EXAMINATION OF DIAMOND GRAINS IN SEGMENTS ON METALLIC BINDERS FOR GRANITE SURFACE TREATMENT

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Abstract

The article presents the results of pilot abrasive tests of diamond segments, made on various metallic binders in powder metallurgy technology, intended for grinding granite surfaces. The article presents the results of testing the hardness of abrasive segments based on the Brinell method. The impact of hardness of segments on their ability to maintain diamond grain in the binder was noticed, which translated into the wear of abrasive segments during their work. The tribological tests of their wear during operation (research cycles), determined by the loss of mass of abrasive segments in the process of grinding the granite surface of Strzegom type, with given kinematic parameters and constant pressure were carried out. Research on the wear of diamond segments was carried out on the author's own research stand. A special test stand has been designed and made, which makes it possible to attach segments in a non-destructive manner. The tribological tests were carried out taking into account the factors of surface parallelism of the diamond segments to the work surface (granite slab) and at the axial pressure (perpendicular) to the surface being worked. A detailed description of the test stand is discussed in the paper. The article presents the results of microscopic observations of the examined segments after selected research cycles, using the optical microscope in the inverted system of the Nikon Eclipse MA200. The cognitive goal of the research was to broaden current knowledge on the properties of abrasive segments during their work and to examine the changing surface of the diamond segment matrix in the cyclic work process.

Keywords: Diamond abrasive segments, hardness tests, tribological tests, abrasive wear

1. HARDNESS IN TRIBOLOGICAL EVALUATION OF DIAMOND SEGMENTS ON METALLIC BINDERS

The pilot tests were carried out in connection with the growing market demand for diamond tools for grinding stone materials and for searching for ways to increase their effectiveness on the processed material [3, 4]. The main purpose of the work was to determine the consumption of diamond grains in the material forming the diamond segment matrix reflecting their actual functioning. Two types of segments were tested on metallic binders with a constant concentration of 30% diamond and granules of 355/300 and 300/250, with varying hardness of the metallic adhesive A1 - 86 HB and A2 - 101 HB.

In industrial applications, the materials used lead to the creation of different levels of rezistance, hence it is required to know the processes taking place in the segment in order to ensure rational usable and qualitative properties.

Due to the complex structure of the diamond segment, it is appropriate to use the so-called equivalent hardness of the material, which is a mixture of various materials including abrasive additive with a higher hardness than the binder and a variable percentage of this component in the diamond segment matrix. The equivalent hardness of a diamond segment is equal to the sum of the products of the percentage of individual components and their hardness, as described in sources [2, 5]. One of the known and so far used dependences determining the amount of wear (loss of mass) from the basic parameters in the abrasion process is the Archard formula (1) presented below [6].

$$W = k\,L\,d\,/\,H \quad (1)$$

where W - material consumption, k - constant dependent on the conditions of wear, L - is the total normal load, d - friction path, H - hardness of the binder.
Hardness conditioning abrasive wear was reflected in the Archard formula, which took the form determined by the formula (2):

$$W = K\,s\,p\,/\,p_m \quad (2)$$

where K - constant enabling the friction conditions dependent on diamond grain, its concentration in the segment, Young's modulus for the binder and forms of wear products, s - friction path, p - the total normal load, p_m - unit pressure triggering plastic deformation - hardness equivalent.

The presented dependences require determining the constant K, which depends on many factors that must be determined by the necessity to carry out long-term tests including: variable granularity, abrasive concentration, Young's modulus for the binder and forms of wear products. In the given work, it was limited to determining by diamond abrasive wear analysis for two types of binder hardness with the values specified in **Table 1**, for a constant concentration of diamond grain in the matrix of the binder. The amount of micro-grain consumption and the places after the grains being peeled out in the binder was determined by the percentage ratio to the total amount of grains present on the reference surface determined before the next series of tribological tests. The results of hardness tests carried out for two types of segments A1-SM and A2-T are summarized in **Table 2**.

Table 1 Results of HB hardness testing of diamond segments on metal binders, under load 613 N

Sample	Measuring 1	Measuring 2	Measuring 3	Hardness
A1-SM	86	89	84	86
A2-T	100	105	98	101

2. RESEARCH ON THE WEAR OF DIAMOND SEGMENTS IN THE PROCESS OF THEIR INTERACTION ON THE SURFACE OF GRANITE

For the observation and measurement of the degree of wear of the diamond segment matrix, the tests were carried out on the author's research stand, where tests of two pairs of diamond segments with different hardness of the binder were carried out. The examined segments were subjected to abrasion as a result of the interaction of the abrasive surface; of tested segments (single) and a round granite disk with a diameter of 140 mm made in WaterJet technology rotating at a rotational speed of 660 rpm at constant pressure load. This complies with the requirements set out in normative documents [7, 11].

Super hard abrasive materials from which tools are made must have specific properties selected for a particular work material as well as the type of the interaction process. These properties determine the abrasive material characteristics and the tool characteristics, which based on the recommendations from the literature [1, 8-10] were included in the given task.

