Flexural strength of porous ceramic-bonded composites for abrasive tools

Yu. Bagayskov[1,*]

[1] Volzhsky Polytechnic Institute (Branch) of Volgograd State Technical University, Volzhsky, Volgograd Region, Russia

Abstract. One of the main parameters to measure a grinding tool performance is the material strength. This is especially true for grinding wheels operating at speeds of 35 to 60 m/sec. The grinding wheel performance can also be impaired by its imbalance due to defects in its geometry and nonuniform distribution of weight over the volume. However, a way to improve the grinding efficiency is to use high-porosity low-hardness grinding wheels with lower strength properties. Research shows that the lower the grinding wheel's strength – the bigger its structure number, the higher the content of burnable pore forming agents. This isespecially applicable to tools made from silicon carbide rather than fromalundum (electric corundum). The particle size of thepore forming agent has no major effect on the grinding wheel strength. Ceramic bonds with better adhesive capacity should be used together with overall improvement of the grinding tool structure.

Performance capacity of abrasive tools depends on many factors, including the strength of their composite materials. It is manifested in the increased service life of a tool both in terms of dimensional wear and breakdown. It is especially essential for ceramic-bonded grinding wheels as they operate at rotation speeds above 35 m/s and feature certain weight imbalance in the center of gravity [1, 2, 3]. As a result, rupture stresses above the material's ultimate strength can occur. Besides, it is commonly known that strength is related to hardness: less hard and less strong tools wear down faster in the course of grinding. On the other hand, the modern trends of increasing efficiency of such tools are associated with increasing the material's degree of structural porosity while decreasing hardness. It is of particular importance for rapid processing (over 60 m/s) of heavy-duty materials without burns. The strength of tool composites will obviously decrease at increased porosity and decreased hardness [4].

Material porosity can be increased rather substantially by injection of burning [5], fusing or dissolving artificial porogens to the molding compound while tools are being manufactured.

The degree of porosity and strength of abrasive-tool materials with various ceramic bond parameters were studied in terms of the abrasive material type and the bond type, the structure number, the abrasive grit and the porogen content [6].

---

[*] Corresponding author: instra-ysb@rambler.ru

In fact, the structure number determines the abrasive and bond correlation in the overall structure of the tool material (mass); the higher the number, the less abrasive and the more bond are there at the same pore volume.

Samples with the following parameters were studied: abrasive materials white fused alumina of grade 25A and green silicon carbide of grade 64C with the abrasive grain size F60 (250 µm), initial structure No. 6 and 8. A porogen was injected for structure No. 8 and higher. Fusing bond K5 and sintering bond K33 were used for the fused alumina and silicon carbide, correspondingly. The bond is based on refractory clay and feldspar. The fusing bond is distinguished by availability of borax glass and talc. Crushed fruit cores of various sizes (No. 25, 40 and 80, which correspond to 250 µm, 400 µm and 800 µm) and amount (7, 10 and 15 % of the abrasive grain volume) were used as burning additives at the porogen temperature of 1220 – 1250 °C.

The main structural-mechanical properties (density and porosity) and compression strength of the sample tool materials after burning were measured.

The studies showed that the sample density decreased by 13 – 20 % after injection of a burning additive, besides, the results were higher for silicon carbide. Decrease takes place approximately in proportion to increase of the structure number, grit size and porogen quantity. The sample porosity increases approximately by 30 % with increase of the structure, grit size and porogen quantity. However, the sample porosity cannot exceed that of the structure 6 samples without a porogen (for fused alumina) at low porogen grit size (No. 25 – 250 mm).

The strength properties decrease by 27 – 40 % with porogen injection from structure number 6 to 8, i.e. from 50 % to 46 % of the abrasive content in the mass, then the level mainly stabilizes almost independently of the porogen fraction and quantity (the maximum result fluctuations are 15 %).

The main study results are demonstrated in the diagrams.

Fig. 1 shows dependence of porosity and strength under compression of the tool material, including porogen injection, on the structure number. Fig. 2 shows dependence of porosity and strength under compression of a highly-porous material on the porogen grain size; Fig. 3 — on the porogen content.

The following can be concluded on the basis of the analysis results. Even at the initial structure (No. 6), both porosity and strength of silicon carbide wheels is 5 — 10 % lower than those made of fused alumina, in case of porogen injection — by 10 — 20 %. Thus, at lower porosity, a silicon carbide tool is less strong than a fused alumina tool. As is known, this is due to the low adhesiveness level of the bond for silicon carbide.

Besides, rapid decrease of strength properties is observed both for fused alumina and silicon carbide wheels as the structure number changes to 8 (abrasive content of 46 % in terms of the mass volume), i.e. as porogen injection starts. Increase of the porogen grain size number affects porosity to a greater extent and hardly affects strength, especially for fused alumina. However, increase of the porogen content almost proportionally affects porosity increase and strength decrease of both tool types.

