KAPITEL 4 / *CHAPTER 4*
USE OF VIBRO-CENTRIFUGAL METHOD FOR PROCESSING PARTS FROM SUPERHARD CERAMICS

ВИКОРИСТАННЯ ВІБРОВІДЦЕНТРОВОГО СПОСОБУ З МЕТОЮ ОБРОБКИ ДЕТАЛЕЙ З НАДДТВЕРДОЇ КЕРАМІКИ

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Introduction

During the development of the country's economy, special attention should be paid to the technical re-equipment of all sectors of the national economy. In particular, it is recommended to pay special attention to the development and implementation of high-quality tools and the use of new progressive cutting materials for new technological processes.

The main task in the field of mechanical engineering is to increase productivity, efficiency, reliability and durability of manufactured parts, and to reduce labor intensity. But the machining of progressive super-hard cutting tools is difficult and costly.

4.1. Selection of tool materials for machining superhard ceramics

The development of modern mechanical engineering is associated with the development and implementation of the latest materials and progressive technological processes for their processing. The unique properties of ceramics make it possible to use it in various fields of technology, including as cutting tools and parts of machines, devices and electronic equipment. Due to the high rigidity of the material, machining of workpieces is possible only with the use of synthetic diamonds [1]. Basically, ceramic cutting inserts (CCI) are used in continuous semi-finishing and finish turning. In these processing operations, they have an advantage over traditional cutting materials in terms of rigidity, wear resistance and chemical inertness to most of the processed materials. An important quality of ceramic plates is their ability to maintain high rigidity at sufficiently high temperatures arising in the tool-machined material contact zone.

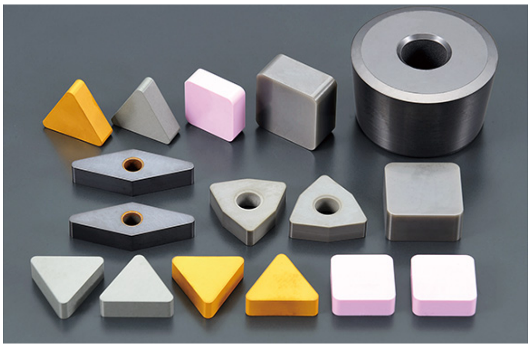


Figure 1 - Appearance of ceramic plates used as cutting material

Since all ceramic parts are brittle, they tend to crack under stress from a cutting or grinding tool. A point load with a sufficiently small plastic deformation leads to the fact that, under the influence of diamond grains, the ceramics, feeling strong mechanical and thermal loads, crumble; As a result, a groove appears, the width of which exceeds the area of collision of the diamond grain with the material, and cracks (longitudinal, radial, lateral chips and other defects of brittle origin) appear in the areas adjacent to the groove, which has a significant effect on the quality of the processed products and their resource works for consumers. Studies have shown that the most productive is vibro-abrasive processing using a suspension containing diamond powder SDM 20/14 (Fig. 2). This is due to the ability of SDM 20/14 diamond particles to maintain their cutting ability due to constant micro-spalling of the contact areas as a result of vibration and shock loading in the processing zone.

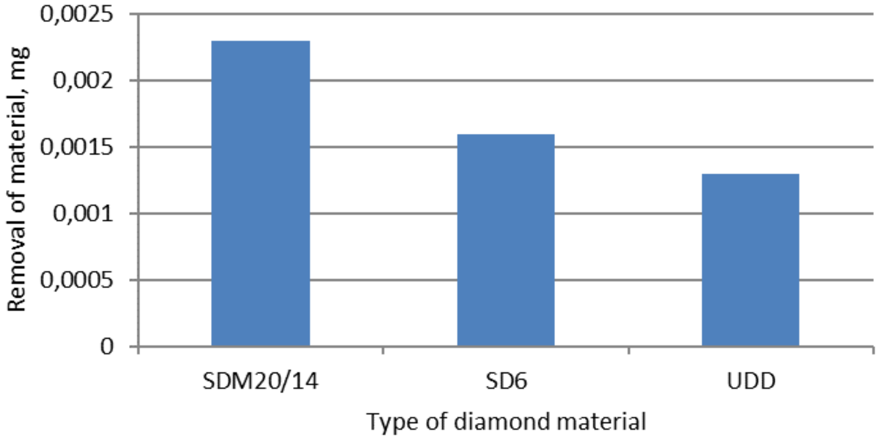
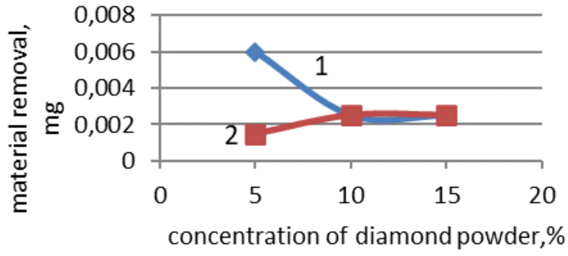
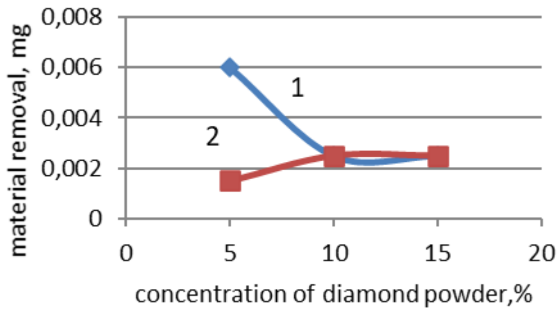


