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## ON THE ABRASIVE WEAR HIGH STRENGTH COATING LAYERS ON MACHINE PARTS TESTING

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### SUMMARY:

Plasma coating technology was applied to machine parts. During application, the jet formed hits the surface of the material and particles are deposited on the surface. In this way, layers of high thickness can be applied and thus revitalize worn machine parts. The paper examines the abrasion resistance of Al<sub>2</sub>O<sub>3</sub> and Al<sub>2</sub>O<sub>3</sub> phosphate layers applied to the base material using plasma technology. The abrasion resistance of the applied layers was tested using the ASTM G 65-85 method. The results of the tests on the loss of the material due to abrasion wear for the two types of coatings in each of the three tested samples are presented. The results of the loss of the material volume at different speeds of the test device wheel are also presented. The phosphate impregnated layer on Al<sub>2</sub>O<sub>3</sub> samples showed significantly higher abrasion wear resistance.

Keywords: *plasma application, ceramic coatings, abrasive wear*

### INTRODUCTION

The research of metallic materials in the world is directed in two directions: the creation of new materials and the refinement of existing ones. Aluminum is the metal most commonly represented in the earth's crust (7.5%), and belongs to the group of light metals whose specific gravity is 2.7 mg / m, which is 1/3 of the specific gravity of steel. It is resistant to corrosion and has a high electrical conductivity.

Therefore, it is necessary to direct research into the application and satisfactory exploitation of these materials. One of the basic conditions for long-term protection of metals from corrosion is a good surface preparation. Warm plasma coatings on aluminum alloys have shown high quality, providing both improved adhesion and corrosion protection [1,2,3,4,5,6].

Thermal coating is a very widespread method of coating formation. The basis of warm application is the melting of the additional material and directing the molten material towards the surface of the base material, where rapid curing and deposition occur. Different warm deposition processes differ according to the characteristics of the additional material (wire or powder) and the energy source required for melting [2,7,8,9,10,11].

One of the hot deposition methods used is plasma application which can be applied to various materials (ceramics, metals or alloys). In this process, the gas mixture is ionized using an electric arc. The energy obtained in this way is used to apply extra material, powdered, at high speed over the base material. The high temperatures (1600°C) achieved allow the ceramic materials to melt. The application of plasma ceramic coatings has found application in many cases where high temperature resistance and wear and corrosion resistance are required.

As these processes can be coated with a large thickness (up to several mm), they can be used to improve the performance characteristics of new or repair damaged parts. About 50% of all wear cases are due to the abrasion process. A characteristic of this type of wear is the presence of hard abrasive particles of mostly mineral origin, so it is often called mineral wear. Typical examples of abrasive wear are working parts of agricultural, construction and mining machinery, submerged sludge pumps, tools for particle separation, etc. The highest resistance in these tribological systems is threatened by excessive abrasion wear, low resistance to surface fatigue and the least dangerous, ie tribo-corrosion wear is acceptable. These coatings can be successfully used for the restoration of worn parts of agricultural machinery. A well-regenerated part can reliably perform its function in a technical system.

## MATERIAL AND METHOD OF WORK

### Method of operation

The plasma deposition process was carried out at the Materials Institute "of the Tampere University of Technology, Finland.  $\text{Al}_2\text{O}_3$  layers were applied using the A 3000 S plasma process using Amperit 740.1 powder. The thicknesses of the layers were between 350 and 400  $\mu\text{m}$ . was steel (S235JO).

For samples with aluminum phosphates, the porosity of the  $\text{Al}_2\text{O}_3$  layers was reduced by the addition of phosphorus using a solution  $\text{Al}(\text{ON})_3 - \text{N}_3\text{RO}_4$  with a weight ratio of 1: 4,2; with the addition of 20% distilled water. The solution was impregnated in room temperature and atmospheric pressure.

The impregnation time was 12 hours after which the samples were thermally treated. Thermal treatment was performed in three steps: 2 hours at 100°C, 2 hours at 200°C and 2 hours at 400°C.

### Metallographic analysis of specimens

The experimental investigations in this paper include structural characteristics testing by metallographic testing using optical microscopy. The specimens were prepared for metallographic analysis by being cut rarely and then put in nital. When cutting the sample (mechanical and thermal method), special care must be taken to avoid structural changes. The magnification on the light microscope was optimal 200 times [12].