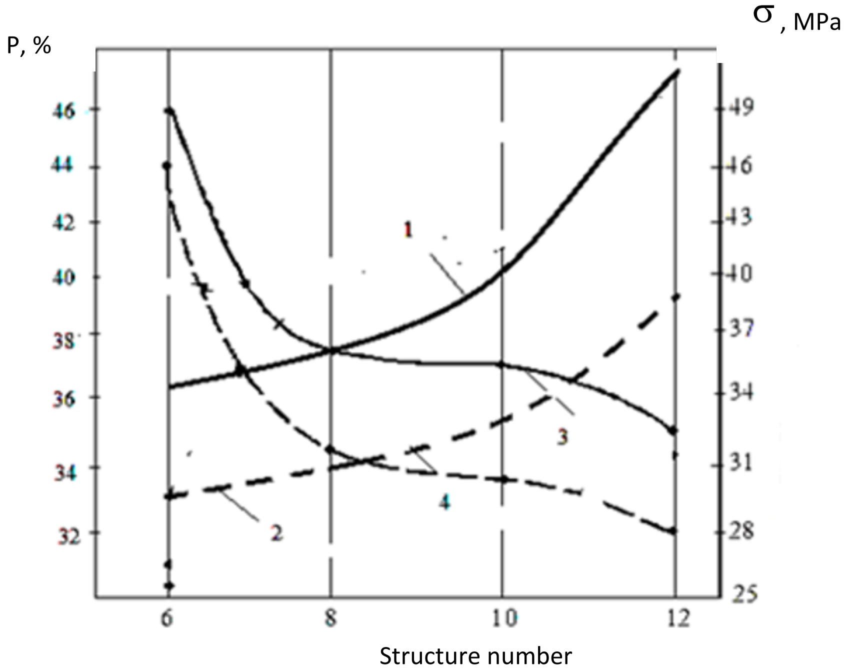

Fig. 1. Dependence of porosity (1, 2) and compression strength (3, 4) of a highly-porous tool material on the structure number: 1, 3 — fused alumina 25A; 2, 4 — silicon carbide 64C (porogen grain size No. 80, quantity 10 % of the abrasive weight)

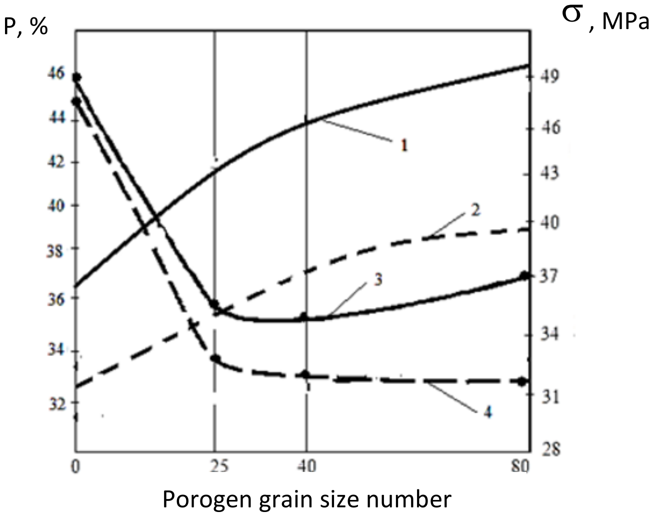

Fig. 2. Dependence of porosity (1, 2) and compression strength (3, 4) of a highly-porous material on the porogen grain size: 1, 3 — fused alumina 25A; 2, 4 — silicon carbide 64C (structure No. 10, quantity 10 % of the abrasive weight)

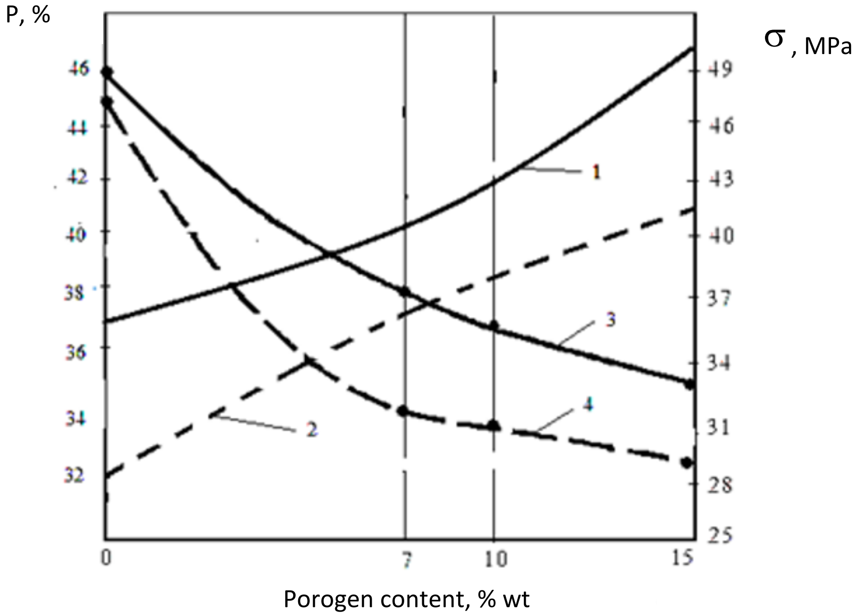

Fig. 3. Dependence of porosity (1, 2) and compression strength (3, 4) of a highly-porous material on the porogen content: 1, 3 — fused alumina 25A; 2, 4 — silicon carbide 64C (structure No. 10, porogen grain size No. 80)

It is recommended to use stronger adhesive ceramic bonds and wheel designs with reinforcing elements and to introduce wheel manufacturing procedures with a rotating compression mold more widely.

