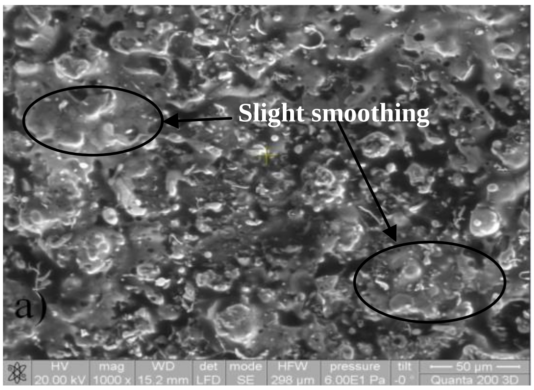


Figure 2: *The appearance and the size of impression left on the sample with lubricant*



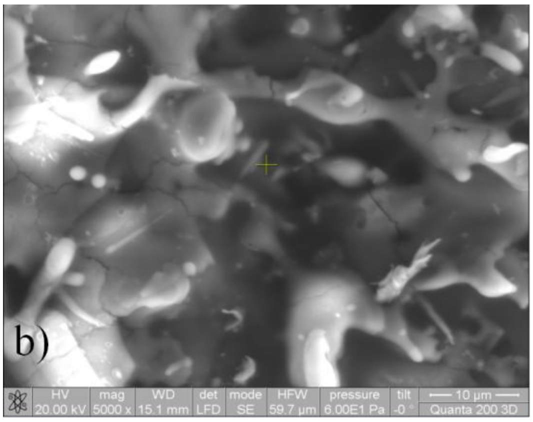


Figure 3: *The appearance of the impression left on the sample: a) 1000x; b) 5000x*

The fact that the deposited layer doesn't show wear is presented in the EDAX chemical analyzes (Fig. 4) where only the presence of Al, O_2 and Ti can be seen for the analyzed area. The distribution map presents a uniform distribution of the elements.

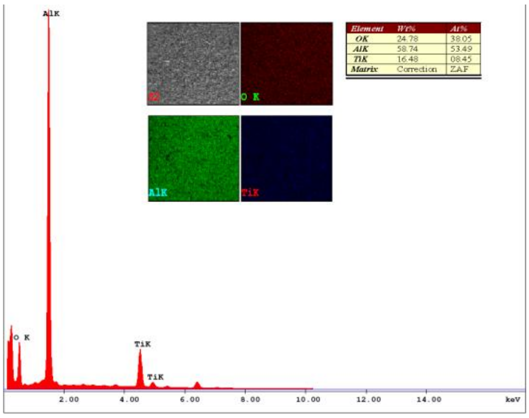
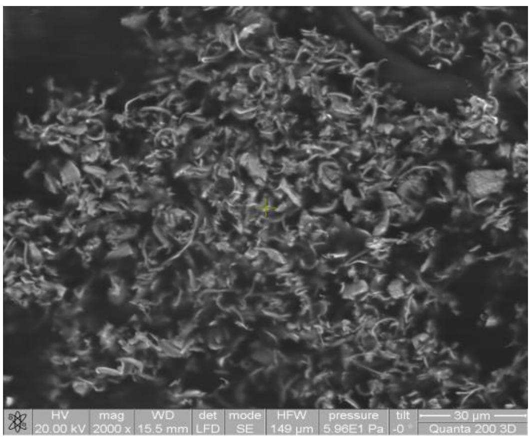


Figure 4: *Map distribution of the elements and EDS analyses of the wear*

Due to the test some powder residue resulted. This residue was collected and its chemical composition was analyzed in Fig. 5.



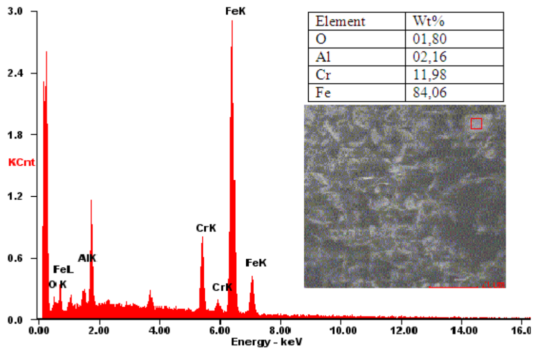


Figure 5: *SEM and EDAX analysis of the residual powder after the friction test*

The nature of the powder belongs to the pin and not from the sample surface. This is confirmed by the EDAX analysis in which only the chemical composition of the pin is observed. From this we can conclude that the coating material is tougher then the material from which the pin is made of.