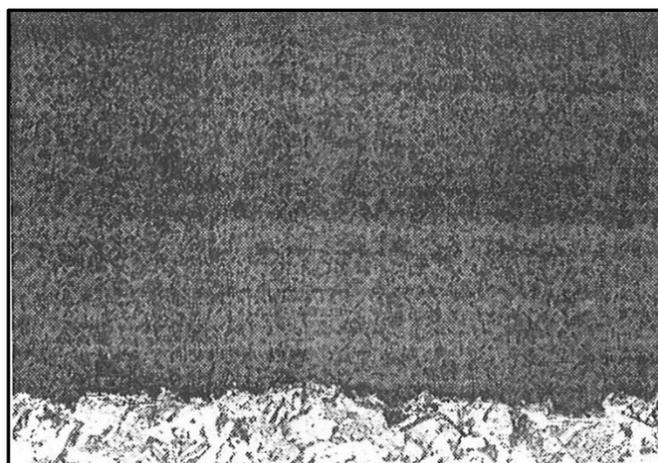


Figure 1. The microstructure of the sample sprayed on the layer of  $\text{Al}_2\text{O}_3$ , magnification 200:1

Figure 1 shows the microstructure of the sample to which the  $\text{Al}_2\text{O}_3$  layer was applied, and Figure 2 shows the microstructure of the sample to which the  $\text{Al}_2\text{O}_3$  layer was impregnated with aluminum phosphates.

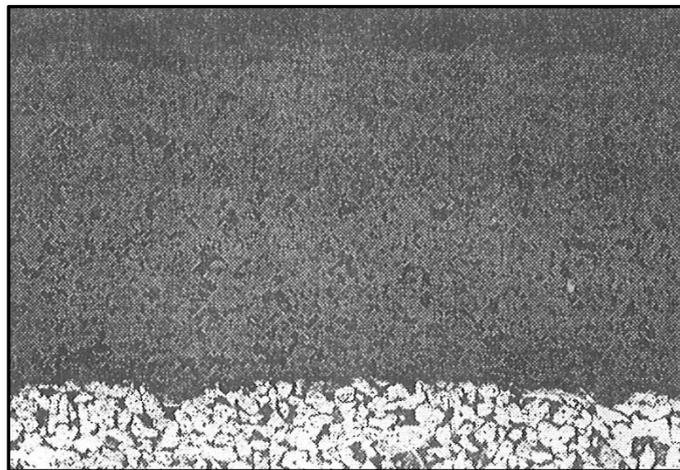


Figure 2. The microstructure of the sample sprayed on the layer of  $\text{Al}_2\text{O}_3$  impregnated with aluminum phosphate, magnification 200:1

### Hardness test

The hardness test was carried out by the method of Vickers HV 0,3 and the results are given in Table 1. The test was performed by means of an imprinter which is pressed into the test material and the size of the imprinted trace is measured. The punch is made of diamond in the form of a regular four-sided pyramid with an angle at the top  $136^\circ \pm 0.5^\circ$ . According to the standard procedure, the optimum pressing force was 10 N. The time of application of the pressing force into the surface of the material sample was 10-15 s, with a steady increase in force.

Table 1. Results of hardness testing

Type of the Layer	Hardness HV 0,3
$\text{Al}_2\text{O}_3$	920
$\text{Al}_2\text{O}_3$ impregniran Al fosfatima $\text{Al}_2\text{O}_3$ Impregnated with Al phosphates	1120

### Abrasive wear resistance test

Abrasive resistance testing was carried out using the methodological "dry sand / rubber wheel" according to ASTM G 68-85 standard, variants of procedure B and C, Table 2 [13].

The standard ASTM G 65-85 test unit is made of dry sand and a rubber wheel method and consists of a 12x12x75 mm abrasion tube, with a standard rounding using Ottawa AFS 50 70. A typical sample is rectangular 25 x 76 mm and between 3.2 and 12.7 mm thick. Quality The test surface must be flat to a maximum of 0.125 mm. The test tube rests on a wheel covered with rubber with a hardness of about 64 Shorr, and is loaded with weights via a crank arm. The force F is 130 N or 45 N, depending on the variant of the procedure, and the number of revolutions of the wheel, which is regulated by the speedometer, is also variable.

