

WEAR RESISTANCE OF THE LAYER Al_2O_3 - TiO_2 SPRAYED WITH PLASMA SPRAY DEPOSITION METHOD

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Abstract: *The incorrect operation of the camshaft affects not only the normal engine service, but also its economic indices. The gas distribution mechanism elements are especially submitted to mechanical wear. Therefore, the main aspects of this type of wear can be found, grouped as followed: contact wear, abrasive wear, fatigue wear, particularly its pitting, exfoliation, cracking. The deposited layer comes as a filler element to the basic material and between these two can speak of a limit of separation or interface more or less clearly delineated. This paper presents a new concept of thermal barrier coating for the prevention of delaminating of the sprayed layer. This consists in an adherent layer of Ni Mo Al (90-5-5) and a top coat of Al_2O_3 - TiO_2 , deposited by atmospheric plasma spraying (APS) on specimens of nodular cast iron of which the camshaft are made. Using the CETR UMT-2 tribometer there were made friction and wear tests. Highlighting and interpretation of the structural changes caused by the tests carried out have been made using modern methods of structural analysis.*

Key words: *microscopy, wear, tribometer CETR UMT-2, Al_2O_3 - TiO_2 , APS*

1. Introduction

In the gas distribution system, the camshaft has the role of order, through cams, valve movement, in accordance with the development cycle engine, in each cylinder. The main applications of shaft distribution are given essentially by bending, torsion and the crushing, at the level of cams.

Materials recommended for implementation the shafts distribution must ensure, following processing and heat treatment sufficient rigidity and high resistance to wear cams and spindles.[1]

For this reason it need to use plasma spray deposition method, given by the wide range

of powders that can be used, both pure and in various combinations, experimental determined (ex: Al alloys and oxides, Si or W carbides, Ni-Cr-Ti alloys which can compose carbides or nitrides, intermetallic compounds, ceramic materials with B or Si oxides or nitrides, borides or carbides).[2]

This opportunity to apply layers of different thicknesses, compositions and surface quality required make from the thermal spray an ideal way to avoid premature wear and replacement of different components.

2. Experimental procedure

This paper presents a new concept of

thermal barrier coating for the prevention of delaminating, spalling and surface distress of the sprayed layer. This consists in an adherent layer of Ni Mo Al (90-5-5) sprayed with electric arc and a top coat of $Al_2O_3-TiO_2$, deposited by atmospheric plasma spraying (APS) with SPRAYWIZARD-9MCE Sulzer Metco.

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

Deposition parameters for atmospheric plasma spray (APS) are presented in Table 1, and intermediate layer parameters with Ni Mo Al deposited by arc are shown in Table 2.

Technical parameters Table 1

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% H ₂
Spraying distance	120 mm

Technical parameters Table 2

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

3. Experimental results

Both samples were mounted one by one on the device shown in Figure 1. The tests were performed in dry conditions and in oil-lubricated conditions SAE 5W-30 Audi Original with viscosity, $51.7 \text{ mm}^2/\text{s}$ at 40°C according to ASTM D-445.



Fig. 1. CETR UMT-2 tribometer

The tests were accomplished with CETR UMT-2 tribometer for system pin-disk. Has been used a pin with diameter of 6.3 mm and a disc of $Al_2O_3-TiO_2$ sprayed. At a radius of 10 mm from the centre of the disc was applied through pin a normal press force $F_z = 10 \text{ N}$, for a period of 10 minutes.

The tests were performed under conditions of dry friction as well as and under conditions of lubrication. Because the surface roughness is very important, it was measured before and after the abrasion test, to estimate the wear due to the friction [7]

Other relevant tests were performed using the scanning electron microscopy Quanta 200 3D Dual Beam. In Figure 2 it is presented the way how the sample is mounted in the workroom of installation.

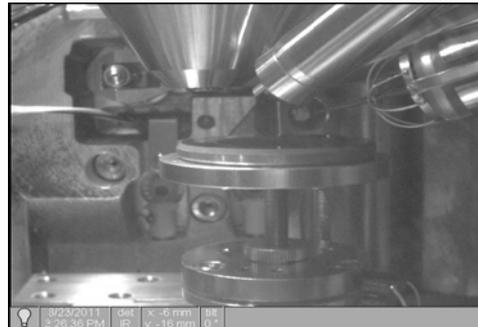


Fig. 2. The way how the sample is mounted in the workroom of the installation

The analyses presented below were performed using microscopy with electron microscope Quanta 200 3D type. Working

in High Vacuum mode (the pressure of the order of 10^{-4} Pa), the sample being attached on the specific support with bands using a special carbon, and the EDS analysis was performed using EDAX – AMETEK, attached on the same scanning electron microscope.

