VIBROABRASIVE TREATMENT OF ULTRA-HARD CERAMICS

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Abstract. The article reveals a possibility of treating ultra-hard nitride ceramics by means of vibro-abrasive treatment. It was proved that the value of residual stresses of the second kind in ceramic samples sufficiently reduced after such treatment. Also it was confirmed experimentally that material removal increased with time. The article contains Difractograms of the surfaces. The surface quality of nitride ceramics was thoroughly analyzed. The grade of abrasive material was determined practically.

1. Introduction

Foreign and domestic experience shows that the role of tools is growing more and more at operations with mechanical treatment, which are characterized with increased thermo-power loads at high speed cutting, at treatment of parts, made of quenched, heat-resistant steels and alloys and also various composite materials.

The work has been constantly gone on, in search of creating maximally universal tool materials, that would be able to ensure high exploitation indices of metal treating tools at their different exploitation conditions. The quality of treated surfaces and intensification of production have always been of paramount importance for researchers in the domain of metal treatment. Therefore, it is necessary to seek ways of improving these factors. Application of new high-strength materials as tool cutting plates seems to be one of these ways.

A great number of researchers dealt with solution of problems with treatment of ultra-hard nitride ceramics. Among them such scholars like, Childs T, Maekawa K., Obikawa T., Yamane Y., Sumiya H., Harano K., Ishida Y., Sugihara T., Tanaka H., Enomoto T., Rogov V. A., Shkarupa M. I., Grishin D. K., Halpin T., Byrne G., Barry J., Ahearne E., Yamaguchi H., Srivastava, A. K., Tan, M., Hashimoto F. and many others, who investigate ultra-hard materials, their production and application may be mentioned. They investigate treatment with diamonds of technical ceramics, strength of cutting ceramics, they study the influence of the state of blades edges of cutting tools upon efficiency of cutting tools. Also, they study rapid diamond treatment of technical ceramics. So far, the researchers have failed in succeeding in finding a complex solution of the problems, which they are facing. Thus, we may conclude that the problem of treating ultra-hard ceramics remains quite urgent. One of such solutions is vibration treatment.
2. Experimental Methods

Samples with cylindrical shape were treated at experimental studies, they were made of ultra-hard nitride ceramics, on the basis of cubical boron nitride (hereinafter CBN) ”composite 05 IT”(NK18–20 HPa) Ø 7.0 mm in height and 3.2 mm in width.

As workspace suspension on the basis of monocorundum, with diamond cut according to FEPA F100 (acc. to SSU 12 grain size – 150–125mcm) comprising 90% of the entire volume, added with powders of various artificial diamonds (UDA, AC6, ACM) 5%, 10% and 15% in concentration of the entire abrasive volume.

Figure 1 represents the diagram of the laboratory unit. The unit was assembled on a rectangular platform (1) and had four spring supports (2). An unbalanced vibrator-motor was installed between the supports (3) an operating chamber being place don the platform (4).

![Figure 1. Laboratory vibro-unit.](image)

The samples were treated for 10, 20 and 40 minutes. The amplitude of vibration was 5mm, the frequency was~25-30Hz. A ceramic plate in its original state was considered to be a reference sample.

In order to determine the values of alternations of internal stress due to power and thermal influence occurring at treatment of ultra-hard ceramics, ceramic samples without any treatment and after treatment with different time spans (after 10, 20 and 40 minutes) were investigated, after that an X-ray inspection was carried out with application of DRON-4-3 diffractometer. The results of the X-ray analysis were processed with application of MathCAD program.

It was found out that the value of residual stresses of the second type in the samples decreased from 697 MPa prior treatment to 409 MPa after 40 minutes treatment.

For determination of the influence of vibration treatment upon tools strength cutting picks were used, equipped with cutting plates in initial state and after treatment with different time spans. A blank, made of 45 (45-50 HRC). Steel was ground.

3. The results of investigations

At vibro-abrasive treatment material is removed due to the action of vibration force, because of simultaneous action of three mechanisms: shearing, tearing and micro-cutting. The amount b of removed material is but one of the principal indices of productivity of any treatment method. Vibro-abrasive treatment of ultra-hard ceramics is not an exception. The index, that determines the value of material removal and, thus, productivity as well is the time of treatment [1]. The diagram, showing the dependence of the value of material removal upon time is shown in Figure 2.
The experiments confirmed the correctness of the theory that the longer the treatment lasted the more material would be removed. In this case ultra-hard ceramics will not be an exception.

The surface quality, determined by roughness is another important productivity index. The surface roughness was measured in five directions, pictured in Figure 3, in order to exclude random results.

**Figure 2.** Dependence of the value of material removal upon time of treatment.

**Figure 3.** Orientation of directions for measuring the height of micro-unevenness on the surfaces of each specimen. (×500).

Figure 4 represents profilometry of specimens’ surfaces after 10, 30, and 40 of treatment in one direction.

After treatment for 10 minutes,  
Ra 0.21

After treatment for 30 minutes,  
Ra 0.19

After treatment for 40 minutes,  
Ra 0.11

**Figure 4.** Profilometry diagrams of the surfaces of ultra-hard ceramics after treatment.
The investigations showed that in accordance with profilometry diagrams of surface treatment (Figure 4) after 10, 30 and 40 minutes treatment the smallest roughness turned out to be Ra (3) = 0.13 mcm after 30 minutes treatment.

