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RESEARCH OF RESIDUAL STRESSES IN SYSTEM "SPRAYED PARTICLE - SUBSTRATE"

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ABSTRACT

Results of researches of residual stresses in separate structural elements of sprayed composite particles of coatings FeCr30Mo3+7%graphite+70%TiC, FeCr30+10% graphite+70%TiC are represent.
Data was received by roentgen-structural analysis of sprayed compositions with studying of parameters their thin structure and measure of lattice deformation of basic phases of composite materials (TiC, solid solution on Fe base).

1. INTRODUCTION

Serviceability of the wear-resistant coatings, being object of researches, in many respects is defined by their stress state. It is known, for example, that stretching stresses in surface layers of coatings activate their mechanical destruction during friction. Such stresses in layers on boundary with a substrate reduce adhesive strength of coatings. Therefore experimental researches of parameters of a stress state in system "sprayed particle - substrate" are actual enough.
The purpose of researches is studying of residual stresses in separate structural elements of sprayed composite particles of coatings FeCr30Mo3+7%graphite+70%TiC, FeCr30+10%graphite+70%TiC. The specified coatings are perspective for restoration and hardening of the machines details maintained at disadvantageous conditions of friction.
The derived data can be used at the comparative analysis of quality of similar composite coatings for a choice of composition of the initial sprayed powder materials applied by a plasma spraying.

2. METHOD OF INVESTIGATION

Results of investigation was received with use roentgen-structural analysis of sprayed compositions with studying of parameters their thin structure and measure of lattice deformation of basic phases of composite materials (TiC, solid solution on Fe base).
Stresses conduce to homogeneous and asymmetric change of interfacial distance of crystallite lattice and, therefore, to displacement of diffraction line on angle $\Delta\theta$, which is determinate from expression

$$\Delta\theta = -\varepsilon \, tg\theta_0 . \qquad (1)$$

Usually ε are measure along the several directions making various corners ψ with a normal to a surface of a sample. At definition of the sum of the main stresses of first kind in phase TiC and a solid solution on basis Fe are use dependence [3]:

$$\sigma_1 + \sigma_2 = \frac{E}{\mu}\left(\frac{d_\perp - d_0}{d_0}\right). \qquad (2)$$

In view of the equation (2) and technology of reception of samples for determination of an stress condition it is finally accepted

$$\sigma_1 + \sigma_2 = \frac{E}{\mu}\left(\frac{d_{coat} - d_{powd}}{d_{powd}}\right), \qquad (3)$$

Calculation of parameters of the formula (3) is executed on programs FOURL1 and MIC2L software package GOR.

3. RESULTS OF INVESTIGATIONS AND DISCUSSION

Investigation results of stress condition of phases α-Fe and TiC in sprayed particles are represented on figures 1 and 2 and in tables 1 and 2. As view from figures 1 and 2 main lines α-Fe and TiC on position in roentgen spectrums are different from table data of cards [6-0696] and [32-1383], which are representative for non-stressed condition. On that shift of lines in spectrums is irregular — front and rear lines the worst are shifted. Besides it is observed α-Fe and TiC line broadening. All that evidence about microdeformation stress condition of phases α-Fe and TiC in sprayed particles. Analysing data of tables 1 and 2 it is required to note in carbide phase are formed stretch stresses, and in solid solution compress that. On that absolute value of structural elements stresses of compositions FeCr30Mo3+7%graphite+70%TiC is above in comparison with composition FeCr30+10% graphite+70%TiC. It is explained with presence molybdenum, which improve wettability of carbide phase by binder solution on iron base. Cohesion strength of composition is increased, but at the same time opportunities of a relaxation of stresses in it are reduced.