In order to complement these images were made and EDS chemical analysis on different areas to be evaluated the stage wear on the layers subjected to test friction.

3.1. The analyses performed on the sample subjected to dry friction.

In Figure 3 it shows that the width of the impression left on the sample due to friction is between $677 \mu\text{m}$ - $705 \mu\text{m}$, but with very few changes in the superficial layer, as shown in Figures 4.a) and b).

The fact that the deposited layer doesn't show any exfoliation was demonstrated in the EDS chemical analyzes presented in Figure 5 which shows only the presence of Al, O₂ and Ti in the analyzed area and in the distribution map is observed a uniform distribution of the elements.

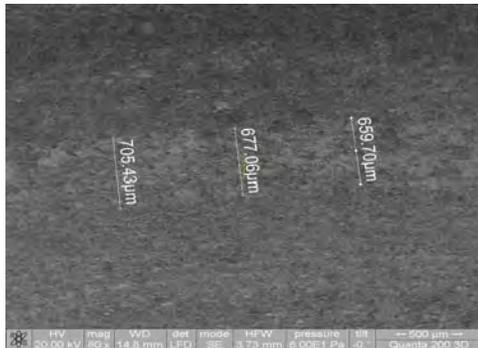


Fig. 3. The appearance and the size of impression left on the sample due to dry friction

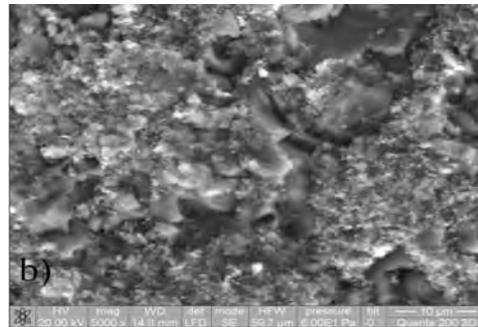
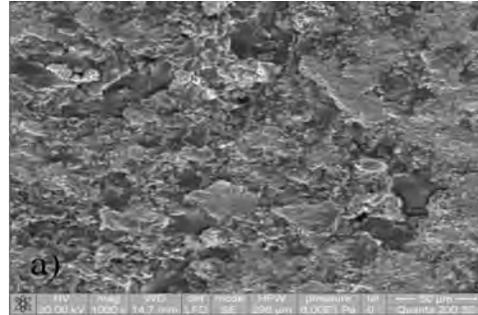


Fig. 4. The appearance of the impression left on the sample: a) 1000x; b) 5000x.

In the distribution map from Figure 5 it can be observed that a apart from the wear produced on the sample, on it's surface there are present traces of iron, this fact is due to adherence of particles of iron that resulted from the wear of the pin.

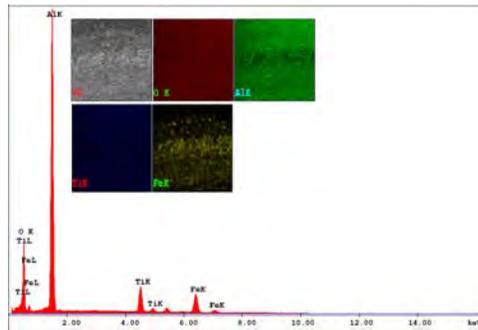


Fig. 5. The map of the chemical elements distribution and the EDS analysis of the area subjected to wear

In the Figure 6 is presented the variation of the friction coefficient due to dry friction a normal force of 10 N. At the start of the test the friction coefficient has a tendency of accelerated growth up to a maximum of 0.65, then has a tendency to decrease to around 0.58, and in the last part of the friction test the coefficient stabilizes around the value of 0.56.