The tested segments were subjected to a process of abrasion at a constant pressure load, the disc was pressed against the disc with a force of 20 N. The sample was fixed in a vise on a guide ensuring constant pressure by means of a spring mechanism, the value of which was checked by weight. The constructions of the author's test stand are shown in **Figure 1**, where: 1-stand frame, 2-rotary drive with attached granite disc, 3-binding of the diamond segment, 4-spring clamping mechanism of the tested sample to the granite disc.

Figure 1 Author's stand for tribological tests of individual diamond segments

When testing the wear of abrasive grains of diamond segments, a control measurement of the rotational speed of the drive was made after 30 seconds of operation. The rotational speed at the clamping load was controlled by a time tachometer for measuring the speed, type TC10P (accuracy class 1.0).

The speed measurement was carried out to control the kinematic parameters of the abrasive wear process of segments with different hardness of its binder. The aim of the study was to determine the factors affecting the wear of diamond grain deposited in a metallic bond with different hardness. The grain was controlled after each abrasive cycle. The cycle of mutual abrasion of the sample with the treated material had distance L = 1065 m.

The tests were carried out on diamond segments manufactured in industrial conditions. The exposed abrasive surface was subjected to a friction load to determine the degree of grain wear for both groups of the tested segments.

Two groups of segments measuring 10x40x10 mm were tested. Samples for two series of tests from each group were subjected by the manufacturer to the preliminary process of grain exposure, the procedure consisted of a short-term contact of the segment with a soft abrasive material. Both groups had a constant abrasive concentration of 30% with grit for A1 355/300 and for A2 300/250. The weight of the segments before the test cycle was: A1-SM1 26.7 g, AS1-SM2 26.6 g, A2-T1 36.1 g, A2-T2 35.8 g. The amount of exposed diamond grains before the first test cycle on the working surface for segments: A1-SM1 = 126 grains, for A1-SM2 = 134 grains, for A2-T1 = 119 grains, for A2-T2 = 112 grains. The difference in the weight of segments results from the used recipe of a metallic binder used to produce segments that are currently the subject of research by the "Poldiam" company for the purpose of developing an inventive project.

The abrasive wear of the diamond segment binder was determined according to the weight method. The results of the measurements are summarized in **Table 2**, where the weight loss of segments after each test cycle is presented.

Table 2 Mass loss of diamond segments after each abrasive interaction cycle (RAD WAG WPA 40/160/C/1 weight with an accuracy of 0.00001 g)

Sample no.	Weight before 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)
A1-SM1	26.72985	0.06903	0.06637	0.06610	0.06610	0.06563	0.06499
A1-SM2	26.57854	0.08512	0.08415	0.08315	0.08210	0.08190	0.08140
A2-T1	36.09199	0.09457	0.08763	0.08753	0.08699	0.08653	0.08190
A2-T2	35.83471	0.07179	0.06789	0.06710	0.06700	0.06689	0.06670

3. OBSERVATION OF DIAMOND GRAIN WEAR IN THE ABRASIVE SEGMENT UNDER THE MICROSCOPE

The assessment of diamond grain wear in the segment in the research process was carried out using the Nikon Eclipse MA200 optical microscope. Observations of the working surface of diamond segments under the microscope were carried out for each group of generic segments of varying hardness. A general and detailed analysis of the surface after each abrasive load cycle was performed with a magnification of 10x the working surface to determine the total amount of working grains. After each abrasive cycle of the diamond grains, they were also observed at 50x magnification in the 1x1 mm field of observation at the locations of diamond grains with an estimate of the total loss, related to the total amount of protruding grains. To determine the micro-grain wear, the method of calculating the volume loss in percentage, to which it was included; micro chipping at the edges of grains and grains lost from the binder. The assessment of the diamond grains wear is expressed as a percentage of the total number of grains distributed over the entire base area with a scaled to metric value for the total amount of grains distributed on the base surface of the segment preceding the abrasive cycle. Selective information on micro-chipping types for both segment groups of different hardness is shown in **Figure 2**, where representative photographs of diamond grains after the 3rd and 6th cycle of their work for each type of grain and the type of metallic binder are provided.

