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ABOUT THE DEPOSITION OF SUPERALLOYS BY MEANS OF SUPERSONIC HVOF PROCESS

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Abstract: *The influence of the parameters of HVOF-technology on the quality of coatings obtained of three powder superalloys: 502 P, SX 199 and 6P50 WC has been studied in the paper. Experimental results about microhardness, porosity and roughness of the three coatings under three regimes of deposition have been obtained.Optimal parameters of the supersonic system of deposition "MICROJET-POWDER"have been found in relation to microhardness, porosity and roughness of the obtained coatings.*

Keywords: *tribology, superhard coatings, tribotechnologies, microhardness, roughness, porosity*

1. INTRODUCTION

Thermal deposition represents a complex of processes, where the introduced in the input material is heated and shooted in the form of independent particles or drops onto the given surface. The thermal deposition device generates heat necessary for the process by means of inflammable gases or electrical arcing.

During the heating, materials pass in plastic or melted state and are involved and accelerated to the basic surface in the stream or jet of gases under pressure. By their impact with the surface particles are deformed and build thin lamellas (splashes), which form contact bonds on the one hand with the roughness of the prepared surface, and, on the other hand – with the neighbouring lamellas.

The particles/drops cool during the impact with the surface and pile up a splash in laminar structure forming the deposited coating.

Figure 1 shows schematically the cross-section of the laminar structure of the deposited coating. It is a non-homogeneous structure containing a certain amount of pores and oxides in the case of metal deposition. The deposited material could be any fusible substance – metals, metal compounds, cements, oxides, polymers, etc. The source material can be given in the form of powder, wire or rod.

The forming contact bond between coating and basic surface could be mechanical, chemical and metallurgical, or combination of the three.

The properties of the deposited coating depend on the mutual action of different factors – source material, type and parameters of the used technological process, subsequent treatment of the deposited coating [1], [2].

The basic criterion for using a given material as a coating is the possibility that its particles are fusible or can transform in a state of high plasticity, deforming afterwards during the impact with the surface. The high temperatures combined with the possibility of regulation of composition, stream energy and its spatial configuration to the surface give a great variety of materials to form coatings of different characteristics.

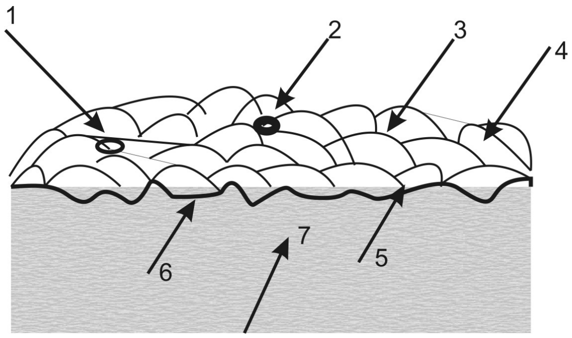

Figure 1. Typical cross-section of laminar structure of deposited coating

1 – pores; 2 – oxide inclusions; 3 – cohesion contacts between coating's parcticles; 4 – splashes (lamellas); 5 – adhesion contacts between surface and coating; 6 – roughnesses in the surface layer of the basic surface 7.

HVOF is one of the most recent methods in the tribotechnologies for thermal deposition of coatings. It represents a gas-flame supersonic process, where oxigen and combustible gas are used under high pressure.

Typical combustible gases are propane, propylene and hydrogene. The burning gas mixture is accelerated to supersonic velocity and the source powder material is injected in the flame.

HVOF technology minimizes the used thermal energy and maximizes the kinetic energy of the particles, so that coatings of high density, low porosity and high adhesion strength are obtained.

HVOF systems are compact, suitable for open-air usage; they are however mainly used in workshop conditions.

Wear-resistant coatings obtained by HVOF technology are widely used for improvement of the resource of contact elements, joints and systems, especially such of large size, in power engineering, industry, transport, etc.

The deposited HVOF coatings of superalloys are extremely important under conditions of high abrasion, erosion and cavitation [3], [4].

The paper aims investigation of the influence of the parametrs of HVOF-technology on the quality of coatings obtained from powder superalloys.

2.1. Experimental study

Coatings deposited by HVOF-technology obtained of three powder superalloys: 502P, SX199 and 6P50WC, have been studied.

Tables 1, 2 and 3 show the data about the chemical composition and physic-mechanical properties of those superalloys.