Figure 2 - Influence of the brand of diamond powder on the amount of removal when processing a sample of PCSM brand "Borsinite"

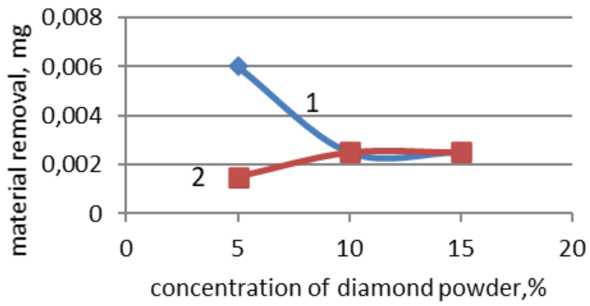
The use of suspensions with monocorundums and diamond powders in different concentrations during abrasive processing significantly affects the amount of removal from PCSM samples (Fig. 3). As can be seen from the figure, the use of mono-corundum in the suspension in addition to diamond powders significantly increases the removal rate. It should be noted that when processing samples in the form of plates, the removal rate is significantly higher, which is probably determined by its area. This is especially important when using SDM20/14 diamond powder in a suspension (Fig. 3, a). For simultaneous processing of both types of samples, the best result occurs when the concentration of diamond powder is 10%. This applies to all studied diamond grades. From a comparison of the results shown in Fig. .3, a, b, it can be seen that the removal of material during abrasive processing of plates with PCSM using a suspension with SDM diamond powder is higher than that of SD6 diamond. This result is due to the difference in the mechanical properties of SDM20/14 and AS6 diamond particles [2]. The amount of material removed at a concentration of 15% SDM20/14 diamond powder testifies to the widespread truth - "the more, the better", that is, the higher content of diamond powder in the suspension causes the intensification of the removal from the PCSM sample.



a



b



c

a – SDM20/14; *b* – SD6; *c* – UDD (1 - plate; 2 - cylinder)

Figure 3 - Influence of the concentration of diamond powder in suspension on the amount of material removed from the sample

When using a suspension with UDD diamond powder at a concentration of 5%, cylindrical PCSM samples are most effectively processed. In this case, the largest contribution to the amount of removal is made by mono-corundum powder, however, in terms of the absolute amount of removal it is inferior to the case of using suspensions with diamond powders SDM20/14 and SD6. When abrasive processing of two types of PCSM samples using suspensions with SD6 diamond powder at concentrations of 10% 15%, the amount of material removed is approximately the same (Figure 3, b). A similar picture, but with a lower absolute magnitude of the survey, is observed when using a suspension with UDD diamond powder. In these options, focusing on the economic factor, it is better to use suspensions with a diamond powder concentration of 10%.

4.2. Surface quality of ceramics after vibro-centrifugal treatment

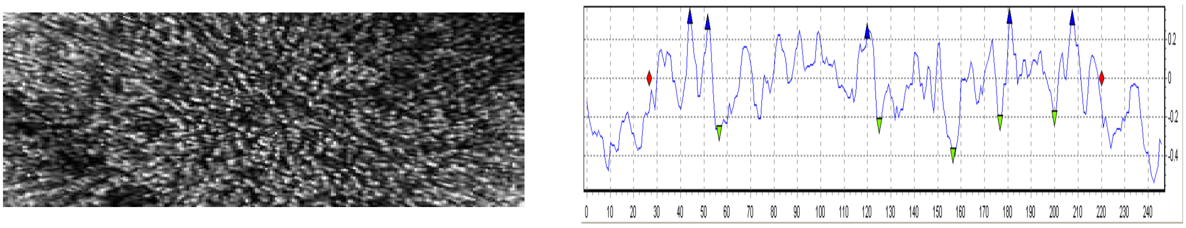
Ensuring high quality of machined mechanical engineering products, their operability in operation is associated with the need to form the necessary parameters of roughness and state of the surface layer at the working sections of cutting tools [3]. Traditionally, the finishing treatment of the surfaces of tools is carried out by methods of diamond abrasive processing - both bound and free abrasive. A promising finishing method is vibroabrasive machining [59], which allows not only to reduce the roughness of the surfaces of tools, but also to control the value of the radius of rounding of their cutting edge. Until now, there is experience in the use of such processing in the manufacture of cutting tools equipped with a working part of hard alloys. Taking into account the wide distribution and high cost of tools made of superhard polycrystalline materials (PCSM) based on cubic boron nitride (CBN), it is of considerable scientific and practical interest in improving the methods of their manufacture. Vibration-abrasive machining as a finishing method, which in traditional applications is characterized by high productivity and is effective when it is necessary to ensure a high quality of the processed surface, can be quite effective in this case. It should be borne in mind that products made of PCSM have high rigidity, are difficult to machine and the process of their vibro-abrasive processing is characterized by a number of significant features. The quality of the processed surface during vibration processing of superhard ceramics was determined on a non-contact interference 3-D profiler "Micron-alpha", shown in Fig. 4, the purpose for the registration and analysis of microfotography of surfaces by the method of processing a sequence of interference patterns in the white world, namely [4]:

