Surface quality of the plasma cermet coatings after grind finishing

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Abstract. The paper presents the study results of the grind finishing effect on the surface quality of cermet wear-resistant coatings obtained by plasma spraying of mechanical mixtures. The main component for the formation of mixtures was alumina with additions of nickel or cobalt powders. The sprayed compositions surface analysis indicates the structure specificity of cermet coatings. The presented typical images of topographies and profilograms of the investigated compositions surfaces show that coatings of nickel-ceramic mixtures have an acceptable level of roughness after grind finishing.

1. Introduction

Finishing machining of wear-resistant plasma coatings is designed to form the required geometric and dimensional accuracy, as well as the surface roughness of machine parts. The main method of finishing the sprayed coatings is grinding. Despite the lower performance compared to other methods of machining, grinding is a more efficient method for processing plasma coatings. The technological capabilities of grinding process are more versatile in terms of both the implementation method and the surface hardness level to be machined [1-7].

Since plasma wear-resistant coatings possess high physico-mechanical and operational properties, the grinding process is accompanied by certain difficulties. Compared to homogeneous materials, sprayed coatings are characterized by a more complex level of stress-strain state associated with their structure specific character, the presence of a transition boundary and the occurrence of thermal stresses due to different thermal expansion of the coating and the substrate. Additionally, the sprayed layer has a laminar structure and incorrectly selected machining modes can cause defects in the form of cracks, splintering and delaminations.

The papers [8-14] analyze the formation of wear-resistant metal-ceramic plasma coatings whose grinding is of particular research interest.

Ceramic coatings of alumina have high hardness, but at the same time, they are characterized by substantial brittleness leading to their destruction when shock loads occur. The use of metal bond ceramics is a promising direction for improving the quality and performance of wear-resistant coatings. This method allows combining highly rigid and more plastic components in one composition, thus providing an efficient balance of properties [11].
The preferred technology for the formation of cermet coatings is the process of powder mixtures plasma spraying. This technology has high production capacity and low labor intensity. Besides, it allows mixing dissimilar components, and, by changing their composition and ratio, controlling the properties of the obtained coatings [10-12].

However, the heterogeneity of the components further complicates determining the technological modes of grind finishing. The presence of alloying elements and hardening phases of oxide ceramics adversely affects the durability of the cutting tool whose physico-mechanical properties are almost comparable with those of coatings. Thus, the finishing machining of composite coatings has its own specifics and requires research.

The paper aims at studying the grind finishing effect on the surface quality of cermet wear-resistant coatings obtained by plasma spraying of mechanical mixtures.

2. Materials and methods
Two compositions of specific formation powder mixtures described in the previous work [11] were used to study the surface quality of the cermet coatings after finishing machining by grinding. The main component in both compositions was $\text{Al}_2\text{O}_3$ powder; an additional component in the first mixture was PG-12N-01nickel powder, and in the second one it was PGN-V3K cobalt powder.

3G71 model surface grinder was used for finishing machining of the sprayed surfaces. Workpieces were based on the machine table by a magnetic holding plate. Grinding was carried out with a 300 mm diameter abrasive wheel of green silicon carbide with grains of 80 (F24) grit number. The wheel was of medium hardness (L) with an open structure (8) on a bakelite bond (B).

The cutting speed during grinding corresponded to 35 m/s at a spindle speed of 2250 min$^{-1}$. The cross feed was 0.3 mm on the double stroke of the table. The working stroke was 100 mm (including the workpiece length and overrun), the speed of the longitudinal movement of the table was within 11...14 m/min, which corresponded to the frequency of 55 ... 70 double strokes per minute. The value of the cutting depth was set within 0.02 ... 0.03 mm. The removable allowance for finishing machining of plasma coatings was 0.1 ... 0.15 mm (with a thickness of the sprayed layer of 0.50 ... 0.54 mm). Aqueous solution with the addition of 2% NaNO$_3$ at the flow of 2.4 l/min was used as the lubriccoolant. Grinding was performed in several passes and was completed with a sparking-out process.