Fig. 6 shows the evolution of the friction coefficient during the test. The friction coefficient starts with a value of 0,28 and drops to 0,24, value around which remains constant until the end of the test. This happens due to the slight smoothing of the roughness of the surface.

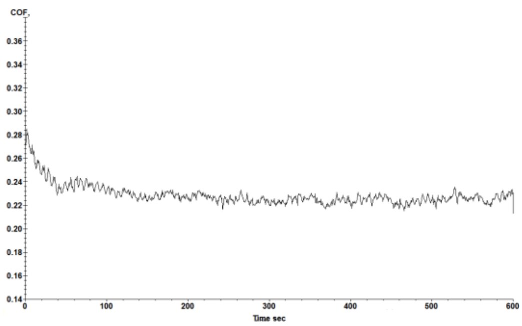


Figure 6: *The variation of the friction coefficient from the pin-disk test in lubricant friction conditions*

Fig. 7 presents the profile of the surface after the wear test. The wear depth on the surface is not very big as can be seen from the profilometry.

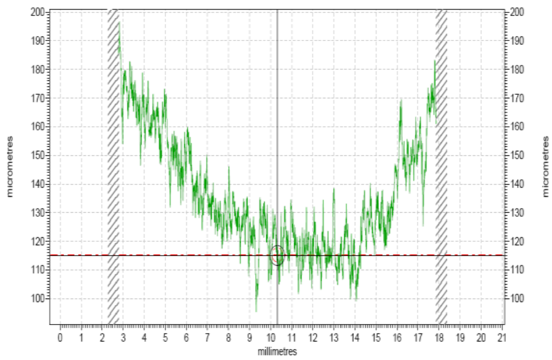


Figure 7: *The form of the channel due to wear in conditions of lubricant friction*

The wear depth is only 60 µm, and is present only in the top layer of the coating sprayed on the disk.

In Fig. 8 is presented the analysis of the surface roughness. The analyses was made with a LS-Line type device. The arithmetic average roughness Ra of the profile is 5.3764 µm, the root mean squared roughness Rq of the profile is 6.8016 µm and the average height roughness Rz is assessed at 37.9427 µm.

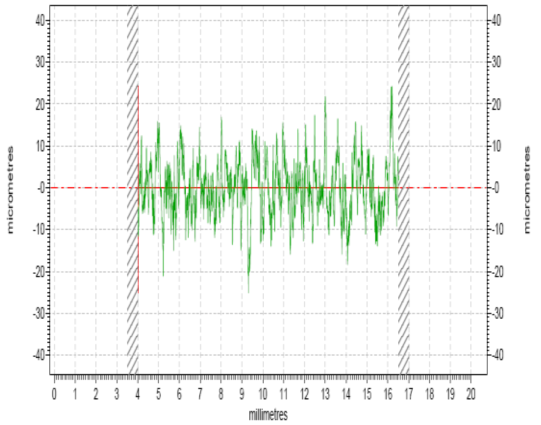


Figure 8: *Roughness values in condition of friction disk with the lubricant*

3.2 The analyses performed on the sample with 40Cr130 coating subjected to oil lubricated friction

The wear track on the second sample is shown in Fig. 9. The width of the wear track is between 336 µm - 374 µm. On the surface of the layer only a smoothing appears which is shown in Fig. 10.a and b. There are no traces of pitting on the layer.