The scheme of the abrasion tester is shown in Figure 3. The diameter of the tire wheel on the test device is 228, 6 mm, the width and thickness of the rubber ring is 12.7 mm, the sand nozzle is made of hammer

(DIN EN S235JRG2) and achieves flow rate of 250-350 g / min, engine speed of the electric motor is 196 rpm.

The results of monitoring the behavior of regenerated machine elements in operation show that the lifespan is not the same. Often higher. The cost of regeneration is from 10 to 20% of the new machine part.

Table 2. Variants of the testing process

Variants of the process	Value of the forces on the test tube	No. of revolutions of the wheel [rev/min]	The relative distance traveled [m]
A	130	6000	4309
B	130	2000	1436
C	130	100	71.8
D	45	6000	4309

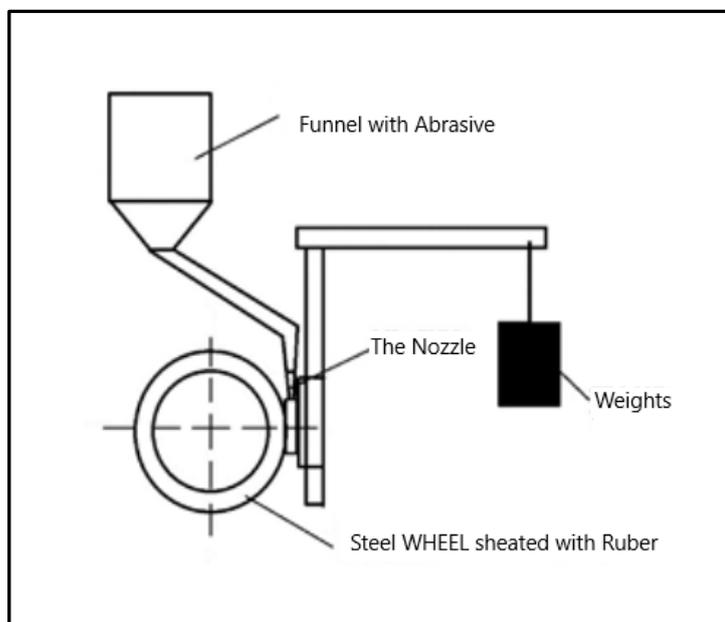


Figure 3. Scheme of the abrasion resistance testing device

For variant B, the force on the test specimen was 130 N and the rpm was 2000 rpm. For variant C, the force on the test specimen was also 130 N, but the number of revolutions was 100. For both types of layers, three specimens were tested. Samples after wear are shown in Figure 4. The results of VASTM volume loss in mm<sup>3</sup> are shown in Table 3 and Figures 4 and 5. The layer density used for calculating volume loss ΔVASTM was 3.98 g / cm<sup>3</sup>.

Table 3. Results of the resistance testing to abrasive wear process by the ASTM G 65-85 method, for three specimens

Procedure varijante	ΔV, mm <sup>3</sup>					
	Al <sub>2</sub> O <sub>3</sub>			Al <sub>2</sub> O <sub>3</sub> Impregnated with Al phosphates		
	1	2	3	1	2	3
B	36,407*	43,367*	42,236*	4,673	6,106	5,327
C	2,387	2,663	2,733	1,482	2,211	1,608