Figure 4 - Non-contact interference 3-D profilograph "Micron-alpha" [5]

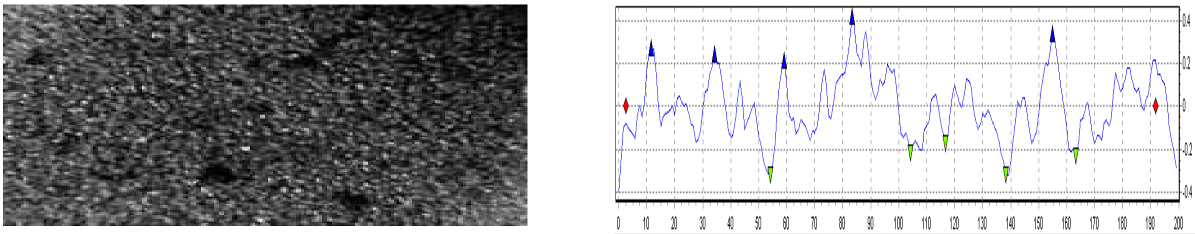
Non-contact interference 3-D profilograph "Micron-alpha" can:
- build 2D and 3D surface profiles;
- quantify the characteristics of the surface;
- calculate the volume of the protrusion (depression):
- observe interference patterns [5];
- to carry out metallographic studies.

Technical characteristics of the "Micron-alpha" device Scanning field (XY) μm 100 × 90 (1300 × 1000) Horizontal resolution (XY). Mcm 0.16 (2) Maximum measured relief height (Z), μm 40 (120) [115] Vertical resolution (Z) nm 3 (5) Time of 3D topography acquisition, min. 0.5 - 5 [115] In fig. 6.5 shows profilograms and fragments of the surface of the samples after 10 min of treatment.

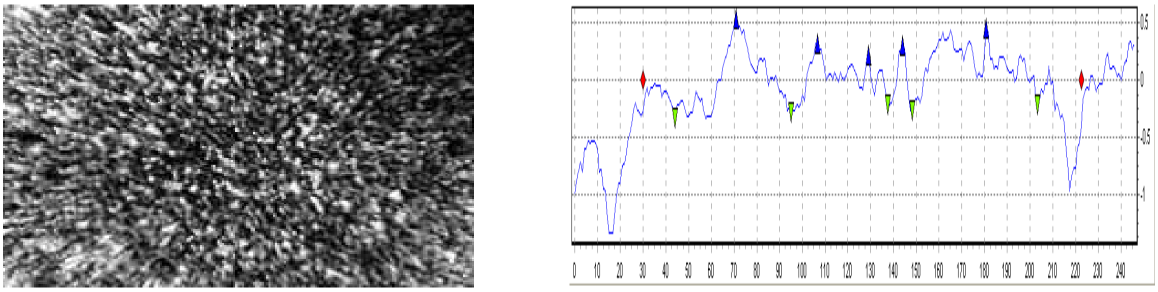
Analyzing the profilograms, we conclude that the highest quality processing took place with a mixture of mono-corundum and UDD diamond powder at a concentration of 15% [6]. Average Ra = 0.11. In the process of removing shavings during diamond grinding of ceramics, individual diamond grains are involved in conjunction with a bunch of tools. When studying the nature of the destruction of the



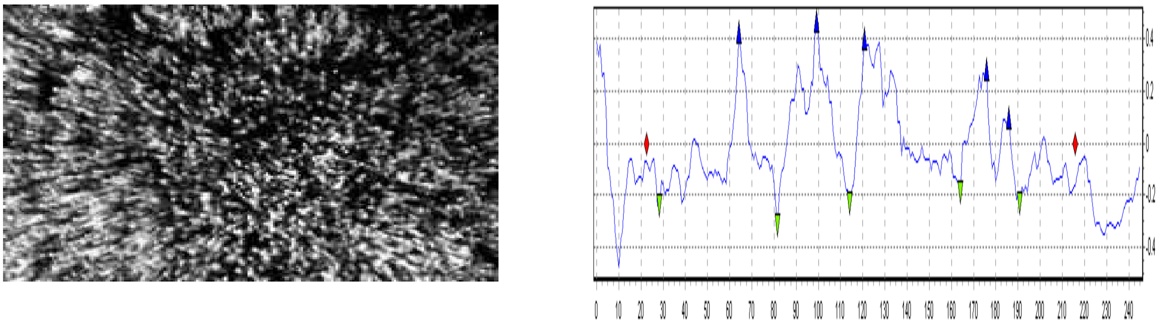
a) monocorud + SDM diamond powder at a concentration of 15%. Ra = 0.11