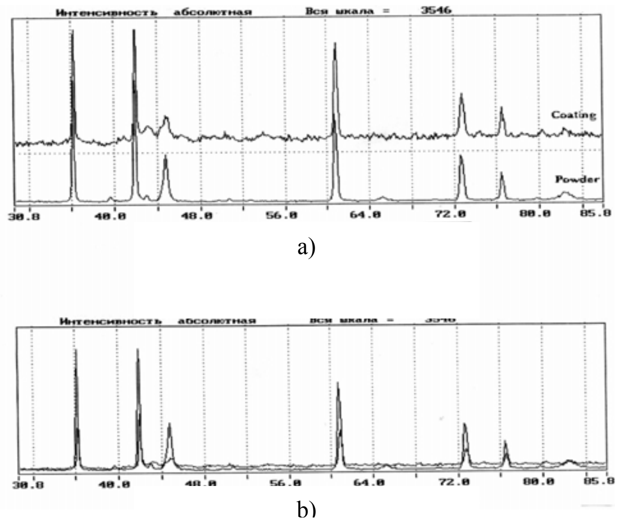
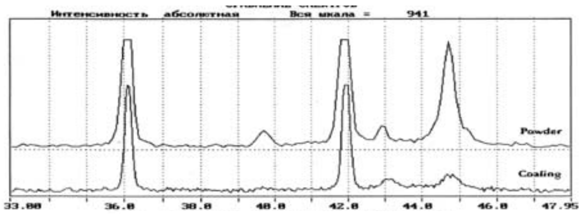
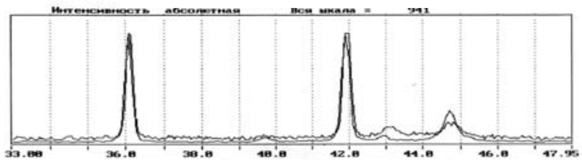


Fig. 1. Comparative image of diffractograms of initial powder FeCr30Mo3+7%graphite+70%TiC and sprayed compo-

sitions: a – not combined diffractograms; b – diffractograms combined on axis Y in a zero level



a)



b)

Fig. 2. Comparative image of diffractograms of initial powder FeCr30+10%graphite+70%TiC and sprayed compositions: a – not combined diffractograms; b – diffractograms combined on axis Y in a zero level

Table 1. Results of determination of the sum of the main stresses in TiC and Fe in sprayed composition FeCr30Mo3+7%graphite+70% TiC

TiC [32-1383]

d_{ASTM}, Å	I_{ASTM}	d_{powd}, Å	I_{powd}	(hkl)	d_{coat}, Å	I_{coat}	$\Delta d/d \cdot 10^{-3}$	$(\sigma_1+\sigma_2)$, MПа	E/n, MПа	$(d_{coat}-d_{powd})/d_{powd}$
2.499	80	2.488	77.6	1 1 1	2.481	79.8	-2.814			
2.1637	100	2.156	100	2 0 0	2.151	100	-2.319			
1.5302	60	1.526	58.2	2 2 0	1.523	67.4	-1.966			
1.3047	30	1.301	31.1	3 1 1	1.301	31.3	0.000			
1.2492	17	1.247	18.2	2 2 2	1.245	19.8	-1.604	642	400000	-0.001603849
1.0818	10	1.080	8.2	4 0 0	1.079	8.5	-0.926	370	400000	-0.000925926
0.9927	13	0.991	14.4	3 3 1	0.990	12	-1.009			
0.9677	25	0.966	26.7	4 2 0	0.965	23.2	-1.035			
0.8834	25	0.882	22.6	4 2 2						
0.8327	16			5 1 1						

Fe [6-0696]

d_{ASTM}, Å	I_{ASTM}	d_{powd}, Å	I_{powd}	(hkl)	d_{coat}, Å	I_{coat}	$\Delta d/d \cdot 10^{-3}$	$(\sigma_1+\sigma_2)$, MПа	E/n, MПа	$(d_{coat}-d_{powd})/d_{powd}$
2.0268	100	2.027	34	1 1 0	2.023	19.7	-1.973			
1.4332	20	1.433	2.8	2 0 0	1.447	4.3	9.770			
1.1702	30	1.172	5.8	2 1 1	1.165	2.8	-5.973			
1.0134	10	1.016	1.9	2 2 0	1.018	3.6	1.969	-597	303448.3	0.001968504
0.9064	12	0.906	1.7	3 1 0						
0.8275	6			2 2 2						