\* There has been a breakthrough of the surface layer

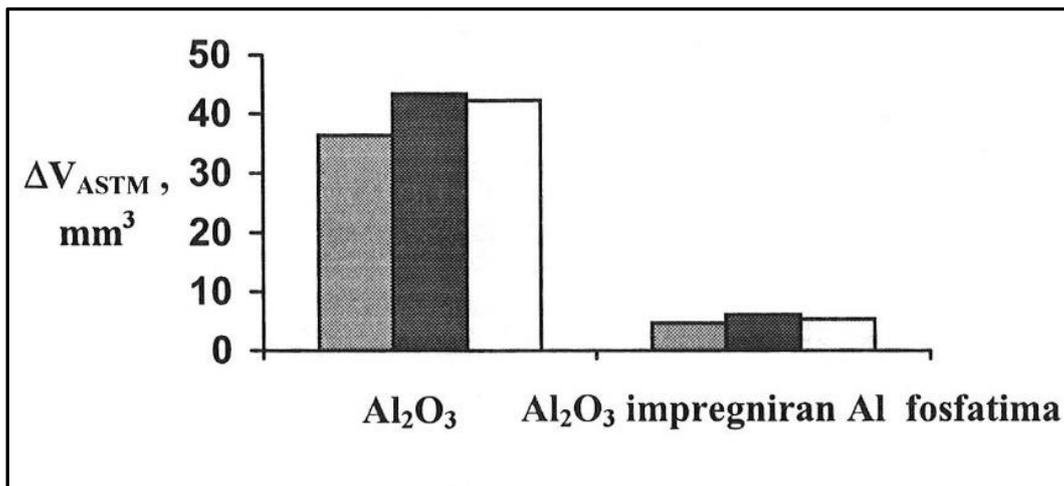


Figure 4. Loss of volume after abrasive wear according the Method ASTM G 65-85, process variant B

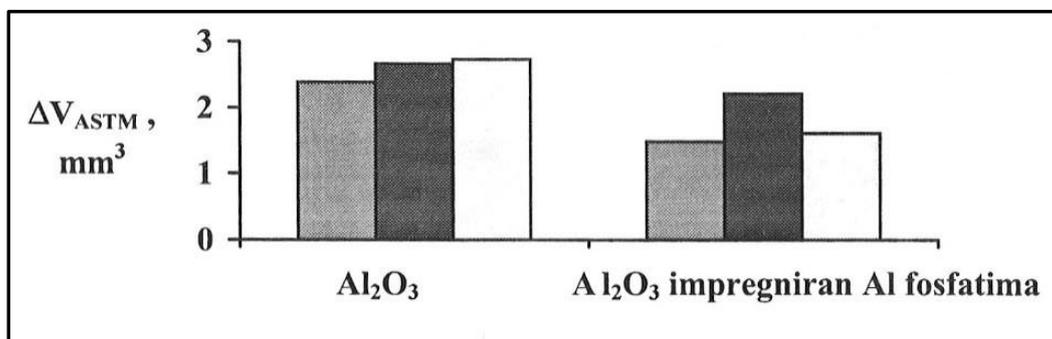


Figure 5. The volume loss after abrasive wear according the Method ASTM G 65-85, process variant C

In addition to testing according to the ASTM G 65-85 method, the course of wear of the samples was also carried out, during force on specific specimen of 130 N, after 100, 200, 300, 400 i 500 rotation points. The results of the VASTM volume loss in mm<sup>3</sup> are shown in Table 6 and Figure 7. rotations of wheel.. 400 i 500 rotation points. The results of the VASTM volume loss in mm<sup>3</sup> is shown in Table 4 and Figure 7. rotations of wheel..