Table 1. Superalloy 502 P

№	Chemical composition	Specific weight	Melting point ^{o}C	Mohs' hardness
1.	Cr , 13,94 %	7,18	1850	9
2.	Si , 3,65 %		1414	7
3.	B , 2,52 %	2,3	2300	9
4.	Fe , 4,19 %	7,86	1535	4
5.	Ni , balance		1455	3,8
6.	Co , 0,03 %		1490	
7.	C , 0,59 %			

Table 2. Superalloy SX 199

№	Chemical composition	Specific weight	Melting point ^{o}C	Mohs' hardness
1.	Cr , 21 %	7,18	1850	9
2.	Ni , 7 %	8,9	1455	3,8
3.	$WC-Cr_3C_2/C$ 6,1%	18,91	3370	9

Table 3. Superalloy 6P50W

№	Chemical composition	Specific weight	Melting point ^{o}C	Mohs' hardness
1.	Cr ,13,15 %	7,18	1850	9
2.	Si , 4,28 %		1414	7
3.	B , 2,87 %	2,3	2300	9
4.	Fe , 0,04 %	7,86	1535	4
5.	Ni , balance		1455	3,8
6.	Co , 0,04 %		1490	
7.	C , 0,58 %			
8.	W balance		3370	9

Briefly, the basic interactions between the components of the *superalloys* are:

- At high temperatures chrome (Cr) combines with carbon(C), silicon$(Si)$and boron (B) creating metalloids. With carbon it forms hard and churlish structure Cr_3C_2 of green color, which does not dissolve in acids. Chrome with atomic weight 52,01 and valency +VI, +III, +II has the isotopes 52, 53, 50, 54. The presence of impurities makes it brittle.

- At high temperatures boron (B) combines with variety of metals (Fe, Ni) forming borides. With carbon it forms boric carbide of great hardness.

- Nickel with atomic weight 58,69 and valency +II, +III has the isotopes 58, 60, 62, 61, 64. It enters the composition of superhard alloys, and exhibits ferromagnetic properties. Nickel is weakly attacked by acids; strong alkalis do not affect it. In oxidant media and high temperatures it combines with oxygen and forms hard oxides NiO of green color.

- Cobalt (Co) and iron (Fe), like nickel, show ferromagnetic properties and are used in the production of superhard alloys with magnetic properties.
- At high temperatures tungsten forms carbides with carbon: WC and W_2C of hardness similar to that of diamond.

The three superalloys 502 P, SX 199 and 6P50WC are obtained by agglomeration process with included phase of sintering. Grain size is in the interval 45+22,5μm. The superalloys sustain coating deposition by the supersonic HVOF process with the system MICROJET-POWDER GMA Belgium.

Coatings have been obtained at three basic technological deposition regimes. The characteristics microhardness, porosity and roughness are studied. The technological parameters are given in Table 4.

Table 4: Technological parameters

Parameters	Regime 1	Regime 2	Regime 3
C_3H_8 / O_2	45%/100%	55%/100%	55%/100%
Speed of deposition	5 diamonds 700 m/s	7 diamonds 1000 m/s	7 diamonds 1000 m/s
Distance orifice-surface	L = 80 mm	L =120 mm	L=160 mm
Angle of the jet	90^o	90^o	90^o
Air pressure	5 bar	5 bar	5 bar
N_2 pressure	4 bar	4 bar	4 bar
Rate of powder feed	1,5 tr/min	1,5 tr/min	1,5 tr/min
Average consumption of powder	22 g/min	22 g/min	22 g/min

2.2. Experimental results

Figures 2, 3 and 4 show graphically the relationship of microhardness in units HRC and coating thickness h [mkm] for each of the three coatings under technological regimes 1, 2 and 3.