The topography study and the measurement of the coatings surface roughness after the finishing machining was carried by Zygo New View 7300 research complex.

3. Results and discussion
Figure 1 shows the images of the sprayed cermet compositions surfaces obtained using a Carl Zeiss Axio Observer Alm scanning microscope [11].
Both images demonstrate a uniform distribution of the mixtures components and clear boundaries between them. Dark areas are the particles of oxide ceramics; lighter areas are particles of nickel and cobalt powders. The average porosity value for both compositions does not exceed 6...8%. Owing to the segregation effect during plasma spraying, the ratio of components in the resulting cermet coatings differs from the ratio in the mixtures before spraying.

Grind finishing of cermet coatings was carried out in the whole range of the specified cutting conditions with intensive forced cooling. Lower cutting mode processing was applied to the sprayed coatings as compared to homogeneous materials of similar hardness. This mode prevented such a defect as coating delamination from the substrate which occurs at high values of cutting force and insufficient adhesion strength. The absence of thermal cracks on the machined surfaces proves the fact that there was no excessive thermal effects during grinding. Correctly selected abrasive wheel characteristics and its timely dressing allowed for minimum clogging and a stable renewal of the cutting surface during grinding. In general, the investigated coatings proved to be machinable by grinding, despite the heterogeneity of its components physical and mechanical properties.

Figures 2 and 3 represent the results of finishing processing studies in the form of topographies and profilograms typical images of the corresponding cermet coatings surfaces. The surface microrelief is formed differently at grinding of sprayed coatings and homogeneous materials.

Figure 2. Nickel-ceramic mixture coating after grinding: a - surface topography; b - surface roughness

Figure 3. Cobalt-ceramic mixture coating after grinding: a - surface topography; b - surface roughness
The presented surface topographies of the coatings after grinding reveal open porosity which has a significant impact on the roughness value. When abrasive grains penetrate into the coatings, it is the pores that are stress concentrators and have a significant impact on the development of microcracks and material delamination during grinding. Additionally, the presence of open porosity eliminates the possibility of using such finishing operation as polishing, since the abrasive material clogs into the pores creating scuffs on the interfacing surfaces.

The surfaces profilograms reflect an irregular distribution of microasperities depending not only on the grinding process but also on such structural characteristics as the degree of the powder particles meltedness and the cohesive bond strength between them.

Research results showed the ambiguous impact of the grinding process on the coatings surface roughness. The nickel-ceramic coating surface has a low level of roughness \( Ra = 0.45 \) µm. The opposite pattern is traced in a cobalt-ceramic coating. Since the cobalt-ceramic coating has a rough surface after grinding, the resulting topography and profilogram reveal clearly visible "blanks" beyond the resolution of the device. The approximate value of the cobalt composition roughness is \( Ra = 3.00 \) µm, which does not correspond to the nature of the finishing processing. This effect is due to the ejection of cobalt powder particles from the structure of the coating in the grinding process.

4. Conclusion

The absence of thermal cracks and the coating delamination from the base on the machined surfaces confirmed the correctness of the selected grinding modes and abrasive tools. Grind-finished plasma coatings are characterized by open porosity which has a significant impact on the microrelief formation and level of roughness.

The surface of the nickel-ceramic coating has an acceptable level of roughness after grind finishing machining, which allows providing geometric and dimensional accuracy and using these cermet coatings to harden the parts of various process equipment operating under increased wear conditions.

The machining of cobalt-ceramic coatings did not produce the expected results. The surface roughness of these coatings with a lot of blanks after grinding is explained by the low cohesive bonds between the components of this mixture. The practical use of cobalt-ceramic mixture coatings requires optimization in both grinding modes and plasma spraying modes in order to form a structure with better characteristics.

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