Research to Evaluate the Effectiveness of the Diamond Disc for Grinding the Granite Surface

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Abstract. The material and geometric design of the diamond disc for grinding granite surfaces is in the aspect of increased global demand for the use of granite slabs for the construction industry an important and economically justified task in the development of innovative technologies for the surface treatment of the building materials. The task undertaken to increase the quality and efficiency of machining processes by increasing the quality parameters of the finishing discs consists of evaluating the geometry of the abrasive segments and a group of materials for making flexible diamond discs formed on the synthetic binders. Polyurethane resins modified with the copper powders and quartz flour were selected for making the shields. The discs used synthetic MBD diamond powder with a grain size of 40/45 # and a concentration of 25%. In the analysis of the structural solutions, the average geometric efficiency index of the active surface of the grinding discs with a diameter of 100 mm was determined, with a kinematic load of n = 366 ÷ 960 rpm, moving with a progressive speed of 0.02 m/s and results of pilot abrasion tests made on the experimental samples of the circular diamond segments operating at the kinematic load n = 660 rpm and pressure on the surface of the 40 N disc.

1. Introduction

Diamond tools on polymer binders are used for machining flat and curved stone surfaces. They are already manufactured in the world with patented polymer compositions under the name of numerous products [1-3]. Such tools are mainly characterized in the following range: hardness; where it stands out soft, medium hardness and hard. In this type of tools, due to the above-described property, the aim is to produce discs with high elasticity and medium hardness to high, whose parameter is related to shaping thermal resistance, which allows the use of such structures in a wide range of technological tasks resulting from diamond powder size. The range of granular diamond powders used for the production of diamond tools on polymer binders results from the technological operation and the finishing of granite. The diamond powder used for finishing granite operations is with grains in the range of 50÷3000#. Binders in flexible diamond discs are compositions of polymer resins with the possibility of shaping their hardness and thermal resistance. The big advantage of these systems is: curing at room temperature. In order to ensure the shaping of the target geometry, the conditions and recommendations contained in [4-7] were taken into account. Evaluation of flexible discs in the work process, high strength of the abrasive segment structure, thermal resistance and optimal segment hardness and associated abrasiveness to ensure work with increased abrasive efficiency was based on
[4, 5, 8, 9]. For the new design of the flexible disc, a binder based on the Polyo-Isocyanite resin composition was selected which is characterized by: a small contraction, a long life span. The applied composition with the use of fillers, the formed segment is resistant to high temperatures (200°C). It is possible to obtain the hardness of the segment from the molded composition with the participation of this binder according to Shore hardness "D" from 60÷95 according to (DIN 53505). Hardness is determined depending on the proportion of fill and modifiers included in the composition. The resin is characterized by bending strength (according to ISO 178) above 95 N/mm², impact strength (according to ISO 179) above 40 kJ/m² and tensile strength (according to ISO 527) 60÷70 N/mm². Filling used in forming the hardness of segments of diamond tools is quartz powder and metal powders. As a modifier of hardness and thermal resistance copper and bronze powder in the form of dust with a grain size of 0.063 mm was made, it acts as a hardness regulator and heat dissipation regulator from the tool's working surface, minimum purity is 99.5%, promotes increased strength of the formed structure.

2. Abrasion testing of a diamond segment molded on a synthetic polyurethane resin

For the purpose of investigating the abrasiveness of diamond segments formed on polyurethane adhesives modified with the addition of quartz powder, bronze powder with the participation of synthetic MBD grains with a grain size of 40/45 #, a concentration of 25% made on the test bench shown in Figure 1.

![Figure 1. Stand for testing the abrasiveness of the diamond segment in order to assess the ability to keep the diamond grain in the binder [5]](image-url)
In the research process; the samples were subjected to a kinematic interaction at \( n = 660 \) rpm at the pressure of the segment in the disk with 40N force during 6 test cycles of 60 seconds, the weight loss was determined for the assessment of the ability to hold the diamond grain in the synthetic binder segment. The material and the geometric design of the diamond disc for the sanding of the granite surface is in the aspect of the global demand for granite slabs for building construction an important and economical task in the development of innovative technologies for the surface treatment of building matrices. The task undertaken to increase the quality and efficiency of machining processes by increasing the quality parameters of grinding with flexible discs for finishing grinding sanding is based on the assessment of the geometry and the group of composition of materials in order to clarify the composition formula for the implementation of effective flexible diamond discs formed on synthetic binders. Polyurethane resins modified with metal powders and quartz flour were selected for the execution of the discs. The disc segments used synthetic MBD diamond powder with a grain size of 40/45 # and a constant optimal concentration of \( K = 25\% \). The results of the tests of abrasiveness of the formed segments with the modifier in the form of a bronze powder are summarized in Table 1.