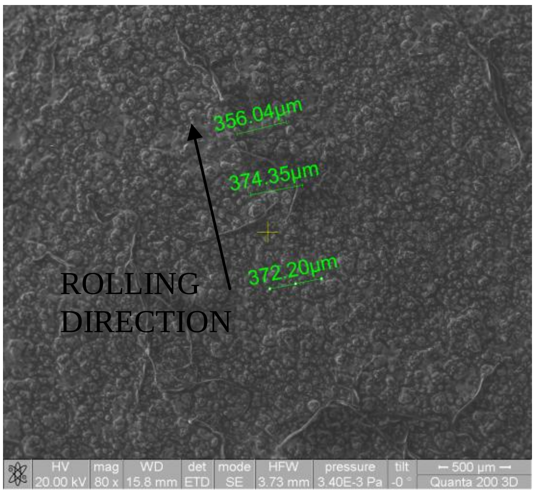


Figure 9: *The appearance and the size of impression left on the sample with lubricant*

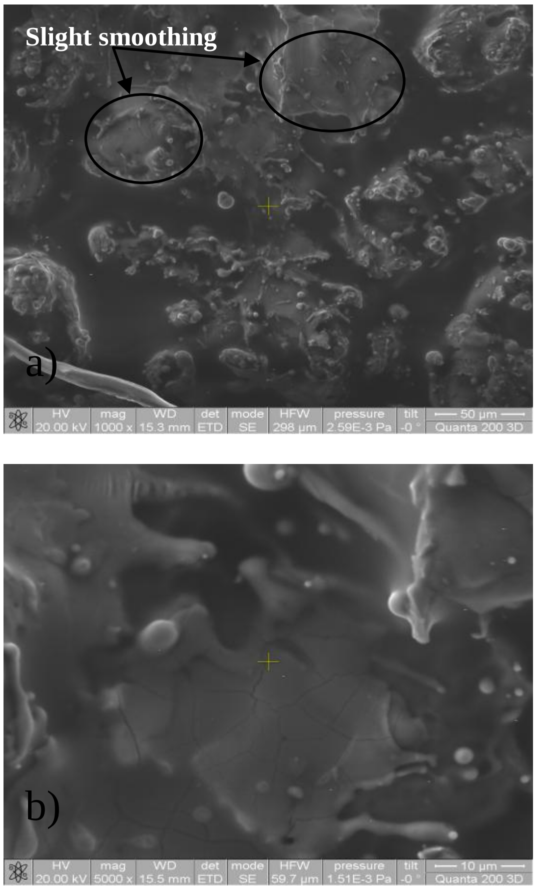
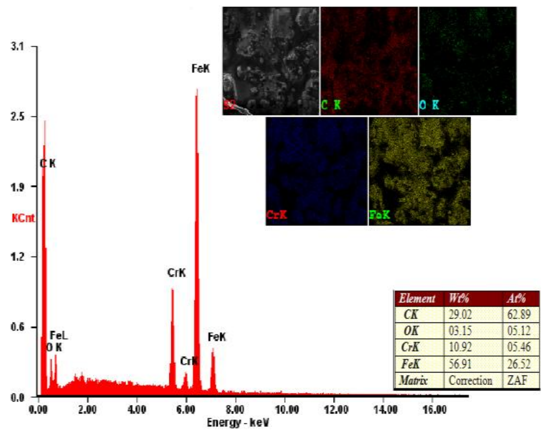


Figure 10: *The appearance of the impression left on the sample: a) 1000x and b) 5000x*

The fact that wear didn't occur in the deposited layer is also shown by the EDAX chemical analysis presented in Fig. 11, in which the presence of Cr, O_2, C and Fe in the analyzed areas can by observed. The distribution map presents a uniform distribution of elements. No conclusive remark can be made about material transfer between the two bodies in contact because both are steel alloys.



Element	Wt%	At%
CK	29.02	62.89
OK	03.15	05.12
CrK	10.92	05.46
FeK	56.91	26.52
Matrix	Correction	ZAF

Figure 11: *The distribution map of the chemical elements and the EDS*

Fig. 12 shows the evolution of the friction coefficient during the wear test in the presence of lubricant. The friction coefficient shows a downward tendency in the beginning of the test from the value of 0,16 to 0,13, after this value it is approximately constant until the end.