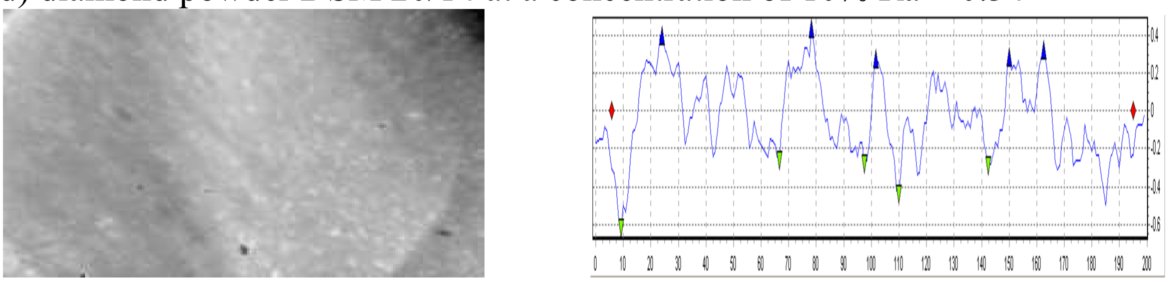
b) UDD diamond powder at a concentration of 10% Ra = 0.12



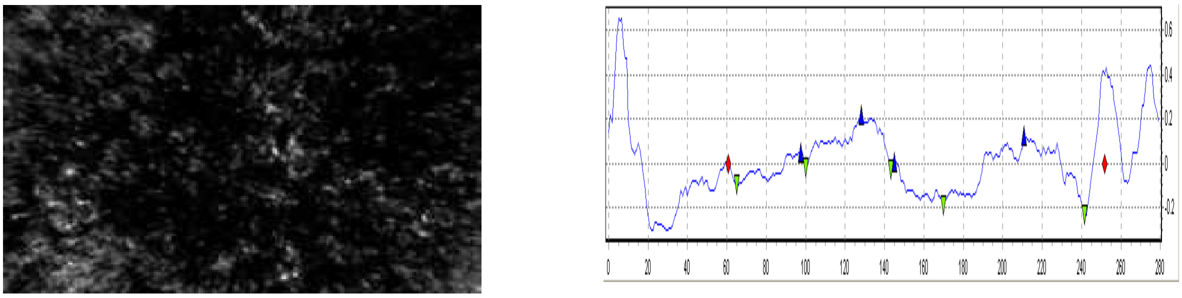
c) diamond powder SD 6 at a concentration of 10% Ra = 0.14



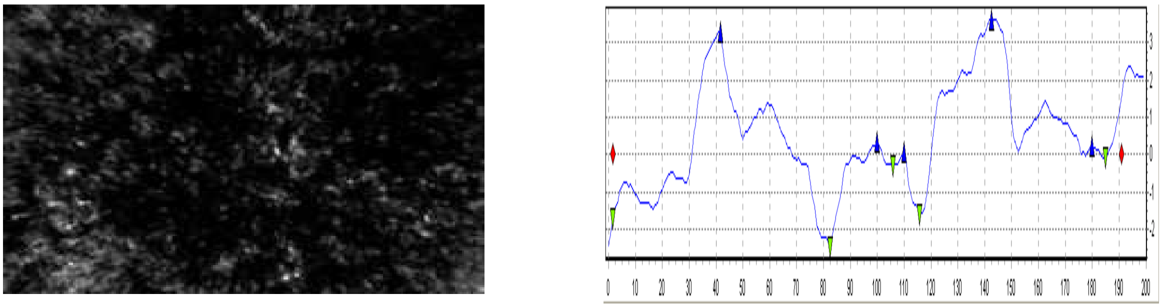
d) diamond powder DSM 20/14 at a concentration of 10% Ra = 0.34