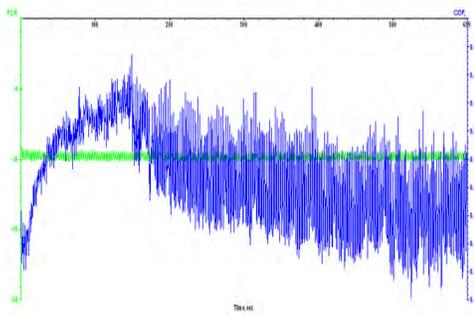


Fig. 6. The variation of the friction coefficient from the pin-disk test with dry friction conditions

In the Figure 7, it is presented the scanned surface of the disc after the wear test with a resulting wear depth of 120 μm . The form of the channel resulted due to wear is obtained with the Form TalySurf Intra 50 roughness tester, produced by Taylor Hobson, England.

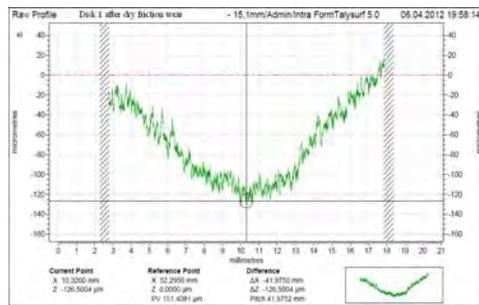


Fig. 7. The form of the channel due to wear in conditions of dry friction

In Figure 8 is presented the analysis of the roughness on a type LS-Line profile. The arithmetic average roughness R_a of the profile is 5.0331 μm , the root mean squared roughness R_q of the profile is 6.4922 μm and the average height roughness R_z is assessed at 35.5171 μm .

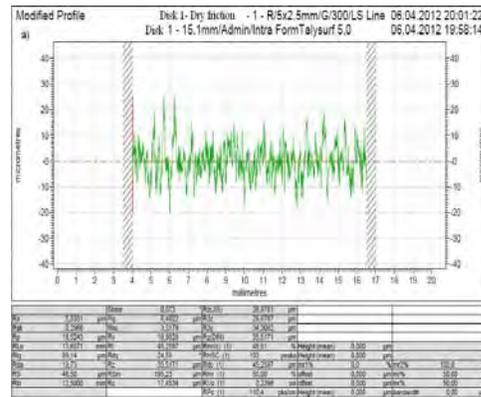


Fig. 8. The values of the disk roughness under dry friction conditions.

3.2. The analyses performed on the sample subjected to lubricate with ester-containing oil SAE 5W-30 Audi Original with a viscosity 51.7 mm^2/s at 40°C, according to standard ASTM D-445.

In Figure 9 it 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 10.a) and b). [6]

The fact that the deposited layer doesn't show wear was demonstrated in the EDS chemical analyzes presented in Figure 11 which shows only the presence of Al, O₂ and Ti in the analyzed area and in the distribution map is observed a uniform distribution of the elements.

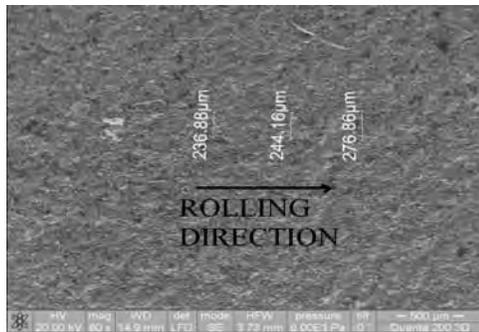


Fig. 9. The appearance and the size of impression left on the sample with lubricant

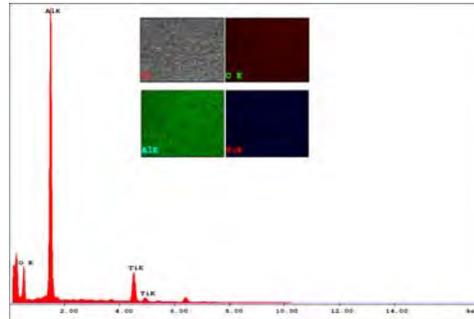


Fig. 11. The map of the chemical elements distribution and the EDS analysis of the area subjected to wear

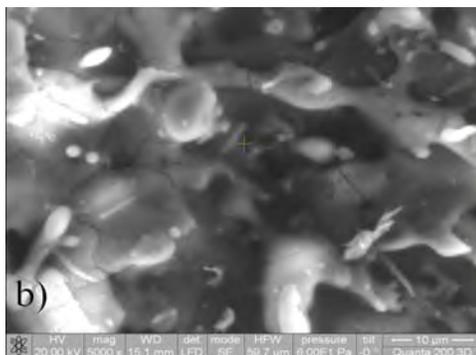
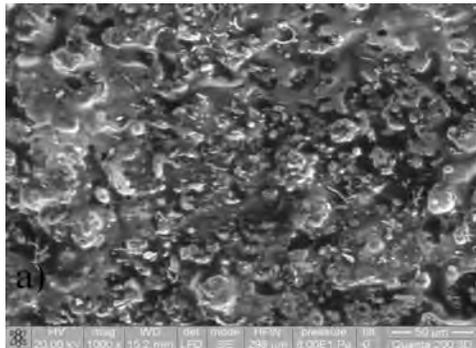


Fig. 10. The appearance of the impression left on the sample: a) 1000x; b) 5000x.

