Properties of Coating Structure Based on the Mixture of Copper, Zinc and Corundum Powders Formed Under the Influence of Technological Parameters of Gas-dynamic Spraying

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The modern engineering materials are required to work under high and intense loads, in the absence of lubrication and exposure to aggressive media. Cold gas-dynamic coatings based on particles of copper, zinc and corundum have the greatest advantages that allow various parts to work in such operating modes.

The coverage of the entire surface area by the method under consideration is formed by sequential application of layers with a constant overlap of the previous layer. The layer itself is produced from the metal particles mixture with plasticity of more than 60% and corundum by providing them with high kinetic energy and speed, heated by air jet that has passed the Laval nozzle. The dispersed particles form a coating layer 6 mm wide with section in the form of the circle segment due to the plastic deformation of metal particles. Corundum increases the particles deformation, breaks down and bounces off the applied surface, leaving only its small fragments in it.

The main purpose of this study was to assess the change of the coating structure properties based on the mixture of copper, zinc and corundum powders under the influence of the gas-dynamic spraying technological parameters, which in turn are interrelated with its operational properties. Under the technological parameters there were considered the layer overlap coefficient and the air flow temperature, and their influence on the corundum content in the coating layer, the Coherent scattering regions size (CSR), and the value of crystal lattice microstrains were estimated.

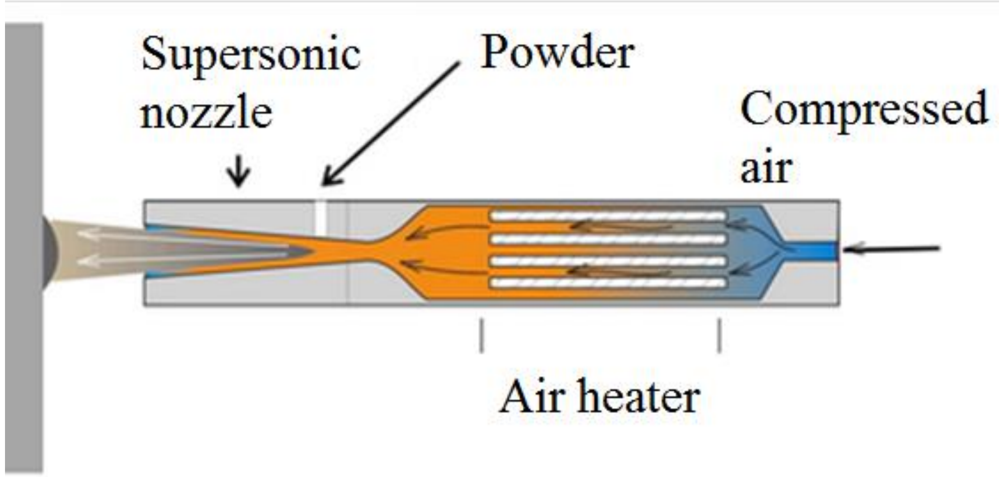

Fig.1 - The scheme work nozzle gas-dynamic installation «DIMET»

Steel AISI 5135 grade was used as a substrate. Using DIMET-404 gas-dynamic unit the coating of the particles mixture of copper, zinc and corundum was applied at a speed of the spraying nozzle movement of 10 mm / s, the distance from the nozzle exit of 10 mm and temperatures of air dispersed by the nozzle of 270° C, 360° C and 450° C. The quantitative composition of the mixture by weight was Cu: Zn: Al_2O_3 = 35%: 35%: 30%. The mixture was prepared at the Obninsk center for powder spraying. The grade is C-01-11 by DIMET . The samples size was 15x15 mm, the spraying surface area was 225 mm^2.

To apply a uniform coating, the nozzle was displaced with overlapping of the previous layer by 64%. The displacement was 2 mm and 55% at displacement of 3 mm, while the nozzle performs a reciprocating motion.

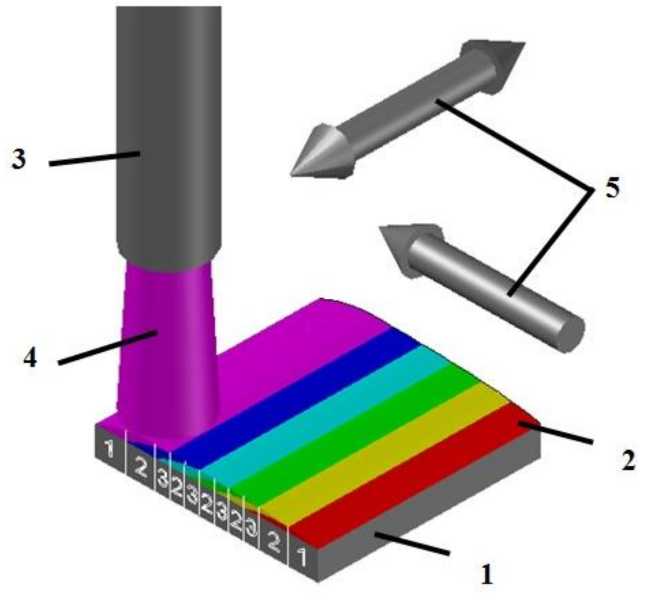

Fig.2 - Scheme of coating application by gas-dynamic spraying with 64% overlap: 1 - substrate, 2 - applied coating, 3 - nozzle, 4 - sprayed particles flow, 5 - nozzle movement direction, numbers - border and number of times of repeated processing, color - layer, formed in one nozzle pass, letters - alphabetical order of layers application

Nozzle displacement of 2 mm resulted in the appearance of areas exposed to particles exposure and heated air flow three times, while at displacement of 3 mm, the surface was subjected to a more uniform treatment no more than two times .