e) diamond powder SD 6 at a concentration of 10% + mono-corundum Ra = 0.18



f) a mixture of diamond powder UDD + mono-corundum Ra (4) = 0.14

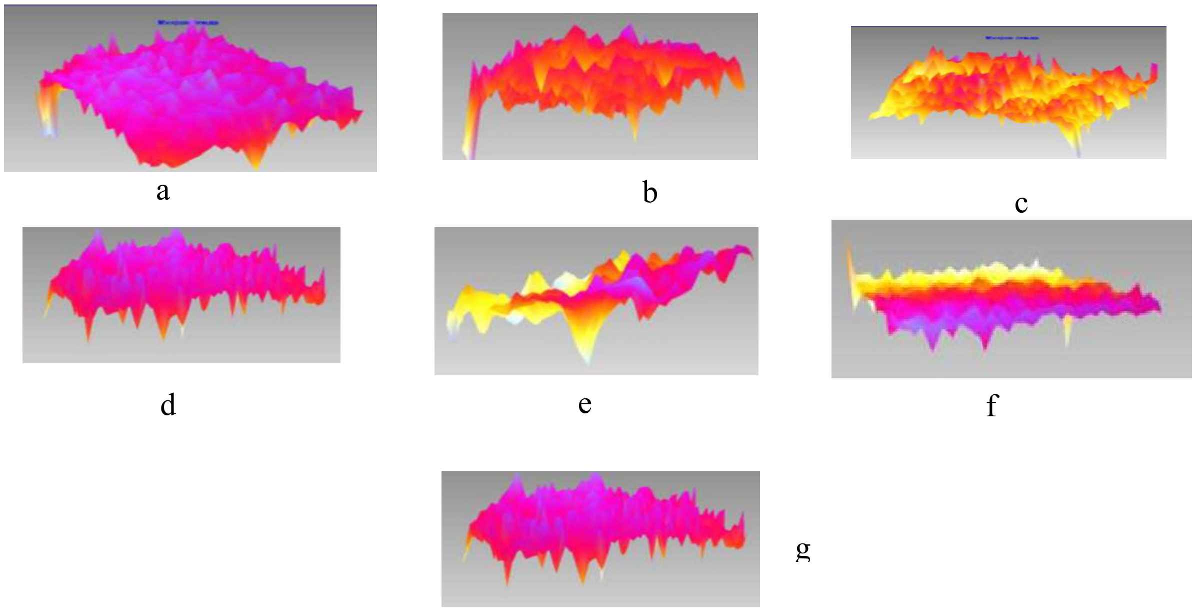


g) a mixture of mono-corundum and white electrocorundum Ra = 1.13

Figure 5 - Profilograms of surfaces

ceramic surface by a diamond grain, it was found that the grain at the beginning and end of the scratch leaves a clear trace without obvious chips along the edges of the trace. A diamond grain, possessing sufficient rigidity, immediately begins to cut off the chips upon contact with the material. The middle part of the scratch has significant tears along the edges along its entire length. The appearance of chips [7], which have reached a certain depth of grain penetration, is explained by the fact that with an increase in the cutting depth, all new edges of the diamond grain come into operation, in connection with which the microcutting forces in the zone of its contact with the sample material grow and are observed together with the formation of a highly dispersed shavings, large areas of material separation. The forces arising during grinding determine the stability of diamond wheels, the quality of processing and allow the choice of rational technical parameters [8]. When grinding ceramics, the state of the surface layer is highly dependent on the cutting forces. Knowledge of the regularities of the change of the latter allows you to reasonably choose the optimal processing conditions. By the nature of the change in cutting forces, one can also judge about the physical phenomena occurring in the grinding zone. The above profilograms confirm the drawings made in 3D graphics. They clearly show the difference in the surface profile of the samples treated with different materials.

The sample surface treated with a mixture of monocorundum and UDD diamond powder at a concentration of 15% looks smoother, without pronounced extrema in the negative and positive directions. Graphic 3D images confirm that the use of a mixture of monocorundum and diamond powder UDD at a concentration of 15% led to the fact that the surface relief of the samples corresponds to the highest surface roughness index [6]. Many industries place high demands on the surface quality of the materials used. This problem is relevant for the metalworking industry, when it is the surface of certain materials that provides the necessary physical effects and operating conditions



a) a mixture of mono-corundum and SDM diamond powder at a concentration of 15%. b) diamond powder SD 6 at a concentration of 10% c) diamond powder UDD at a concentration of 10% d) powder diamond SDM 20/14 at a concentration of 10% e) a mixture of mono-corundum and white electrocorundum f) a mixture of powder of UDD diamond and mono-corundum

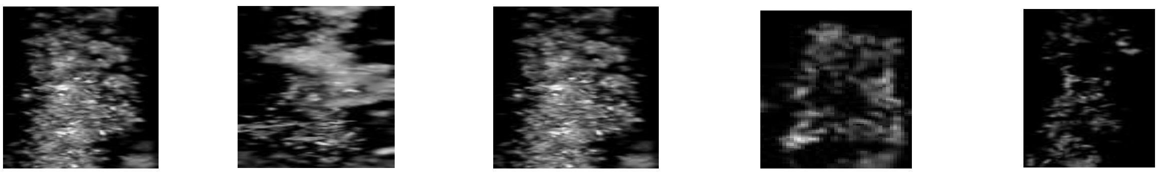
Figure 6 - Profile of the surface of the plate after processing performed in 3D mode (× 500)

of the blade tool. Improving the reliability and durability of cutting inserts, cutters', milling heads and drills is one of the main problems of the modern manufacturing industry. The economic significance of this problem is obvious. As the statistical analysis has shown, the main reason for the failure of cutters, mills and other processing tools is not their mechanical breakdown, but a gradual decrease in the quality of processing, due to and depending on the perfection of processing of cutting inserts and surface defects of these plates, and if the second factor is practically not depends on the processing of these plates, with the exception of the low skill of the processor, the first factor can be corrected using vibration abrasive processing.

