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Coatings

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 3 powder superalloys: 502P, SX199 and 6P50WC 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. Optimum 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.

AIMS AND BACKGROUND

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 – with the neighbouring lamellas.

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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 amo unt 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.

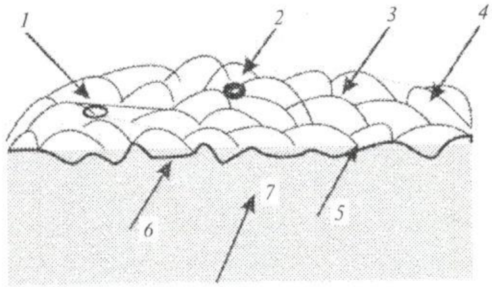

Fig. 1. Typical cross-section of laminar structure of deposited coating
1 – pores; *2* – oxide inclusions; *3* – cohesion contacts between coating parcticles; *4* – splashes (lamellas); *5* – adhesion contacts between surface and coating; *6* – roughnesses in the surface layer of the basic surface *7*

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.

HVOF is one of the most recent methods in the tribotechnologies for thermal deposition of coatings. It represents a gas-flame supersonic process, where oxygen and combustible gas are used under high pressure. Typical combustible gases are propane, propylene and hydrogen. The burning gas mixture is accelerated to supersonic velocity and the source powder material is injected in the flame. HVOF technology minimises the used thermal energy and maximises 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.

EXPERIMENTAL

Coatings deposited by HVOF-technology obtained of 3 powder superalloys: 502P, SX199 and 6P50WC, were studied.

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

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 struc-

Table 1. Superalloy 502P

No	Chemical composition	Specific weight	Melting point (°C)	The 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 SX199

No	Chemical composition	Specific weight	Melting point (°C)	The 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

No	Chemical composition	Specific weight	Melting point (°C)	The 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

ture Cr_3C_2 of green colour, 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 a 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 colour.
- 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 502P, SX199 and 6P50WC are obtained by agglomeration process with included phase of sintering. Grain size is in the interval 45÷22.5 μm. The superalloys sustain coating deposition by the supersonic HVOF process with the system MICROJET-POWDER GMA Belgium.

Coatings were obtained at 3 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°	90°	90°
Air pressure	5 bar	5 bar	5 bar
N_2 pressure	4 bar	4 bar	4 bar
Rate of powder feed	1.5 g/min	1.5 g/min	1.5 g/min
Average consumption of powder	22 g/min	22 g/min	22 g/min

RESULTS AND DISCUSSION

Figures 2, 3 and 4 show graphically the relationship of microhardness in units HRC and coating thickness h (μm) for each of the 3 coatings under technological regimes 1, 2 and 3.