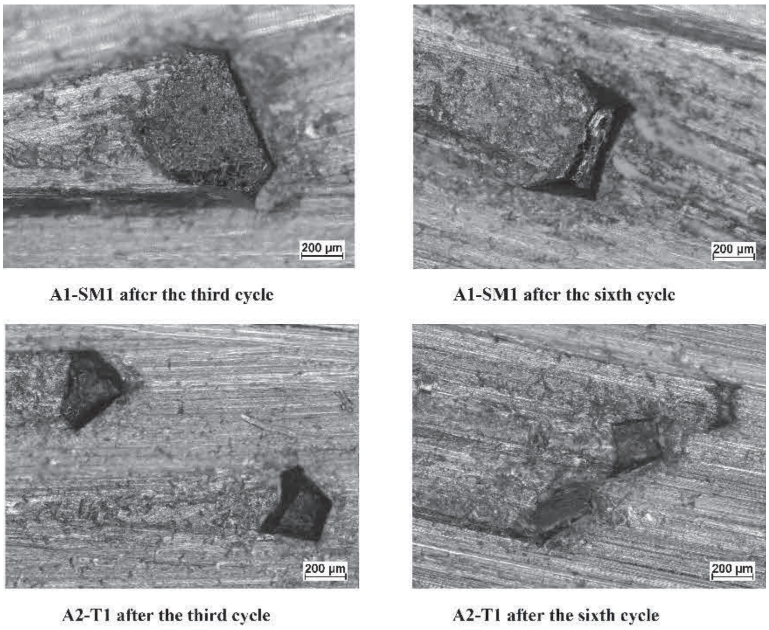

Figure 2 Representative microscopic observation of diamond grains with micro-damage after 3 and 6 abrasion cycle of segments A1-SM1 after L_3 and A1-SM1 after L_6 and A2-T1 after L_3 and A2-T1 after L_6, where the length of the abrasive path it was L_3 = 3195 m and L_6 = 5328 m

To determine the micro-grain consumption, the method of calculating the volume loss in percentage was used, which included: micro chippings appearing on the grain edges, cracks on grain from granite spoil with the content of micro diamond chippings and grains lost from the metallic binder. The evaluation of diamond grains is expressed as a percentage of the total number of grains distributed over the entire area of the segment for the preceding cycle.

Intensity of abrasive wear of diamond grains with a hardness of A1 = 86 HB and A2 = 101 HB, with a constant concentration of diamond in the binder which is 30%, grains with a grain size of 355/300 for A1 and 300/250 for A2, proceeds depending on the degree of hardness of the segment binder. The amount of wear was determined for abrasive cycles dependent on the abrasive path, which is illustrated in **Figure 3.**

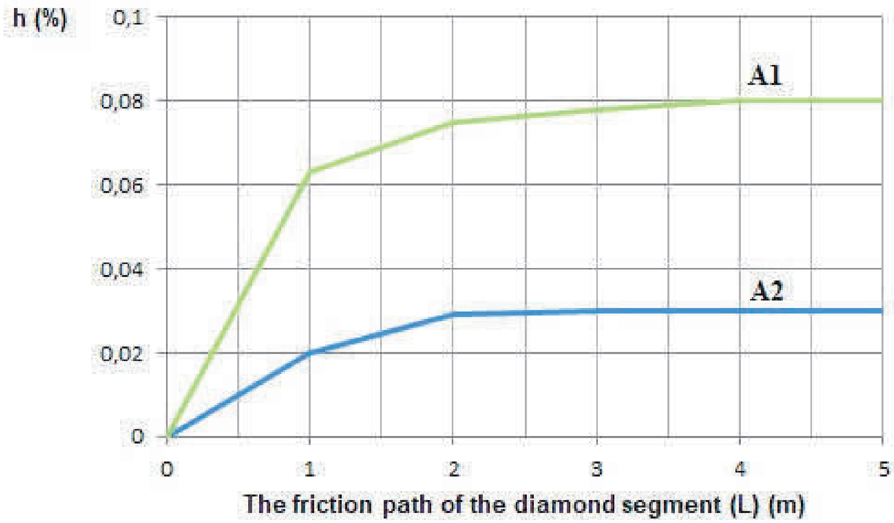

Figure 3 Wear of abrasive grain consumption (h) of grain size 355/300 for A1 and 300/250 for A2 in the diamond segment with hardness A1-86 HB and A2-101 HB for five abrasive cycle (L), where: h - diamond grain loss in % related to the total volume of grains present on the control surface before each test cycle

The evaluation of the optical analysis showed a variable degree of grain wear. The development of diamond grains destruction in both types of segments is slightly different for segment A1, slightly higher consumption, which is shown in **Figure 3** in general. In the research process a significant temperature increase was observed for A1-SM type compositions, the heating temperature exceeded 200 °C (pyrometer measurement). After the transition period of the abrasive road of 2000 m, grain consumption in the segment for both types of hardness stabilizes. The binder consumption in the A1 segment is 17% higher than in A2. In general, it can be concluded that grain abrasive wear is proportional to segment binder wear. It should be noted that the testing process of both groups of segments was conducted without the use of coolant. There was a loss of binder in the segment before the surface of the diamond grain with a visible flow of adhesive on the sides. After passing the friction path above 2000 m, as indicated by the optical analysis and the evaluation of the grain size wear in this calculation, the process of stabilizing the consumption of diamond grains for both types of segments was observed.

4. CONCLUSIONS

The type of wear of abrasive diamond segments in the machining process takes place in two stages; the first stage covers the intensive wear of the segment binder, the second stage after having travelled the 2000 m abrasive road is characterized by their stable work.

It was observed in the research process that as a result of the mechanical-thermal impact on the A1 segment binder = 86 HB and the higher grain granularity 355/300, a higher thermal load is applied, which results in an increase in micro grain crushing and slightly higher wear in the grain compared to the hardness of A2 segments = 101 HB containing 300/250 grains.

The analysis of the mass loss of the binder in the segment's working process revealed lower abrasive wear for the A2 type segments by 17% compared to the A1 type segments, the dependence of the hardness on the abrasive wear of the binder showed a direct proportional relationship.

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