### Table 1. Perfection results of circular diamond segments formed on synthetic binders modified with bronze powders

| No. | Weight before the test [g] | Segment weight loss after 1 cycle [g] | Segment weight loss after the 2nd cycle [g] | Segment weight loss after the 3rd cycle [g] | Segment weight loss after the 4th cycle [g] | Segment weight loss after the 5th cycle [g] | Segment weight loss after the 6th cycle [g] |
|-----|--------------------------|--------------------------------------|------------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------------------------|
| 1   | 2.55993                  | 0.00019                              | 0.00017                                  | 0.00046                                | 0.00468                                | 0.00316                                | 0.00054                                |
| 2   | 2.54565                  | 0.00068                              | 0.00086                                  | 0.00033                                | 0.0077                                 | 0.00008                                | 0.00291                                |
| 3   | 2.51868                  | 0.00025                              | 0.00091                                  | 0.00558                                | 0.00855                                | 0.00467                                | 0.00198                                |
| 4   | 2.65253                  | 0.00066                              | 0.00027                                  | 0.00055                                | 0.00018                                | 0.00113                                | 0.00218                                |

3. **Assessment of the influence of kinematic impact on the friction elements of the wheel**

The methodology of the kinetic influence of the interaction in the work process on the points of the friction elements [10-15] allows us to perform calculations of geometrical parameters of the shield's effectiveness in relation to the surface being processed. The sensor line established in the computer program passes through the dial to determine the given time quantum (\( \Delta t \)) for which the sensors are stored - contact times, the length of the \( L_i = (V_p + V_{ini}) \) is calculated \( \Delta t \), where the parameter values \( V_p + V_{ini} \), are determined at its end a set of angular velocities with the position of the center of the target for the position of the next sensor. The program takes into account the influence on the elementary work field (\( \Delta S_o \)), only the elementary points defined for the diamond segment allows choosing the desired total length of the working tool's impact line on a given point of the work surface resulting from the geometry of the cutting surface. The result of the calculations will be graphs of the effectiveness of the geometrical effect of the dial, which is generally expressed by the dependence (1):

\[
S_g = \sum_{i=1}^{n} L_i [m],
\]

According to this relationship, the impact line of all diamond grains of the working segments of the target was calculated. In solving the task of the disk modeling process as an initial it was to analyze the simulation process of the wheel abrasive with determining the effectiveness of the geometric
surface friction surface treatment. The calculations for discs with working elements commonly used in practice in recent years were compared with the indicators of geometric effectiveness of impact. The results of calculations of the analyzed structures are listed in table 2.

**Table 2.** The indicator of the effectiveness of the geometric interaction of the surface of the active disc with a diameter of 100 mm affecting the surface to be processed at the speed \( n = 660 \text{ rpm} \), and with the progressive speed \( V_p = 0.02 \text{ m/s} \).

| No. | Surface structure | Indicators of impact effectiveness | The share of the geometry of the disc's working surface |
|-----|------------------|-----------------------------------|------------------------------------------------------|
|     |                  | Average impact efficiency \( S_g \) (m) | Standard deviation indicator \( \sigma \) | The relative deviation indicator | Active area of segments \( P_{as} \) | Total surface of the spoil drainage channels \( P_{ku} \) |
| 1   |                  | 366 1.84 0.22 0.14 | 56.40 | 18.00 |
|     |                  | 660 3.68 0.22 0.14 |
|     |                  | 960 7.36 0.22 0.14 |
| 2   |                  | 366 1.38 0.31 0.21 | 56.20 | 18.20 |
|     |                  | 660 2.76 0.31 0.21 |
|     |                  | 960 5.52 0.31 0.21 |
| 3   |                  | 366 1.25 0.30 0.20 | 66.46 | 7.95 |
|     |                  | 660 2.50 0.30 0.20 |
|     |                  | 960 5.00 0.30 0.20 |
| 4   |                  | 366 1.67 0.28 0.18 | 66.95 | 7.45 |
|     |                  | 660 3.34 0.28 0.18 |
|     |                  | 960 6.68 0.28 0.18 |
| 5   |                  | 366 2.69 0.34 0.25 | 49.30 | 25.10 |
|     |                  | 660 5.38 0.34 0.25 |
|     |                  | 960 8.07 0.34 0.25 |

