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# CHARACTERISATION OF APS – Mo WEAR RESISTANT COATINGS

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**Abstract**

*The results of mechanical and structural characterization Mo coatings are presented in this paper. The aim was to respect Pratt Whitney PWA (53-18) recommendation but to realize optimal property by varying the deposition processes parameters. The increasing of wear, erosion and corrosion resistance influence the wide spreading of this coating application. It means the significant increasing of life time for aircraft parts what resulting with decreasing the exploitation and maintains costs.*

**Key words:** *coating, erosion resistance,corrosion resistance,molybdenum*

## 1. INTRODUCTION

Plasma spraying of Mo powder provided at air or vacuum, has important role in production of wear resistant coatings [1]. Thanks to low friction coefficient and excellent wear resistance under thermal, mechanical and chemical influence at temperature below 350ºC, this coating was promoted like suitable for applications at pistons, synchrony rings, hydraulics and pneumatics components, gears etc. In addition, these coatings are applied at processes of revitalization and reparations for aircraft. Molybdenum coatings posses together with wear resistance also the corrosion resistance at inorganic acids, aggressive gases and liquid metals [2].

Advantage of molybdenum coatings is great and relating to excellent reliability, longer life time of parts and decreasing the maintains costs. Plasma spray coatings based on molybdenum or Mo-alloy is very interesting even today respecting the paper published in journals [3,4].

The quality of Mo coatings depends between many parameters but especially of: content and distribution of $MoO_3$ oxide, content of porosity, content of unmelted parts, cohesion strength and adhesion. Structural and mechanical characteristics of coating are directly related with type of deposition process, parameters of process and powder production technology. This technology directly influence the content of oxygen in powder and consequently at content of oxide $MoO_3$ in deposited layer.

In last decade many attempt was done to create computer software for predicting the distribution of temperature and velocity of powder particle in plasma gas flow [5]. That helps us to improve the parameters choice for deposition, but always existing some difference between theoretical computing and the measured results. So still now the best results could be realized using combination simulation model and check in real condition by experiment.

In this paper, the main attention will be concentrated to investigation the structural and mechanical characteristics of Mo coatings produced at atmosphere pressure with Mo powder produced by agglomeration and sintering technology. The aim of this paper is to find out the optimal combination of process parameters to realize the best quality and at the same time to satisfied recommendation PWA (53-18) what is the condition for application in reparation of aircrafts.

## 2. THEORETICAL CONSIDERATIONS

The powder of Mo posses good adherence to most of substrates so technology of deposition is relative easy to realize. Possibility of self adherence to grind or polished surface, together with possibilities for alloying with number of metals, make him convenient to produce contact layers. This phenomenon is explicitly present at connection between Mo and Fe alloy. During deposition appear very thin compound layer at interface, where dominated ε faze – 0,5 till 1 μm /1/. It is possible to find several type of Mo powder with content oxygen from 0,15 to 4,0%. Using powder produced by agglomeration and diffusive oxidation it is possible to deposit the coatings with average microhardness about 1.000 $HV_{0,3}$. Sintered Mo powder contains the lowest level of oxygen what result with lowest level of stabile oxide $MoO_3$. This coatings posse's hardness approximately 400 $HV_{0.3}$. after deposition. The choice of powder is dependent of exploitation conditions. Fig 1 shows morphology of one typical particle Mo powder produced by agglomeration and subsequent sintering. The shape is spherical and looks like pearl. This particle is very porous what influence for better heating and melting in plasma.

Content of oxide in coatings is directly dependent of plasma gasses, power of plasma source and time of particle flaying in plasma jet. The role of deposition temperature at substrate surface is very important. At temperature 370ºC pure molybdenum reacting with oxygen and produce oxide $MoO_2$ that is very unstable end have not protecting effect. Increasing the temperature from 450 to 550ºC stabile oxide $MoO_3$ will be formed and this oxide posses protecting effect. Continuing with increasing the temperature will promote oxidation under parabolic low till 700ºC. Over this temperature $MoO_3$ is sublimated /1/.