Abrasive tools should have a high degree of precision and balance in order to ensure their high operating speed. At the same time, high mechanical tensile strength of the tool composite material is required [7]. There are known structural solutions with tool reinforcement by a layer of fiberglass mesh. Though they are applicable only to organic bonds with polymerization temperature up to 200 °C. A net made of heat-resistant textile is required for the ceramic bond with burning temperature of 1150 — 1250 °C. Studies of net selection in terms of heat-resistance, adhesion to ceramics and shrinkage factor suggest that silica and basalt textiles are the most promising.

There was developed abrasive-wheel design based on ceramic bond [8] and consisting of layers of an abrasive-ceramic mixture and a heat-resistance textile with alternating height; besides the inner diameter of the textile (net) layers should be approximately equal to the wheel inner diameter (d_1) and the outer diameter — to the diameter of the wheel idle part (d_o); the number of the textile layers can be one or more, and the layers can be parallel (Fig. 4).

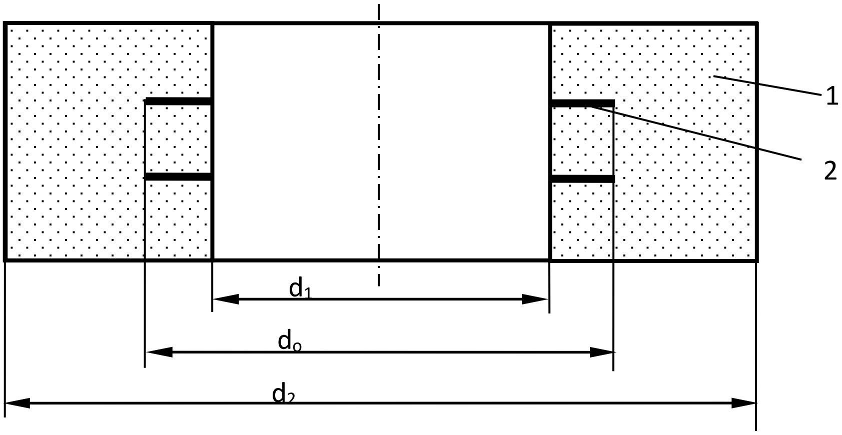

Fig. 4. Wheel design with reinforcing heat-resistant nets, wherein 1 is the abrasive-ceramic material, 2 is nets

The tests made it clear that introduction of reinforcement nets made of heat-resistant textiles increases the tool material’s strength parameters, besides introduction of two and tree nets is more efficient.

Overall increase of the tool material’s rupture strength in this case was 25 — 47 %, which suggests increasing of the operating speed during grinding. This can be of particular efficiency for grinding wheels with high pore content.

References

1. A. Garshin, S. Fedotova, *Abrasive Materials and Tools.Manufacturing Procedure:Study Guide (* SPb: Polytechnic University Press, 2008)
2. Yu. Kovalchuk, *Design Basis and Manufacturing Process of Abrasive and Diamond Tools* (M.: Mashinostroyenie, 1984)
3. V. Ostrovsky, *Theoretical Basis of Grinding (* L.: Leningrad State University Press, 1981)
4. Yu. Bagaiskov, V. Shumyacher, *Performance Increase of Items Made of Composite Materials (* Volgograd: Volgograd State University of Architecture and Civil Engineering, Volzhsky Institute of Civil Engineering and Technologies (branch) of Volgograd State University of Architecture and Civil Engineering, 2005)
5. A.S. 1812087, MKI B24D 3/14. *Mixture for Manufacture of Porous Abrasive Tools*, V. Manunin, Yu. Bagaiskov, A. Lezhnev, T. Dulichenko. Publ. on 4/30/93, Newsletter No. 16
6. Yu. Bagaiskov, *Analysis of Porous Structure Forming Features of Abrasive Tools, Collected Papers of the Conference Abrasive Machining Processes, Abrasive Tools and Materials.* Volzhsky, pp. 67 – 69 (1999)
7. L. Brautman, R. Krok, *Composite Materials. Destruction and Fatigue (* M.: Mir, 1978)
8. Russian Patent No. 2539254. *Ceramic-Bond Grinding Wheel*, Yu. Bagaiskov, V. Shumyacher, A. Lykov, 2015, No. 2.