The results of calculations of the geometrical effectiveness of the disc's influence on the loads: speed of \( n = 660 \text{ rpm} \) and progressive speed of \( V_p = 0.02 \text{ m/s} \) is shown in Figure 2.
Figure 2. Graph of the average effectiveness of the geometrical effect of the disc to the finishing sanding of the granite surface

For the structure from Figure 2 where the value of the average effectiveness of the geometric interaction was shown, which was $S_g = 5.38m$. The construction of the shield is shown on the plan of a circle with a diameter of 100 mm, where the surface of friction segments arranged on concentric rings separated by channels on the length of the emission radii ($r_i$), for which the width of the channels is 0.5 mm and the intersecting channels of each ring on equilateral convergent segments, with which the spoil is discharged in the process of their abrasive action. In a given disc design, the total area of channels for extraction of spoil ($P_{ku}$) is 18.00 cm$^2$. The graph is characterized by a smooth distribution with a slightly yawed curve of the geometrical distribution of the effectiveness of interaction with a saddle reduction in the geometrical efficiency of the inner surface of the disc on a surface with a diameter of 60 mm (width of the saddle). The shield has an active surface of diamond abrasive segments of $P_{as} = 56.40$ cm. The slope of the curve of the geometrical effectiveness of the action slightly deviates from the outer edge of the disk (to the y axis).

4. Discussion
Granite material with a hardness of 7 according to The Mohs scale treated with the abrasive surface as the hardest building material is currently also attracting interest in ongoing construction projects. It is used for the needs of public utility buildings, housing construction and communication construction. With an increased demand for the quantity of processed material, it proves a great interest and, consequently, the search for effective technologies for its treatment by rationalizing the process of manufacturing tools for machining, where it is purposeful and economically justified to pay attention to new solutions in the design of flexible discs for surface treatment.

Tools in the form of flexible discs on synthetic binders used for granite processing are made of synthetic diamond powders in which diamond segments are formed into various forms of geometric resin binders, manufacturers of machining tools; European, American and Chinese companies still
provide new information on innovative construction solutions -material, including mainly the tools with new geometrical forms of abrasive segments mounted in variable geometrical relations on the base surface of the target.

In the group of synthetic binders, new systems of polymer resins have recently emerged that give the possibility of regulating tensile strength, hardness and resistance to thermal loads. From among a large variety of new polymer systems of resins for forming abrasive segments, a polyurethane resin system was selected which is characterized by low shrinkage and due to the important technological feature of long life, which is important when forming the product using fillers. Relatively high to obtain the hardness up to 95 ShD, adjustable depending on the fillers and modifiers used. It gives the possibility of even distribution of abrasive in the matrix structure of the diamond segment.

The theoretical analysis of kinematic processes occurring in the contact zone of diamond grain using for this purpose a computer program simulating the work process of the disc with the workpiece allowed to determine and check geometrical parameters to determine the effectiveness of the disc's influence on the material being plotted as the sum of the length of the individual grains contact line acting on the elementary surface of the workpiece, which is subjected to the interaction of the grain with the force generated from the resulting kinematic load velocity assigned to the grain at a given time, which allowed designing a new structural solution of the flexible disc with increased impact efficiency. The average effectiveness of the geometric interaction for the given geometry of friction segments was determined where the superposition method was used in which the geometrical efficiency at any point of the target can be calculated by summing the geometric efficiency parameter via the sum of parameters assigned on the separated friction surface with ring division of the target.

The conducted abrasion tests of the new composition of modifiers in the diamond segment structure showed a small weight loss for segments modified with bronze powders with the hardness of 85 ShD segments. The tests for the six interactions of the shield with the total length of the abrasive path of the interaction \( L = 10000 \text{mb} \) showed a small abrasion of the segments. The conducted research indicates the desirability of searching for new types of hardness modifiers and modifiers to remove heat from the zone's contact zone - grains with a granite surface.

