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*Mechanics*

# Stone-Cut Diamond Tool on a New Binder

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**ABSTRACT. Diamond stone-working is an essential branch of manufacturing industry. The main economic task is to provide it with sophisticated stone-cut diamond tool taking into account an increase of tool life and reduction of diamond consumption. Application of adhesive-active binder as matrix for diamond stone-cut tool significantly increasies its exploitation properties.** *© 2008 Bull. Georg. Natl. Acad. Sci.*

***Key words:*** *stone-working, stone-cut tool, granite, marble.*

The experience in exploitation of the generally-marketed diamond stone-cut tool and conducted research [1] in the field of stone manufacturing industry show that operability of diamond tool on metal bonds is tenfold lower than the operability of diamond grain. This is explained by the fact that the usually used binder for fixation of diamond grains in diamond layer does not provide necessary adhesive properties with regard to diamonds. While choosing the composition of binders, only mechanical properties have been considered.

As a result of investigations, carried out by S.B.Zadoyan [2, 3], it was established that about 30% of diamond grains falls out of matrix, not reaching their deterioration when working with marble using a standard tool. This, in turn, leads to sharp intensification of deterioration of binder material forming deep cuts on the surface of matrix. The quantity of the broken grains totals only 3.3%.

While working with granite (binder M50) the quantity of the grains fallen out equals 26.5%. The working resource of diamond grains can be considered to be exhausted only in broken grains and the remaining grains falling out have different levels of wearing out [4].

According to the data in [4] actual utilization of diamond grains in the tool with nonadhesive-active binder when working with granite is 6%. The reason is bad fixation of diamond grains. From the above we see the importance of providing strong fixation of diamond abrasive grain in the tool's binder. Research into the working resource of the tool and industrial testing was conducted on rocks whose properties are presented in Table 1.

The necessary condition for high density level and formation of strong diamond-metallic composition at liquid phase sintering, also for fixation of diamond grains in matrix is high level watering and adhesion of diamond with metals.

Table 1

Physico-mechanical properties of granite and marble

| Type of rock | Deposit | Density, g/cm$^3$ | Porosity % | Water absorption, % | Compression strength, kgf/cm$^3$ | Softening coefficient | Abrasion on a disk, kgf/cm$^2$ |
|---|---|---|---|---|---|---|---|
| Granite | Yancev | 2.65 | 0.89 | 0.48 | 1593 | 0.93 | 0.32 |
| Marble | Koelginsk | 2.73 | 1.03 | 0.16 | 663 | 0.92 | 2.44 |

Liquid phase sintering (or impregnation) is used in industry to manufacture binders AH, M3, M50. The binder M03 is baked without liquid phase and consists mainly of cobalt, which even being chemically related to diamond, forms not too strong binders with diamond grains as the contact of metal in hard state and surface of diamond grains is imperfect.

Thus, in order to create the diamond-wear part of the stone-cut tool and metal binder the following should be provided: 1) necessary matrix hardness for marble HKB=80-100 (M3. M8). For granite HRC=18-04 (M50, M03); 2) adhesive fixing of diamond grain in matrix provided with good watering of diamond by binder melting ($0 \rightarrow 0$).

To realize these requirements studies of binder composition, investigation of their adhesive characteristics related to diamond and other hard phase components of instrument compositions, and study of their hardness were conducted. These researches formed the basis for elaboration of compositions of diamond-metallic compositional tool materials for stone-working tool.

The present binders M3, M1, M59 and M03 – possess a definite complex of necessary properties: hardness, wear resistance, ability to self-sharpening.

The perfection of adhesive properties of these binders and with preservation, and perhaps, improvement of their main physico-mechanical properties, contributes to a significant increase of the operability of the tool. With this aim adhesive additives (Ti, Cr) were introduced into alloys. Due to their strong adsorption effect, they sharply changed the level of watering, phase tension and adhesion at the diamond-metal boundary.

The following alloys: Cu-Ag, Cu-Sn, Cu-Ni were selected as the basis of the binders. The first two alloys were introduced into titanium, the third one into chromium. Cobalt powdery binder, into which adhesive-active component Cu-Sn-Ni-Ti was introduced, was also studied. Copper-nickel alloy was introduced into chromium hard phase-powder binder. To the compositions of these binders high melting hard abrasive components boron and chromium carbide, alloys of BK type were added. Their presence increased wear the resistance of the matrix, helped to save hardness in optimal limits. The compositions of the binders utilized are presented in Table 2.

Watering of diamonds and high melting hard components are studied in detail [3].

The most effective binders for final recommendations to the industry were selected after testing each sample of the tools in industrial conditions.

On the basis of a study of the regularities of the packing process diamond-metal compositions at sintering under pressure, depending on different factors (values of the applied pressure, graininess of hard phase, quantity of metallic component, etc.) critical pressures and optimal regimes were found for obtaining dense materials.