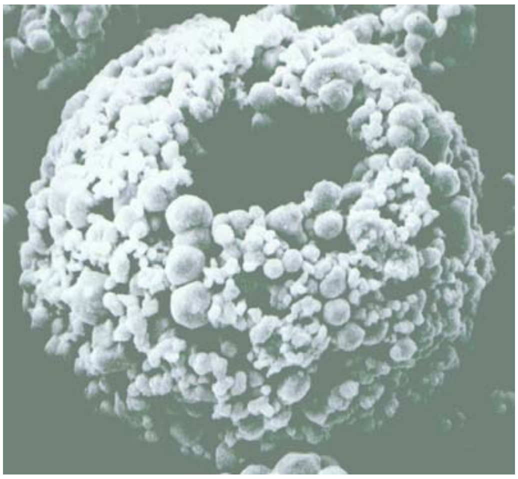

**Fig. 1:** *Morphology of agglomerated and sintered particle of Mo powder /2/.*

## 3. EXPERIMENTAL

In our experiment Mo powder 99,5% clean, with melting temperature 2620ºC was used. Granulation of powder was in range 45 – 90 μm. This powder was produced by agglomeration of ultra fine particles and connected with organic binder. Subsequent sintering was provided to form optimal dimension and shape of powder particles / fig.1.

Deposition of surface coating was done at different samples that were treated by blasting. For blasting process, the white electro corundum was used. The granulation of corundum was 0,7 – 1,5 mm. Particle of corundum was blasting with compressed air with pressure 5 bar. The aim of this process is to reach the roughness 30 – 40 μm so distance (150 mm from surface) and angle of jet was controlled. During this process the surface of samples was activated by removing the thin oxide surface layer and production of special morphology convenient for mechanical connection between two materials – substrate and deposited. Plasma gun type SG – 100 with atmosphere pressure. Plasma was consisted from argon and helium. Temperature of deposition was determined carefully take in count the melting temperature of Mo and temperature of evaporation micro constituent formed during deposition process. Respecting previous the choice of electrical current 600 A and voltage 32 V for deposition was dun. It is well known that melting effects are connected with time of flight powder particles in stream, so the distance from plasma gun and substrate surface was varied. For the first group it was 80 mm, for second 90 mm and the third 100 mm. The rest parameters of deposition was kept constant – flow of primary gas (Ar) – 47 liter per minute, flow of secondary gas (He) – 12 liter per minute, flow of carrier gas (Ar)- 4,5 liter per minute and powder consumption 35 g/min. Thickness of coating was varied in tolerances 0,4 to 0,45 mm what is in accordance with recommendation found in literature.

Samples for measuring the hardness, strength of interface and investigation of structure was produced of steel AMS 5504 in accordance with PWA (Pratt Whitney). Our equivalent is steel is Č.4172 . Dimension of samples for structure investigation and hardness testing was 70x20x1,5 mm. Samples for athesion testing (strenght of interface) had dimenesion ∅25x50 mm.

Strenght of coating was measured by tensile testing two samples with same dimension but one was coated. Samples was conected with glue enough strong to produce higher resistance to tensile stresss than coating. To eliminate the efect of transferyal stresss, special holder was contructed for conection between samples and testing machine. Test was provided at room temperature with tension rate 10 mm/min.

Testing of structures was done using light microscopy with magnification 400x. Light microscopy was used olso to control braking surface after testing the strenght of interface.

## 4. RESULTS AND DISCUSIONS

The results of microhardness measuring are presented at table T1. It is obvious that the microhardness of samples group I and II are lower than it recommended standard PWA (53-18). This standard recommended minimal value for hardness 400 $HV_{0,3}$.

**Table 1.**

| Group of samples | Microhardness $HV_{0,3}$ |
|---|---|
| I | 323 - 342 |
| II | 348 – 383 |
| III | 417 - 425 |

The results of measuring the strenght of coating are given at the table T2. It is obvious that the strenght of first group is lower than it recommended standard PWA (53-18). This standard recommended minimal value for strength 42 MPa /3/.

**Table 2.**

| Group of samples | Strength of interface MPa |
|---|---|
| I | 41,9 |
| II | 47,1 |
| III | 57,98 |

Some literature point out that share of porosity and unmelted particles are in direct correlation with microhardness and adhesion (or strength of interface) [4].

So PWA (53-18) standard strongly recomme-nded that maximal share of pores with dimension 12,7 microns couldn't exceed 3%. Share of unmelted particles with dimension till 38 microns could not exceed 10%.

Figure 2 presented the cross section on surface Mo layer deposited with SG-100 gun at atmospheric pressure using Ar-He mixture (primary gas flow Ar – 47 liter/minute, secondary gas flow He – 12 liter/minute and carrier gas flow Ar – 4,5 liter/minute) and powder flow 35 gram/minute. Structure at fig 2 present the structure of surface layer near the edge of sample but fig. 3 shows structure same layer at the center of the sample. It confirmed that the good uniformity of deposition was realized.