Table 1. - Influence of nozzle displacement on the spraying area.

Nozzle displacement, mm	Overlap coefficient %	Area mm^2 exposed to particles, times		
		1	2	3
2	64	20	90	112.5
3	55	74	148.5	-

X-ray diffraction phase and micro-X-ray spectral analyzes revealed that the coating structure consisted of metals (copper, zinc) and electronic type compounds "ε" and "γ" - phases inherent in copper and zinc alloys (brass)

Table 2. - Influence of the air flow temperature on the coating phase composition.

T°C	Mass fraction of metals and phases, %							
	Cu		Zn		ε – phase		γ - phase	
	Nozzle displacement, mm							
	2	3	2	3	2	3	2	3
270	87.9±1.0	83.8±0.8	1.44±0.17	1.3±0.1	5.3±0.9	8.5±0.9	-	-
360	62.0±0.9	69.0±0.7	7.9±0.6	12.6±0.6	7.9±0.8	10.4±0.5	17.0±2.0	-
540	40.5±0.8	56.0±0.8	9.0±0.6	24.0±0.6	11.4±0.7	12.0±0.7	33.0±0.2	-

The coating structure and properties were affected by two factors: deformation and crushing of the initial powder particles, which occurred due to their collision with the sprayed surface, corundum and with each other, as well as heating. The calculations performed earlier revealed that the particle during the spraying did not heat up above 80˚C, therefore, it was heated after spraying on the surface, when the temperature in the coating formation zone was 90% of the air flow initial temperature. The deformation and heating of the particles occurred with a minimal time difference; therefore, minor changes in the process led to significant changes in the resulting coating properties. With the overlap of 55%, a more dispersed structure was formed, since exposure time had less effect on heating.

The air flow temperature increase led to the particles energy flow increase, which in turn increased their deformation. The microdeformations decrease occurred due to the subsequent heating by the air flow and the return (rest) processes course. A large amount of deformation contributed to the lower heating for triggering the processes of the boundaries rearrangement and migration of atoms.

The results of CSR study and microdeformations revealed that during gas-dynamic spraying of coatings, the metals deformation took place at the low coating heating temperature, while zinc under the impact of corundum was destroyed into small parts without significant microdeformations along the crystallographic planes.

The change in the "c" zinc parameter occurred due to the implanted atom with its increase and because of vacancies with its decrease, under the action of diffusion processes on it.

The change in the corundum content in the coating with increasing temperature is associated with the increase in the coating thickness up to two times and the corresponding increase in the angle of coating spraying depending on the overlap, which led to a greater reflection of corundum particles and less fixation of its fragments in the coating.

Conclusion

As a result of the studies carried out, it was possible to reveal that the gas-dynamic coating spraying based on the particles mixture of copper, zinc and corundum was accompanied by deformation and grinding of metal particles.

With the overlap of 64% and the increase in the air flow temperature, CSR of copper decreased from 200 to 90 nm, and with the overlap of 55%, the temperature did not affect CSR, which ranged from 21 to 62 nm.

CSR of zinc decreased from 200 to 64 nm with the overlap of 64% and the temperature increase, and the overlap of 55% also had no effect on CSR of zinc, which ranged from 20 to 24 nm.

CSR ε – the phase increased from 71 to 87 nm with the overlap of 64% and decreased from 36 to 21 nm with the overlap of 55% with the increase in the spraying temperature.

CSR γ - the phase was detected only at 64% overlap and decreased from 200 to 62 nm with temperature increase.

Microstrains in copper particles with the increase in the spraying temperature decreased from 187% to 119% and did not depend on the overlap.

Microstrains of ε - the phase increased from 0.11% to 0.21% with the increase in the air flow temperature and did not change with different overlap.

The γ - phase, air flow temperature have decreased by half.

The corundum content decreased from 5.4% to 2.2% at 64% overlap and increased from 5.9% to 8.0% at 55% overlap with air flow temperature increase.

Conclusion

At spraying temperature of 450°C, the phase analysis revealed zinc oxide with a mass fraction of 4.3 at.%.

The mechanical and tribological properties of the coating under study were significantly influenced by both the presence of phases and their number, and the magnitude of microdeformations arising in the process of collision of metal particles with the surface and corundum particles, as well as the size of CSR, that is, small fragments into which particles can be crushed during stress on the surface and collision with each other. By varying coating structure certain properties, it is possible to significantly increase the products operational characteristics, which is planned to be done at the next stages of work.