4.3. Varying the radius of rounding of the cutting edge of superhard ceramic inserts

Automation of machine-building equipment, an increase in processing speeds and an expansion of the range of processed materials made it necessary to develop effective abrasive materials that retain the ability to work in extreme conditions. Due to the record hardness of diamonds, a tool consisting of mixtures with a high content of diamond composite materials (DCM) cannot be replaced by any other materials when processing products made of superhard materials, glass, ceramics, natural and synthetic materials [9]. With regard to the final machining operations of parts made of cast irons, hardened steels and non-ferrous alloys - this issue is successfully solved by using tools with cutting inserts made of oxide ceramics. The use of these tools, due to the high hardness and heat resistance of ceramics, allows many times to increase the cutting speed and efficiently perform precision machining of parts, while the technological process meets the ever-increasing environmental standards [10]. The use of tools with existing ceramic cutting inserts in previous machining operations of parts is quite effective. Of greatest interest to the industry are tools with cutting inserts made of nitride ceramics, which have a very wide range of applications. Nitride ceramics are obtained either by hot sintering or by hot isostatic pressing. A very important property of silicon nitride cutters is the high strength of the cutting edge and its reliability. In this case, it is possible to use a cooled liquid in the cutting process. According to the data of foreign companies, silicon nitride tools have proven themselves especially well when machining cast iron (even under high variable loads), as well as when machining nickel alloys and aluminum alloys with a high silicon content. Expanding the scope of tools equipped with ceramics can only be ensured on the basis of an integrated approach to their design, manufacture and operation. One of the tasks requiring an inexpensive and efficient solution in the manufacture of cutting tools is edge rounding. Edge rounding is a serious and multifaceted problem, the solution of which can significantly increase the reliability and durability of the product. The need for edge rounding can be justified by the complex of tasks facing the technologists.

This includes both surface cleanliness during machining and reduced wear on the cutting edge. In this case, the radius of rounding of the cutting edges is taken equal to 0.008 - 0.02 mm. Figure 7 shows photographs of the surfaces of the edges of different samples and the values of the rounding radius.



a b c d e

a) The treatment was carried out with a mixture of mono-corundum and diamond powder SDM 20/14 at a concentration of 15%. Rounding radius - 0.003mm. b) The treatment was carried out with a mixture of mono-corundum and diamond powder SD6 at a concentration of 10%. Rounding radius - 0.008 mm. c) Processing was carried out with UDD diamond powder at a concentration of 10%. Rounding radius - 0.007 mm. d) processing was carried out with SD6 diamond powder at a concentration of 10%. Rounding radius - 0.0076 mm. e) Processing was carried out with SDM 20/14 diamond powder at a concentration of 15%. Rounding radius - 0.006mm.

Figure 7 - Photographs of fragments of the edges of ceramic samples, which are rounded (× 500)

Thus, only for materials that are difficult to process, this value changes in the range of 0.005 - 0.04 mm. The size of the radius of rounding of the cutting edges and the rate of its formation are functions of processing time, size and abrasive type of grain. These parameters are empirically selected in each specific case. As you can see, the radius of rounding of the cutting edge is different when machining with different abrasive cutting materials. But when processing superhard ceramics, its own peculiarities appear. For productive work, you need a cutting tool that processes ceramics. Studies have shown that artificial diamonds can be such a tool, but due to the possible rise in the cost of processing, artificial diamonds make up only 15% of the abrasive mixture used in processing. The studies carried out showed the following results, given below. In practice, processing with SDM 20/14 diamonds turned out to be more productive, but the concentration of SDM 20/14 diamond material was higher than the concentration of ultradispersed diamonds. Therefore, it has been practically established that UDD processes diamond material more efficiently. Figures 8, 9, 10 show the dependences of material removal on the content of diamond powder of different grades in order, as mentioned above, to optimize the process.

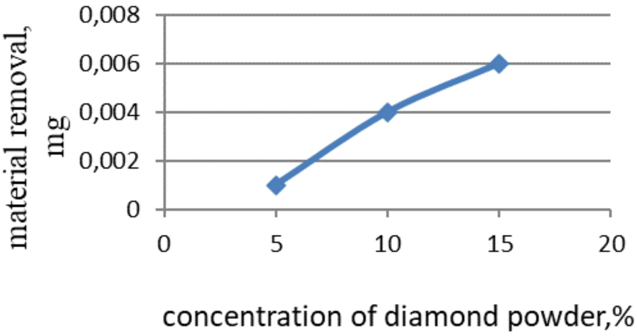


Figure 8 Dependence of the sample edge rounding radius on the content of SD 6 diamond powder in the mixture