The results of shrinkage of compositions of diamonds Cr-Cu-Ni with different composition of liquid phase show that packing depends on the quantity of liquid phase and value of the applied pressure [4]. In order to get dense samples the force up to 150 kgf/cm$^2$ is necessary. Special apparatus for sintering diamond-metallic compositions and sample tools in high vacuum was created [5].

Testing of the obtained sample-tools was conducted on a special stand of Kursebi plant. Diamond specific wear in mg/cm$^3$ was determined (the sample was completely worn out).

Linear speed of working $v$=2.5-3.0 m/s, rotation speed s=0.28 mm/rev., deepness of working h=0.15-0.2 mm. Effort on the tool for granite working totalled 12 kg.

Table 2

Diamond specific wearing at granite working on existing and adhesion-active binders [4]

| Structure of binder, weight % | Trade mark of diamond | Conditional concentration of diamond | Mean specific wearing of diamond, mg/cm$^3$ | Volume of the removed rock, cm$^3$ |
|---|---|---|---|---|
| Co+Cd+FeS(MO3) | A+ACC 400/315 | 50 | 0.18 | 2320.00 |
| (Co+WC)Cu(M50) | A 400/315 | 50 | 0.14 | 736.46 |
| (Co+WC)Cu(M50) | CAM 400/315 | 50 | 0.87 | 115.46 |
| (CuAgTi)+27.5 BK($A_1$) | CAM 400/315 | 100 | 0.094 | 4488.90 |
| (CuSnTi)+27.5 BK($A_2$) | CAM 500/400 | 50 | 0.12 | 1989.0 |
| (CuSnTi)+15BK+12,5 $B_4C$ | CAM 500/400 | 50 | 0.101 | 1978.0 |
| (CuSnTi)+15BK+12,5 $B_4C$ | ACC 400/315 | 50 | 0.111 | 900.0 |
| (CuSnTi)+27,5 BK | A 400/315 | 50 | 0.09 | 554.76 |
| (Cr-$Cr_3C_2$-CuNi)+$B_4C$ | A+ACC 400/315 | 50 | 0.034 | 4590.87 |
| (Cr-$Cr_3C_2$-CuNi) | A 400/315 | 50 | 0.092 | 1623.04 |
| Co+40% CuSnTi | A 400/315 | 50 | 0.11 | 1441.4 |

Table 3

Diamond specific wearing at marble working on existing and adhesion-active binders [4]

| Structure of binder, weight % | Trade mark of diamond | Conditional concentration of diamond, % | Mean specific wearing of diamond, $mg/cm^3$ | Volume of the removed rock, $cm^3$ |
|---|---|---|---|---|
| Cu+Sn+FeO(M3) | ACK 400/315 | 50 | 0.0081 | 25938.2 |
| Cu+Sn(M1) | A 400/315 | 50 | 0.0066 | 15195088 |
| (CuSnTi)+27.5 BK | CAM 500/400 | 50 | 0.00515 | 19383 |
| CuSnTi | A 500/400 | 100 | 0.00135 | 114663.1 |
| (CuSnTi)+27.5 BK | A 400/315 | 50 | 0.003 | 19420 |

Low stability of the tool made with diamonds CAM 400/315 with M50 binder is established. The data of the results for tools with adhesive active binders for CAM and natural diamonds are presented in Tables 2, 3.

Despite the fact that the applied synthetic diamonds are almost the same in all the tools, specific consumption is changed due to composition of the binder. The tool with silver containing binder and CAM had specific consumption 0.094 $mg/cm^3$. Good results were obtained with tool made of diamond CAM 00/400 with binder BK6 – 15%, $B_4C$ – 12.5%, the rest CuSnTi.

**Conclusions.** Thus, the results of the investigation show that the best binder for working Kursebi granite are Cu-Sn-Ti with introduction of BK. Specific consumption on diamonds in the tools on this binder is twice less than on the existing ones.

Optimal compositions of binders from which industrial samples were manufactured (segments for saws) have been selected. Natural tools for cutting stone, segment circles with 1600 mm in diameter were made on the basis of the best out of the elaborated binders (Cu-Ni-Cr-$Cr_3C_2$-$B_4C$). They went through industrial testing and showed specific consumption of diamonds in 1.5-2 times less.

Thus, application of adhesive-active binders as matrix for diamond stone-cut tool helps significantly to increase its exploitation properties.

*მექანიკა*

# ახალი ალმასური ქვისმჭრელი იარაღი ადჰეზიური შემკვრელით

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(წარმოდგენილია აკადემიკოს რ. ადამიას მიერ)

**სტატიაში განხილულია ახალი ალმასური ქვისმჭრელი საიარაღო მასალის შემკვრელი, რომელიც შეიცავს კობალტის (Co), ბრინჯაოს (Cu+Sn), ტიტანისა (Ti) და რკინა-გოგირდის (Fe+S) ლეგირებული შენადნობის შეცხობილ ფხვნილებს. ადრე არსებულებისაგან განსხვავდება იმით, რომ შემკვრელში ტიტანი (Ti) შესულია ტიტანის ჰიდრიდის ($TiH_2$) დაშლის პროდუქტის სახით.**

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