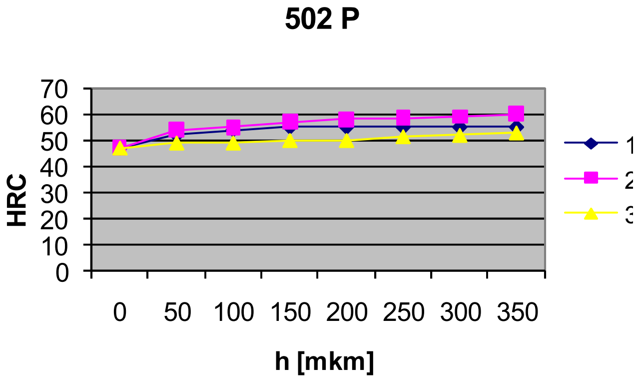

Figure 2. Microhardness versus thickness of the coating 502 P

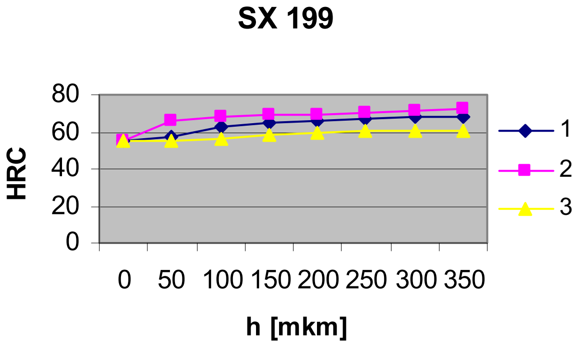

Figure 3. Microhardness versus thickness of the coating SX 199

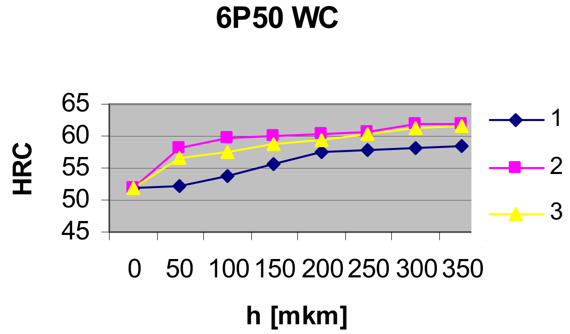

Figure 4. Microhardness versus thickness of the coating 6P50 WC

Figures 5, 6 and 7 give the results of porosity of the three coatings for the three technological regimes according to the data in Table 5.

Table 5. Porosity P

Regime	**502 P**	**SX 199**	**6P 50W**
1	3,7	3,55	3,25
2	2,5	2,3	1,55
3	4,7	4,55	3,8

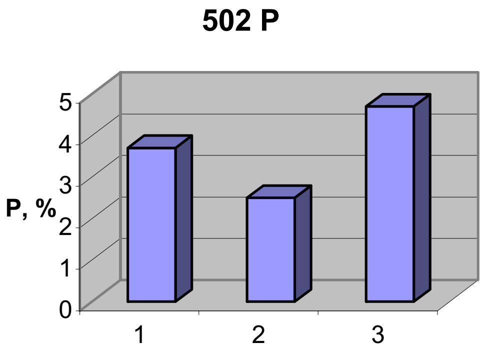

Figure 5. Variation of porosity of coating 502 P for the three technological regimes

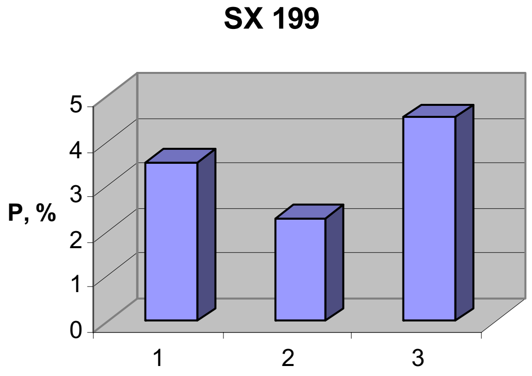

Figure 6. Variation of porosity of coating SX 199 for the three technological regimes

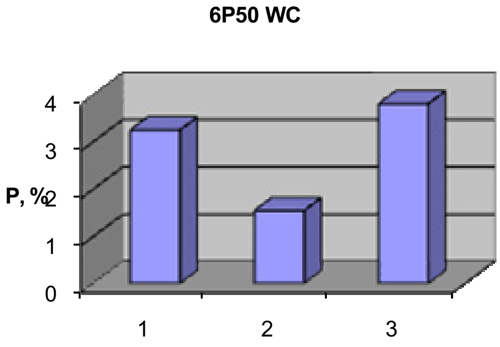

Figure 7. Variation of porosity of coating 6P50 WC for the three technological regimes

Results of roughness Ra study for the three coatings under the three regimes are given in Table 6, and as diagrams – in Figures 8, 9 and 10.

Table 6. Roughness Ra

Regime	502 P	SX 199	6P 50W
1	12 μm	9 μm	9 μm
2	7 μm	6 μm	7 μm
3	6,5 μm	8 μm	9 μm

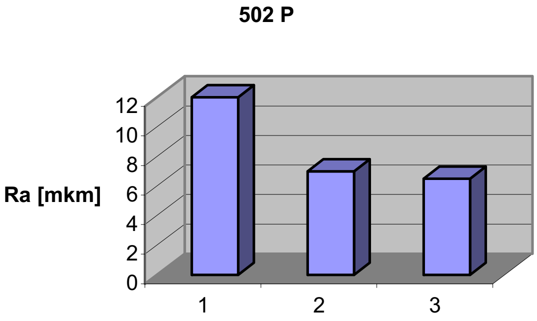

Figure 8. Variation of roughness of coating 502 P for the three technological regimes