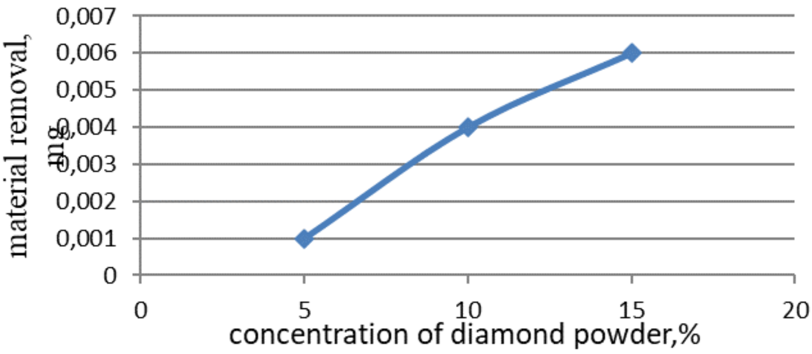


Figure 9 - Dependence of the sample edge rounding radius on the content of UDD diamond powder in the mixture

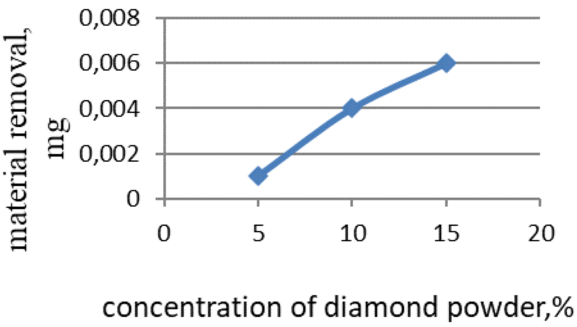


Figure 10 - Dependence of the sample edge rounding radius on the content of SDM 20/14 diamond powder in the mixture

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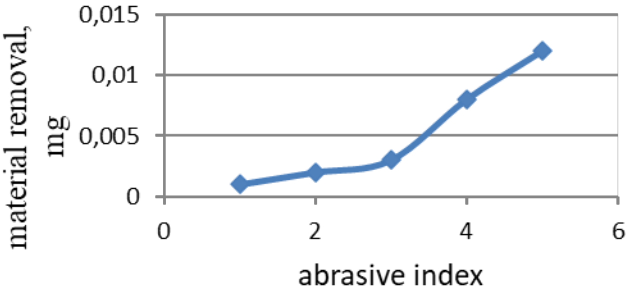
Analyzing the dependencies presented in Figures 2, 3, 4, we can conclude that the use of any of the three presented diamond powders (SDM 20/14, UDD and SD 6) with a content of 15% in a mixture with mono-corundum gives the greatest result of the rounding radius , and if we talk specifically about each powder, then the highest productivity was demonstrated by the UDD diamond powder in the amount of 15% in the mixture [8]. Explosive transformation is used to obtain UDD diamond powder. The properties of such diamonds largely coincide with the properties of natural diamonds, but differ from natural ones in the amount of impurities. Perhaps that is why their use as an abrasive and more acceptable. In order to confirm the conclusion that it is the abrasive material based on any diamond that can increase the material removal rate, a number of studies were carried out. The processing was carried out using different abrasive materials, as well as a mixture of materials. First, the samples were processed with corundum abrasive materials, then diamond materials were added to the mixture. Figure 11 shows the dependence of the amount of material removed from the used abrasive material.



1 - mono-corundum; 2 - mono-corundum + white corundum; 3 - mono-corundum + 15% ACM 20/14; 4 - mono-corundum + 15% AC 6; 5 - mono-corundum + 15% UDD.

Figure 11 - Dependence of the rounding radius on the used abrasive material (mixture)

The processing was necessarily carried out under the same conditions in order to exclude the random component of the study, namely, the constant processing time and vibration amplitude. Analyzing the dependence shown in Figure .11, we conclude that the use of ultradispersed diamonds as an additive in a mixture of abrasive powder made it possible to achieve sufficiently high results during processing, both independently and in a mixture with monocorundum. Analyzing the graph shown in Figure 12, we can make an unambiguous conclusion that the processing time has a direct impact on the radius of rounding of the cutting edge. In this regard, it is fair to assume that the longer the processing of the samples takes place, the greater the amount of rounding of the cutting edge will be. Therefore, having specified the required radius, you can choose the processing time and vice versa. The radius of the cutting edge can be matched to any type of finishing. In contrast to the wear of the flank of the tool, the radius of rounding of the cutting edge increases uniformly throughout the entire period of operation of the cutting tool. In this case, on the classic graph of the cutting tool wear, there will not appear portions of curves that are almost parallel to the time axis, which are always present on the curves of the flank wear. The used abrasive material is mono-corundum + 15% UDD.