**Fig. 2.**

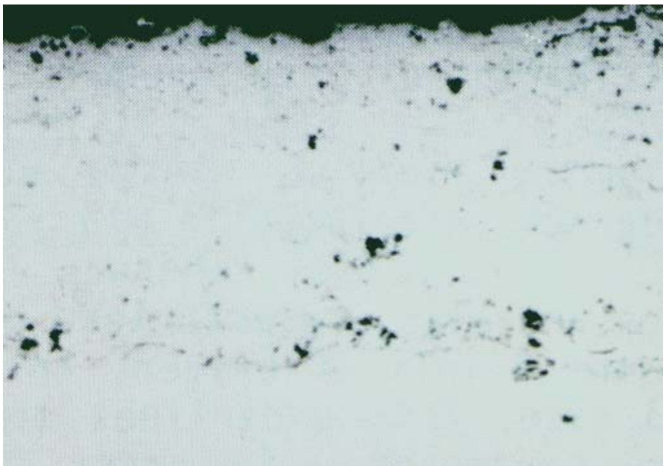

**Fig. 3.**

Influence of distance (between plasma gun and substrate) on interface strength is presented at fig 4. It is obvious that satisfactory interface strength (over 42 MPa) could be reached in the case that distance is over 81 mm.

Microhardness of coating shows that only with distance near to 100 mm the critical value could be reached (400 HV) – fig.5. Based on the results it concluded that plasma spraying have to be realized with distance 100 – 105 mm.

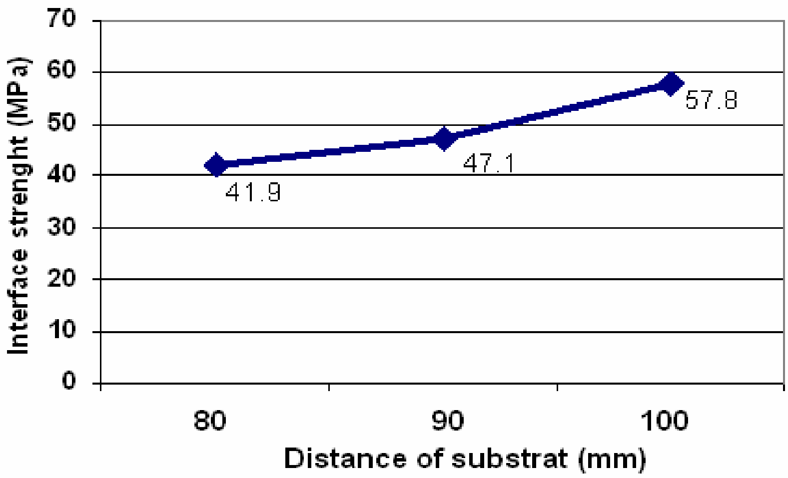


**Fig. 4:** *Influence of distance on interface strength*

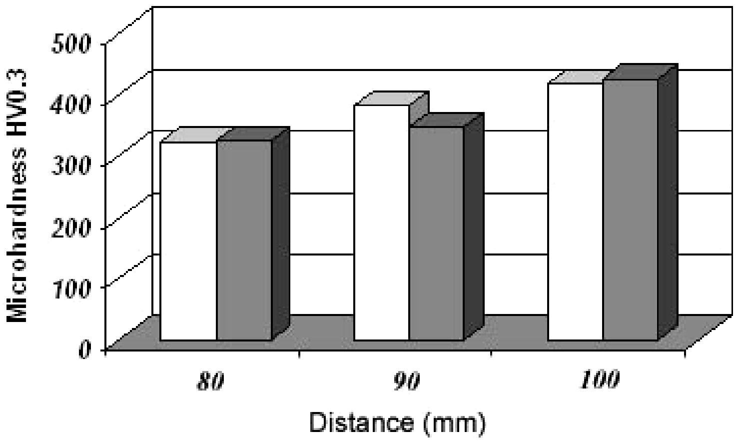


**Fig.5:** *Influence of distance at microhardness of surface layer.*

## 5. CONCLUSION

Successful deposition of Mo surface layer by APS technology could be realized by carefully adjusting the parameters of process like type of plasma gun, current and voltage, gas mixture and gas flow rate, type of powder, dimension of powder particles, temperature of substrate and specially distance.Distance between plasma gun and surface of substrate influence significantly on melting effect, but also on oxidation of melted particles. It shows the great influence on interface strength but particularly on surface layer microharness.

After experimental investigation it appear that optimal distance necessary to satisfied the both critical values – for interface strength and microharness – have to be between 100 and 105 mm.

## 6. LITERATURE

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