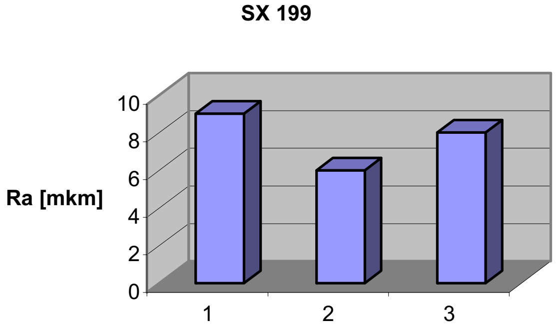

Figure 9. Variation of roughness of coating SX 199 for the three technological regimes

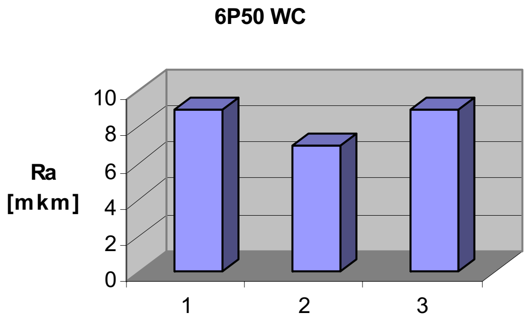

Figure 10. Variation of roughness of coating 6P50 WC for the three technological regimes

2.3. Results analysis

The analysis of the results of microhardness of the coatings in Figures 2, 3 and 4 has shown that evidently microhardness increases with increment of thickness h of the coatings of the three kinds under the three regimes. It has, however, different values and variation character. The maximum value is for h = 350 µm. For coatings *502 P* and *SX 199* the dependence is linear (Figures 2 and 3). The maximal hardness is for coating *SX 199* with the amount of 72 HRC at technological regime 2. This microhardness is obtained yet for the small coating thickness h = 100 μm, then it increases very slowly. The lowest microhardness is for h = 100 μm of coating *502 P,* namely 53 HRC under technological regime 3.

The relationship between microhardness of coating *6P50W* and thickness shows highly nonlinear form at the three regimes of deposition (Figure 4). The maximal microhardness 62 HRC appears for the coating with thickness h = 350 μm under regime 2, it is however lower than the microhardness of coating *SX 199* at the same regime.

Figures 5, 6 and 7 show diagrams of porosity P for the three coatings deposited at the three different regimes. All three coatings have their lowest porosity if obtained at technological regime 2. Minimal porosity shows coating *6P 50W*, namely P = 1,55. At the other two regimes the porosity is maximal for coating *502 P* obtained under regime 2; the value is P = 4,7 that is 3 times higher than the porosity of coating *6P 50W*. Coating *SX 199* obtained under regime 2 shows porosity close to that of coating *6P 50W*.

The diagrams of roughness Ra of the three coatings under the three regimes of deposition are given in Figures 8, 9 and 10 obtained according to the data in Table 6. The diapason of the obtained roughness is between 6 μm and 12 μm. The minimum Ra = 6 μm is for coating *SX 199* at regime 2, and the maximum Ra = 12 μm – for coating *502 P* obtained under regime 1.

Above analysis shows that optimum parameters of the supersonic system of deposition “MICROJET-POWDER” from the point of view of microhardness, porosity and roughness of the obtained coatings are as follows:

- C_3H_8-O_2 =55%/100%
- distance between orifice and surface – L = 120 mm
- angle of the supersonic two phase jet related to the surface – 90°
- air pressure of the compressor for cooling the system – 5 bar
- pressure of nitrogen in the batch feeding device – 4 bar
- rate of powder supply of the powder feeder – 1,5 tr/min
- average powder material consumption – 22 g/min.

CONCLUSION

- The paper studies coatings of three superalloys 502 P, SX 199 and 6P50 WC at three technological regimes of deposition.
- Experimental results about microhardness, porosity and roughness for the three kinds of coatings under the three technological regimes of deposition have been obtained.
- Optimal parameters of the supersonic system of deposition “MICROJET-POWDER” related to microhardness, porosity and roughness of the obtained coatings have been found.

The research will continue in the direction of the tribological characteristics of the coatings under conditions of interaction with fixed abrasive and hydro-abrasive, as well as under boundary friction and wear.

The investigation for above study is related to the first stage of the completion of the International Contract № ДНТС 02/12 in the scientific-technical collaboration between Romania and Bulgaria for 2010 in the topic „Tribotechnological study and qualification of composite materials and coatings lubricated by biodegradable fluids”.

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