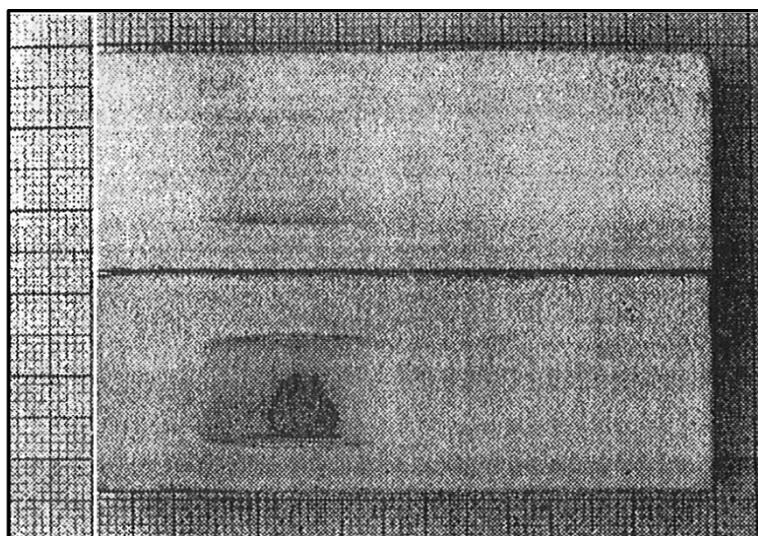


Figure 6. Samples after wear process

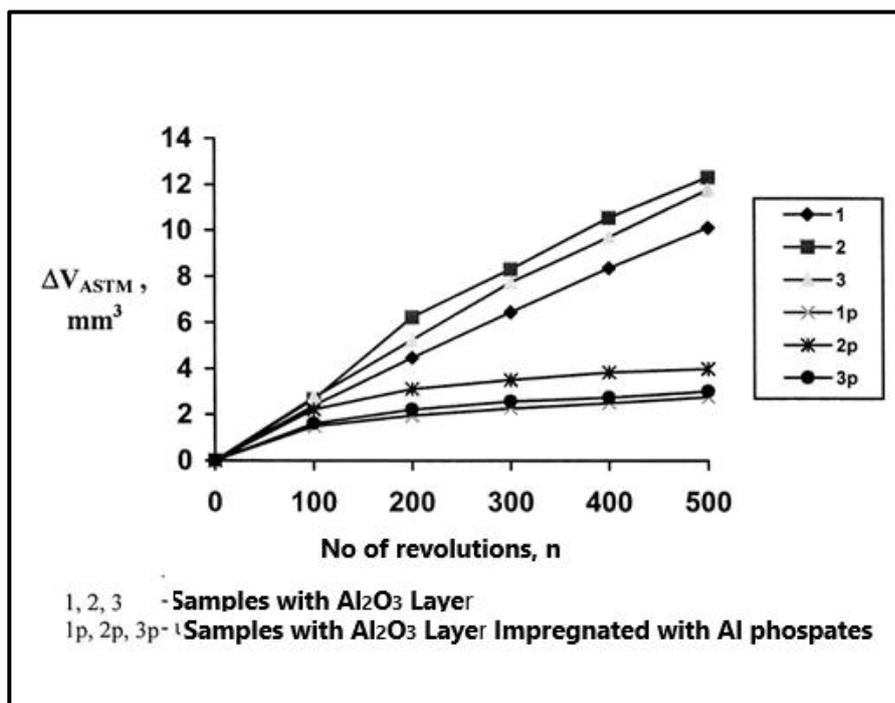


Figure 7. Flow of abrasive wear process

Table 4 Results of the abrasive wear process flow monitoring

No of revolutions	$\Delta V, \text{mm}^3$					
	$\text{Al}_2\text{O}_3$			$\text{Al}_2\text{O}_3$ layer $\text{Al}_2\text{O}_3$ Impregnated with Al phosphates		
	1	2	3	1	2	3
100	2,387	2,663	2,733	1,482	2,211	1,608
200	4,472	6,231	5,251	1,960	3,116	2,211
300	6,457	8,317	7,739	2,261	3,518	2,563
400	8,367	10,553	9,698	2,487	3,844	2,739
500	10,126	12,337	11,784	2,764	3,995	3,015

### 3. CONCLUSION

The test results show that Al phosphate impregnated  $\text{Al}_2\text{O}_3$  strain is more resistant to abrasive wear compared to  $\text{Al}_2\text{O}_3$  layer according to ASTM G 65-85. For variant C, this increased resistance is less pronounced, while for variant B, the  $\text{Al}_2\text{O}_3$  layer impregnated with Al phosphates is more abrasion resistant than the  $\text{Al}_2\text{O}_3$  layer six to nine times. This resulted in complete removal of the  $\text{Al}_2\text{O}_3$  layer in process variant B

Monitoring the flow of abrasive wear indicates that the abrasion resistance of the Al phosphate impregnated  $\text{Al}_2\text{O}_3$  layer and the  $\text{Al}_2\text{O}_3$  layer begins to differ significantly after 200 rpm. As the rpm continues to increase, this difference in resistance is increasingly tarnished in favor of Al-phosphate-impregnated  $\text{Al}_2\text{O}_3$  layers. In addition to the constant control of the tribometer device, the AFS sand quality control (50/70) is particularly important, round and square granular composition is required. Moisture should not exceed 0.5%. Sand exposed to moisture can adversely affect the test results. Multiple uses of sand are not recommended.

The selected coatings are especially abrasion resistant and can be applied to the most demanding parts of modern agricultural technology.

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