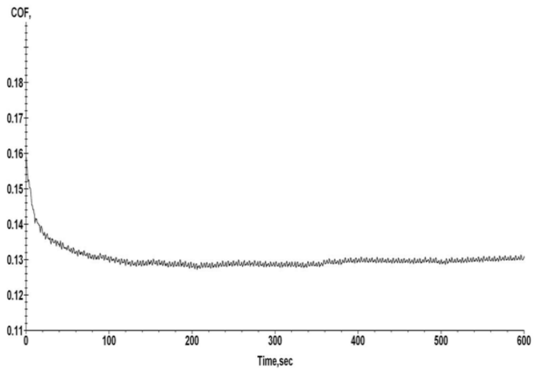


Figure 12: *The variation of the friction coefficient from the pin-disk test in lubricant friction conditions*

Fig. 13 presents the profile of the tested sample. For this sample the profile of the wear isn't very obvious as can be seen from the profilometry. A very good adhesion an stability of the layer is resulted from the test.

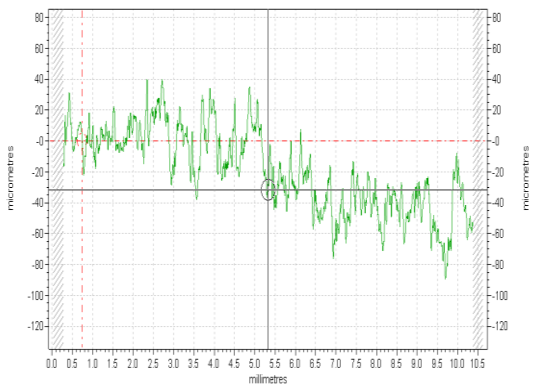


Figure 13: *The shape of the wear trace under lubricant friction condition*

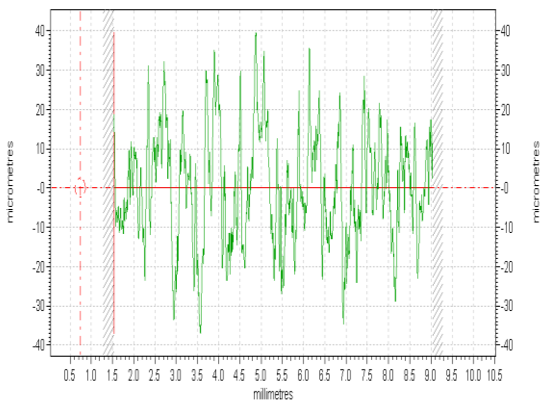


Figure 14: *The roughness values of the sample in lubrificant friction condition*

Fig. 14 shows the roughness analysis of the sample. The arithmetic mean deviation of the roughness profile Ra is evaluated to 11,3891μm. The standard deviation of the assessed profile roughness Rq = 14,0036μm and the average height of roughness profile is Rz = 67,1976μm.

4. Conclusions

For the sample with the Al_2O_3-TiO_2 ceramic coating the resulted powder residue was the outcome of the wear to which the pin was subject. From this it can be concluded that the coating is tougher then the material the pin is made of.

The sample shows a slight smoothening of its roughness. The friction coefficient has a tendency to decrease rapidly from 0.28 to 0.24 after that the coefficient remains constant around the value of 0.23.

Also a clear abrasion wear mark can be seen in the profile of the sample but this mark didn't reach the base material. Following the tests it shows that the sample subjected to oil lubricated friction performed well to wear.

In the case of the 40Cr130 coating the friction coefficient tends to decrease rapidly from 0,16 to 0,13 and then remains constant around this value. No clear wear marks resulted from the profile of the sample.

Both samples had a good behavior to friction wear but the 40Cr130 coating showed a smaller friction coefficient and a better resistance to wear so it can be concluded that is more recommended for deposition to a camshaft.

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We thank to SC Plasma Jet SA for the support in the plasma jet deposition of the analyzed layer from this paper.3 General Style Preferences.

I give thanks to the Faculty of Mechanics for the support and for making available the science of materials and Materials Science laboratories for performing the necessary tests for the paper.

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