Table 2. Results of determination of the sum of the main stresses in TiC and Fe in sprayed composition FeCr30+10%graphite+70%TiC

TiC [32-1383]

d_{ASTM}, Å	I_{ASTM}	d_{powd}, Å	I_{powd}	(hkl)	d_{coat}, Å	I_{coat}	$\Delta d/d \cdot 10^{-3}$	$(\sigma_1+\sigma_2)$, MПа	E/n, MПа	$(d_{coat}-d_{powd})/d_{powd}$
2.499	80	2.488	79.5	1 1 1	2.488	79.9	0.000			
2.1637	100	2.156	100	2 0 0	2.151	100	-2.319			
1.5302	60	1.526	51.8	2 2 0	1.523	61.7	-1.966			
1.3047	30	1.301	27	3 1 1	1.301	41.6	0.000			
1.2492	17	1.247	13.1	2 2 2	1.245	21.6	-1.604	642	400000	-0.001603849
1.0818	10	1.079	5.8	4 0 0	1.079	12.2	0.000	0	400000	0
0.9927	13	0.991	9.7	3 3 1	0.991	13.2	0.000			
0.9677	25	0.966	19.7	4 2 0	0.965	27.1	-1.035			
0.8834	25	0.882	17.2	4 2 2						
0.8327	16			5 1 1						

Fe [6-0696]

d_{ASTM}, Å	I_{ASTM}	d_{powd}, Å	I_{powd}	(hkl)	d_{coat}, Å	I_{coat}	$\Delta d/d \cdot 10^{-3}$	$(\sigma_1+\sigma_2)$, MПа	E/n, MПа	$(d_{coat}-d_{powd})/d_{powd}$
2.0268	100	2.027	26.3	1 1 0	2.027	15	0.000			
1.4332	20	1.429	1.5	2 0 0	1.439	1.2	6.998			
1.1702	30	1.173	3.2	2 1 1	1.17	8.4	-2.558			
1.0134	10	1.014	1.1	2 2 0	1.015	3.5	0.986	-299	303448.28	0.000986193
0.9064	12	0.906	1.1	3 1 0						
0.8275	6			2 2 2						

Note. Column hkl characterises a direction of lines of reflection from planes of a crystal (direction of measurement lines)

5. CONCLUSION

Investigations of parameters of stress condition in system "sprayed particle – surface" are carried out. Results of investigations of residual stresses in separate structural elements of sprayed compositions FeCr(FeCrMo)+graphite+TiC are received by their roentgen-structural analysis with studying of parameters of with studying of parameters their thin structure and measure of lattice deformation of TiC phase and solid solution on Fe base. It was determinated in the said phases are formed corresponding stretching 370-642 MPa and compressing 299-597 MPa stresses. On that absolute value of stresses of structural elements of compositions FeCr30Mo3+7%graphite+70%TiC is above in comparison with composition FeCr30+10%graphite+70%TiC.

The established distribution of residual stresses between structural elements of coatings positively influences on their wear resistance. In particular, compressing stresses in binding phase FeCr(FeCrMo) increase its resistance to mechanical destruction at friction. The opportunity of flaking from a binder of carbide phase which presence as solid particles in a friction zone causes development of abrasive wear process are decreases.

The derived data can be used at the comparative analysis of quality of similar composite coatings for a choice of composition of the initial sprayed powder materials applied by a plasma spraying.

6. CONVENTIONS

θ_0 – diffraction angle, which comply with condition of material without stresses; ε – deformation of lattice; E – Young's modulus for TiC and solid solution on Fe base; μ – Poisson's ratio for TiC and solid solution; $d_{\perp}$ – average interfacial distance of lattice for stressed material in direction, which is perpendicular to surface sample; d_0 – interfacial distance for stressed material; d_{coat} – interfacial distance of lattice in sprayed composite material; d_{powd} – interfacial distance in initial composite powder, which comply with card JSPDS [32-1383] for TiC and ASTM [6-0696] for solid solution α-Fe.

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