5. Conclusions
Conducted tests of the elastic disc formed on synthetic polyurethane resins modified with 10% bronze powder and mineral fill with the quartz powder allowing to obtain the hardness of segments at 85 ShD. Five abrasive wear cycles, each cycle after 60 seconds of friction, at \( n = 660 \text{ rpm} \) showed small weight loss. Abrasion tests for the designed recipe of the composition require the need to redesign the composition of the composite material with an additive that reduces its hardness.

Analysis of the simulation of kinematic processes occurring in the contact zone of the diamond grain with the processed material showed a high value of the average effectiveness of the abrasive action of the rubbing segment relative to the surface being treated. The theoretical tests carried out with the analysis of the geometrical diagrams of the shield's geometrical effectiveness of 100 mm at \( n = 660 \text{ rpm} \), \( V_p = 0.02 \text{ m/s} \) showed high effectiveness of the interaction with the tendency of a slight curve deviation reflecting the favorable nature of the shield contact with the treated surface with a significant decrease, Effectiveness of the abrasive effect on the inner surface of the disc, which in effect leads to a deterioration of the quality of the surface treated, assessed by roughness, for one pass of the disc over the material being processed.

Progress related to the development of the diamond tools is an important area of human activity, still a subject of fascination, as evidenced by the groundbreaking discoveries of the twentieth century
and recent years published by scientists from Jiao Tonga who obtained materials exceeding 18% hardness of diamond.

References

[1] Materiały informacyjno-techniczne firmy 3M (USA).
[2] Materiały informacyjno-techniczne firmy KGS Diamond International (Holandia).
[3] Materiały informacyjno-techniczne firmy Huang Chang Diamond Stone Tools (Chiny).
[4] P. Rajczyk and M. Knapiński, Teoretyczno-doświadczalna analiza procesu wytwarzania tarczy ściernych przeznaczonych do szlifowania wykończeniowego powierzchni granitowych, artykuł przekazany do druku Inżynieria zarządzania. Cyfryzacja produkcji. Aktualności badawcze 1. PWE.
[5] P. Rajczyk, Analiza nowych konstrukcji segmentowych tarczy ściernych przeznaczonych do szlifowania granite, artykuł przekazany do druku Zarządzanie Przedsiębiorstwem. Enterprise Management.
[6] Materiały informacyjno-techniczne firmy Huntsman Polyurethanes (Polska).
[7] A: Bakoń and A. Barylski, Ziarna i Mikroziarna Diamentowe, Wydawnictwo Politechniki Gdańskiej, Gdańsk, 2017.
[8] M. Knapiński and P. Rajczyk, Innowacyjne metody w prototypowaniu diamentowych narzędzi obróbczych do szlifowania powierzchni kamienia okładzinowego, XXI Konferencja „Innowacje w Zarządzaniu i Inżynierii Produkcji, Opole, 2018.
[9] P. Rajczyk and M. Knapiński, Examination of Diamond Grains in Segments on Metallic Binders for Granite Surface Treatment, 27th International Conference on Metallurgy and Materials, TANGER Ltd., pp. 1693-1698, 2018.
[10] J. Rajczyk, Modelling the geometric structure of concrete work item processing, Applied Mechanics and Materials, 2013.
[11] J. Rajczyk, Modelling the dynamic load process in the building technology process, Applied Mechanics and Materials, 2013.
[12] J. Rajczyk, M. Kosin, Methodology of analyzing a new geometry design of a friction plate effect on the engineered surfaces, IET Conference Publications 2011.
[13] J. Rajczyk, Podstawy naukowe doboru struktury geometrycznej i parametrów kinematycznych tarczowych narzędzi do obróbki powierzchni betonowych, Wydawnictwo Politechniki Częstochowskiej, Częstochowa, 2004.
[14] Z. Respondek, Z. Rajczyk, M. Kosin, D. Jończyk and J. Kalinowski, A new method of constructing a disc for concrete surface floating, Advanced Materials Research, 2013.
[15] J. Rajczyk, Z. Rajczyk and M. Al-Mashadani, Systematic motion path of manual floats for concrete surface, IET Conference Publications, 2011.