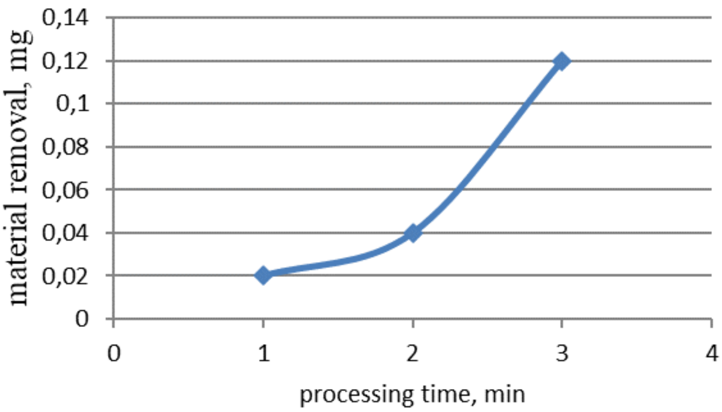


Figure 12 - Dependence of the rounding radius on the processing time

With an increase in the cutting speed and the thickness of the cut layer, the wear of the cutting insert increases. In this regard, the manufacture of ceramic cutting inserts, which allow performing not only the final, but also preliminary processing of parts, is an urgent scientific and technical problem that can be solved by using vibration processing, and an abrasive powder made of mono-corundum can be used as a cutting tool. With the addition of a certain amount of artificial ultrafine diamonds (UDD). The used abrasive material is monocorundum + 15% UDD.

4.4. Stability of cutting tools for superhard ceramics

Tool life T is understood as the total time (min) of its work between regrinds at a certain cutting mode. The stability of turning tools, the cutting part of which is made of different tool materials, is 30-90 minutes. Tool stability depends on the physical and mechanical properties of the tool and workpiece material, cutting mode, tool geometry and processing conditions. The wear of the cutting tool differs by its nature from the wear of machine parts, since the cutting zone in which the tool is located is due to high chemical purity, as well as high pressure and temperature in the contact zone. The process of tool wear during technological cutting of metals includes abrasive, diffuse and adhesive types of destruction of the working edge. The impact of each type of wear depends on the characteristic properties of the material of the tool, the workpiece, as well as the processing conditions, one of which is the cutting speed. The new specialized cutting tools for metalworking offer many of the benefits of this type of tool.

The geometry of the cutting edge, combined with the processing technology, allows you to quickly and efficiently influence the material and ultimately obtain high-quality products. As you know, good machines require high-quality cutting tools. Rational use of machines and tools allows you to fully reveal all the technological capabilities of modern equipment.

With the correct use of an innovative tool, the funds spent on its acquisition are fully justified. The use of wear-resistant tools can significantly increase labor productivity, reducing changeover time [11]. The versatility of the cutting tool allows you to significantly reduce its nomenclature and reduce the machine time spent on technological transitions. For superhard material tools, the stability of the tool will depend on the same factors as a conventional tool equipped with carbide inserts. Correct sharpening and processing of cutting inserts has a great influence on tool life. When machining cutting inserts by vibration free abrasive with the presence of diamonds. The average resistance with such processing increased several times compared to plates made of hard alloy (type VK, TK) and high-speed steel, which is shown in Figure 13.

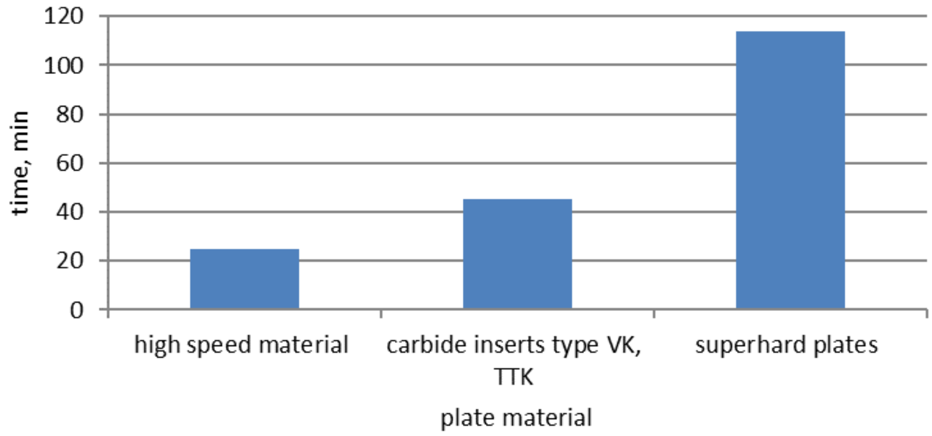


Figure 13 - Dependence of the tool life of the cutting insert on the type of material of this insert

Conclusions

As a result of the study of vibration processing of superhard ceramics with free abrasives by imposing a field of quasi-constant centrifugal forces, considered in the monograph, the following conclusions can be drawn. As for ceramics, here you can pay attention to the fact that the rounding radius increases with increasing processing time, that is, it is possible to obtain the required edge rounding radius by varying the processing time, knowing the amount of material removed per unit time.

When the samples were processed with a mixture of monocorundum and 15% UDD diamonds, the greatest removal of material occurred, i.e. the material removal rate was the highest and, therefore, the radius of the edge rounding was also the greatest. When processing samples with different abrasive materials, abrasive powder with the addition of ultradispersed diamonds was the most productive.

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