These conclusions can be verified by images of the fragments of surfaces beyond which the treatment had been done. It can be seen that the most even surface was the one, represented in Figure 5-a that corresponds to 30 minutes treatment. Below (in Figure 6) there are fragments of the surfaces after treatment [2].

![Figure 5. The state of the surface of the specimen (×500).](image)

Analyzing the profilometry diagrams we arrive at a conclusion that the highest quality of treatment was made by means of the mixture of monocorundum and the powder of artificial diamond UDD, 10% in concentration. The average value of Ra was = 0.11. The diagrams confirm the figures (see Figure 6), executed in 3d format. On them the differences of specimens’ profile, treated with different materials are quite visible.

![Figure 6. The surface profile of the plate after treatment in 3D mode, the time of treatment was 30 minutes, as the tool the mixture of the powder of monocorundum and UDD artificial diamond was used (×1,000).](image)

Application of diamond tools ensured precision and quality of treatment, bigger service life and reliability of operation of machines and instruments [3]. Beside the problem of application of diamond as an additive for treatment, it was important to determine the amount of added powder. In Figure 7 dependence of powder concentration upon the intensity of treatment is shown.

![Figure 7. The influence of diamond powder concentration upon the value of material removal.](image)

Analyzing this dependence we may arrive at a conclusion regarding the advisability of applying a certain concentration of diamond powder. At vibro-abrasive treatment of nitride ceramics with
application of diamond powders in concentration 10% and 15% the value of material removal is approximately equal and it’s sufficiently higher than at application of 5% amount. The same picture is observed at application of mixtures with all diamond powders used. Finally, we may conclude that as the difference in removed material with 10% and 15% is about the same it would be rational to use 10% additive, due to economical reasons. The investigation showed that the most productive treatment was vibro-abrasive treatment with application of mixtures, containing the powder of UDD artificial diamond (see Figure 8). It can be explained by the capability of diamond particles to maintain its cutting ability due to constant micro-shearing of contact sections as a result of vibration and shock loads in the treatment area.

![Figure 8](image)

**Figure 8.** The influence of the diamond powder grade upon the value of material removal at the treatment of ceramics.

Application of mixtures with monocorrundum and diamond powders at different concentrations for vibro-abrasive treatment has a sufficient influence upon the value of removal from NPUM (non-regrowth plates made of polycrystalline ultra-hard materials) specimens. As can be seen in the figure application of diamond powders in suspension alongside with monocorrundum raises the value of material removal drastically.

In our investigation some attention was paid to the presence of residual stresses in ceramic specimens. The results of experiments, aimed at removal of the concentration of residual stresses are shown in Difractograms, in which peaks, caused by alternations of the matrix by residual stresses were shown as extremes. Difractograms [4] were made at different double reflection angles for the same specimens, made of ultra-high nitride ceramics are shown in Figure 9.

Analyzing the Difractograms of the surface of cutting plates, made of ultra-hard ceramics we can conclude that the highest index, characterizing the value of residual stresses is seen on the plate that did not undergo treatment and it sufficiently reduced alongside with the growth of the treatment time. The identical picture can be observed for the analysis of difracograms, prepared at different double reflection angles. The character of difractograms testifies that by applying vibro-abrasive treatment it is possible to reduce internal stresses in the material.
1 – with initial conditions; 2 – at 20 minutes treatment; 3 – at 30 minutes treatment; 4 – at 40 minutes treatment, with reflection angles α – 53°; β – 63°; γ – 97°; ρ – 124°.

Figure 9. Difractograms of ceramic specimens, made of “05ІТ composite”.

4. Discussion
Analyzing the data, obtained experimentally it is necessary to mention a solution for the problem, which we believe to be quite interesting, that lies in reduction of the concentration of internal stresses in ultra-hard ceramics. It can increase the service lives of cutting plates, made of ultra-hard ceramics, virtually, by 2-2.5 times.

Of interest also is the result of material removal, which was shown by artificial diamonds of manifested UDD grade, it can be explained only by their fine dispersity (as compared to DS6 and DSM diamond grades) and, hence, by growth in the contact patch of the abrasive material with the part. The time of treatment, determined during the investigation is also of interest.

5. Conclusions
So, it was found out that for intensification of treatment it is necessary to add an artificial diamond powder of UDD grade into the abrasive mixture, amounting to 10% of the entire volume.

The surface of the specimen, treated with the mixture of monocorrundum and UDD diamond powder in 10% concentration possesses more uniform surface in comparison with other specimens, the parameter of roughness of ceramic plates after vibration treatment can be to Ra = 0.11, it being substantially lower, as compared to other specimens, the presence of residual stresses in the cutting plates, made of ultra-hard ceramics leads to a decrease of their service lives, while abrasive treatment reduces the concentration of internal stresses within 40 minutes of treatment from 697MPa to 409MPa, the character of reduction of residual stresses being the same on difractograms while watching at different double reflection angles, it characterizing the stability of the process of relaxation, whilst further treatment of ceramic parts in time will not produce a positive result, as it means excessive consumption of working time, power and mechanical resources.

The situation in favour of decreasing the value of internal stresses in ultra-hard ceramics can be changed only by application of vibro-abrasive treatment.

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