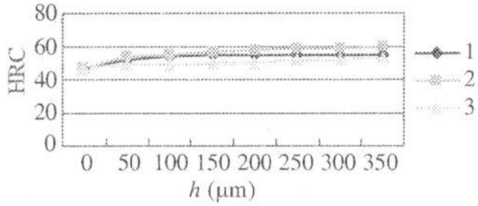

Fig. 2. Microhardness versus thickness of the coating 502P

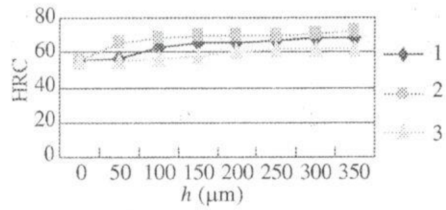

Fig. 3. Microhardness versus thickness of the coating SX199

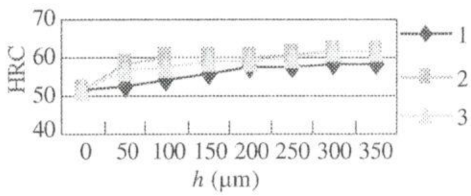

Fig. 4. Microhardness versus thickness of the coating 6P50WC

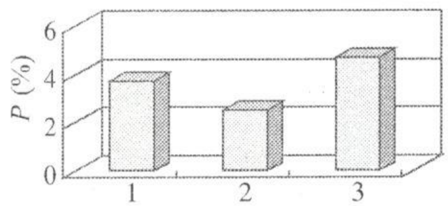

Fig. 5. Variation of porosity of coating 502P for the 3 technological regimes

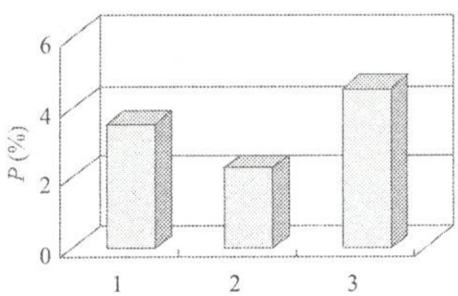

Fig. 6. Variation of porosity of coating SX199 for the 3 technological regimes

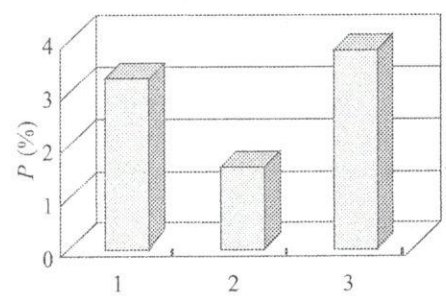

Fig. 7. Variation of porosity of coating 6P50WC for the 3 technological regimes

Table 5. Porosity P

Regime	502P	SX199	6P50W
1	3.7	3.55	3.25
2	2.5	2.3	1.55
3	4.7	4.55	3.8

Table 6. Roughness Ra (μm)

Regime	502 P	SX 199	6P 50W
1	12	9	9
2	7	6	7
3	6.5	8	9

Figures 5, 6 and 7 give the results of porosity of the 3 coatings for the 3 technological regimes according to the data in Table 5.

The results of roughness (Ra) study for the 3 coatings under the 3 regimes are given in Table 6, and as diagrams – in Figs 8, 9 and 10.

The analysis of the results of microhardness of the coatings in Figs 2, 3 and 4 has shown that evidently microhardness increases with increment of thickness h of the coatings of the 3 kinds under the 3 regimes. It has, however, different values and variation character. The maximum value is for h=350 μm. For coatings 502P and

SX199 the dependence is linear (Figs 2 and 3). The maximum hardness is for coating SX199 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 502P, namely 53 HRC under technological regime 3.

The relationship between microhardness of coating 6P50W and thickness shows highly nonlinear form at the 3 regimes of deposition (Fig. 4). The maximum microhardness 62 HRC appears for the coating with thickness h=350 μm under regime 2, it is however lower than the microhardness of coating SX199 at the same regime.

Figures 5, 6 and 7 show diagrams of porosity P for the 3 coatings deposited at the 3 different regimes. All 3 coatings have their lowest porosity if obtained at technological regime 2. Minimum porosity shows coating 6P50W, namely P=1.55. At the other two regimes the porosity is maximum for coating 502P obtained under regime 2; the value is P = 4.7 that is 3 times higher than the porosity of coating 6P50W. Coating SX199 obtained under regime 2 shows porosity close to that of coating 6P50W.

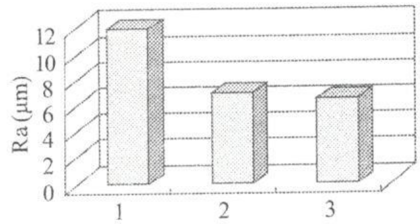

Fig. 8. Variation of roughness of coating 502P for the 3 technological regimes

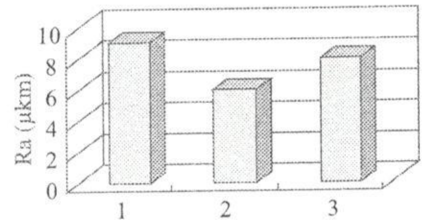

Fig. 9. Variation of roughness of coating SX199 for the 3 technological regimes

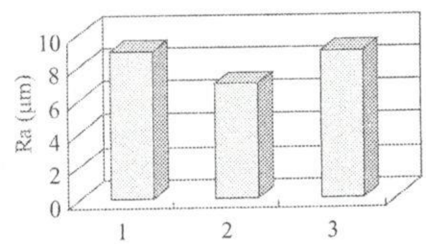

Fig. 10. Variation of roughness of coating 6P50WC for the 3 technological regimes

The diagrams of roughness Ra of the 3 coatings under the 3 regimes of deposition are given in Figs 8, 9 and 10 obtained according to the data in Table 6. The diapason of the obtained roughness is between 6 and 12 μm. The minimum Ra = 6 μm is for coating SX199 at regime 2, and the maximum Ra = 12 μm – for coating 502P obtained under regime 1.

The 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 2 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 g/min;
– average powder material consumption – 22 g/min.

CONCLUSIONS

• The paper studies coatings of 3 superalloys 502P, SX199 and 6P50WC at 3 technological regimes of deposition.

• Experimental results about microhardness, porosity and roughness for the 3 kinds of coatings under the 3 technological regimes of deposition have been obtained.

• Optimum 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.

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