In the Figure 12, is presented a slight finishing of roughness, the friction coefficient has a tendency to decrease rapidly from 0.28 to 0.24 and then coefficient remains constant around the value of 0.23.

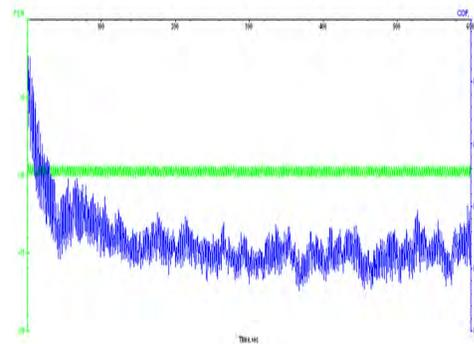


Fig. 12. The variation of the friction coefficient from the pin-disk test in lubricant friction conditions

In the Figure 13, it is presented the scanned surface of the disc after the wear test. In the case by lubricant friction it not been a change in depth very big of the surface contact area, these can be observed in the profilometry. Wear depth is only 60 μm, and is specific only of the upper layers sprayed on the disk.

Compared with profilometry of the Figure 7 is observed very good adhesion and stability of the next layers sprayed so reducing the wear depth in half.

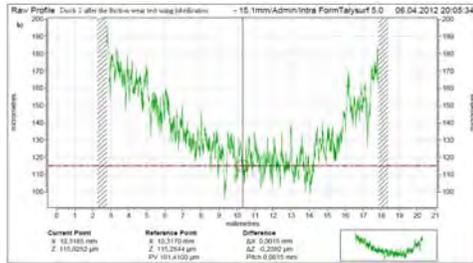


Fig. 13. The form of the channel due to wear in conditions of lubricant friction

In Figure 14 is presented the analysis of the roughness on a type LS-Line profile. The arithmetic average roughness R_a of the profile is $5.3764 \mu\text{m}$, the root mean squared roughness R_q of the profile is $6.8016 \mu\text{m}$ and the average height roughness R_z is assessed at $37.9427 \mu\text{m}$.

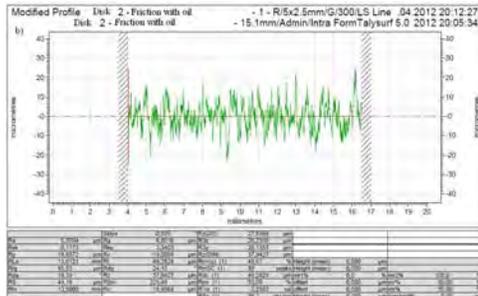


Fig. 14. Roughness values in condition of friction disk with the lubricant

Summary

In case dry friction there was a abrasive wear, width of the impression left on the sample between $677 \mu\text{m}$ - $705 \mu\text{m}$ in comparison with the samples subjected to wear by friction with the lubricated SAE 5W-30 with a viscosity $51.7 \text{ la } 40^\circ\text{C}$, in according to standard ASTM D-445, where is not observed wear in the surface just a finishing of the roughness.

The coefficient variation of friction is higher in the case dry friction, at the start of the test the friction coefficient has a

tendency of accelerated growth up to a maximum of 0.65, then has a tendency to decrease to around 0.58, and in the last part of the friction test the coefficient stabilizes around the value of 0.56. In case with oil, is presented a slight finishing of roughness, the friction coefficient has a tendency to decrease rapidly from 0.28 to 0.24 and then coefficient remains constant around the value of 0.23.

Following tests it results that sample subjected to friction in the presence of a lubricant performed very well to wear. Out of here can be concluded that a powder coating based on the $\text{Al}_2\text{O}_3\text{-TiO}_2$ of the camshaft would lead to an improvement of the functioning in condition of the contact with cam followers.

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