Refinement of the procedure to determine durability of abrasive materials

O Pushkarev and Yu Bagaiskov
Volzhsky Polytechnic Institute (branch), Volgograd State Technical University, 43a Engelsast., Volzhsky, Volgograd Region, 404130, Russia
E-mail: instra-ysb@rambler.ru

Abstract. Material performance as well as its purpose and way of use depend on its physical and mechanical properties. The Shlif device based on a small-sized friction machine was used to test durability of abrasive materials. The conditions and procedure of such studies were refined. Boron carbide with grain size F 80, sample weight of 0.04 g, specific sample load of 0.01 MPa was used as an abrasive body. According to the test results of the samples, the wear time is 5 minutes. Since the results of studying the sample wear are sensitive to process factors and tool parameters, and there is a correlation relationship with the field test results, the results can be used for rapid quality analysis of abrasive tools in the process of production and operation, as well as for designing of new types of tools.

The physical and mechanical characteristics are the main parameters that determine performance, purpose and, thus, application of all structural materials including those abrasive.

Abrasive materials are used as individual particles for cutting elements to manufacture such abrasive tools as honing disks, segments, sticks, and heads. Grains are attached to tools by bonding (ceramic, bakelite, rubber, epoxy, magnesian). They are divided into grinding grains, powders, and micropowders depending on the size. They can be used both as pastes with various bases and loose abrasives [1, 2].

Besides, abrasive materials are used as part of refractory materials and products (ceramic-based mainly). They are also used as part of the composite materials for components of wear-resistant items, filters, and special ceramics.

Abrasive materials mainly include the alumina class materials: monocrystalline alumina, brown and white fused alumina, as well as zirconium, titanium, chrome, and chrome-titanium alloyed fused alumina. Class two comprises silicon carbide, zirconium, tungsten, and boron materials. Such super hard materials as natural and artificial diamonds, cubic boron nitride are distinguished as a separate class [3].

Brown and white fused alumina, certain alloyed fused alumina, and black and green silicon carbide are the most used among those materials.

Studying the physical and mechanical properties of abrasive materials is of scientific and practical interest in order to use those materials in a more efficient and optimal way.

Durability is one of those quite critical parameters [4, 5]. Besides, the known methods of estimating this parameter, used for other materials, are mainly inappropriate. It is necessary to consider peculiarities of abrasive materials, in particular, small sizes, an uncertain shape, very high hardness [6].

Particles of such abrasive materials as fused alumina, silicon carbide, and boron were used for the present studies.
The Shlif small-sized friction machine was used for testing durability of abrasive materials at low speed and pressure values [7, 8].

The device operation principle is attrition, according to a preset program (specific load, speed, process time, availability or absence of an abrasive, lubrication in the friction pair contact area) of three reference samples against a counterbody attached to a facing head that is connected to a motor shaft via a planetary gear system, which enables rotation of the facing head around its own axis and around the fixed axis passing through its center. Besides, the samples’ frictional contact points move along hypocycloid trajectories on the counterbody surface, and the trajectory of each point at any facing head revolution is unique and not repeated at subsequent revolutions, which ensures uniform wear of the samples and counterbody. Relative durability can be estimated according to both linear law and sample wear determined by the sample weight.

Basic specifications of the Shlif device:

- Counterbody speed, rpm — 59.
- Counterbody diameter, mm — 110.
- Test sample diameter, mm — 10 to 50.
- Drive power, kW — 400x235x320.

The samples (22 x 22 x 5 mm) are cut out of the abrasive tool cutting head by a diamond wheel.

To select the optimum conditions and refine the wear test procedure, the abrasion wear regularities of a grinding tool made of brown fused alumina with hardness P, grain size F40, and structure 6 were studied [9].

The analysis results suggest that linear wear of the samples depends significantly on the abrasive powder’s type and grain size. Linear wear progresses as the powder grain size and hardness increase (figure 1). As compared to silicon carbide and fused alumina, boron carbide features the highest abrasive capacity. It is most reasonable to use such material (grit size F80) as an attrition body since the main requirement to the wear test procedures is met: abrading body hardness is 1.5 — 2.0 time as high as abraded body hardness (fused alumina microhardness $H_{\text{III}} = 22$ GPa, that of boron carbide $H_{\text{III}} = 39$ GPa). Besides, boron carbide with particular grit size of F80 is used as an abrading body since it is an approximately average size between grinding powders and abrasive grit.

![Figure 1. Relationship between sample linear wear U and the abrading body grit size and type (abrating body sample weight — 0.04 g, specific load — 0.01 MPa).](image-url)
Since abrasive tool wear during operation is caused by both abrasion of abrasive grains (considered the main process in case of finish grinding) and grain breakdown, correlation of those processes is unknown initially in most of practical cases. So, for overall unbiased assessment of wear resistance, it is necessary that simulated wear of the samples is based on both those factors.

As the sample weight of the abrading body increases from 0.01 g to 0.04 g (regardless of the wear time), linear wear increases gradually and then remains steady at the same level (figure 2). Thus, it is reasonable in this case to take the sample weight of 0.04 ± 0.01 g for wear testing.

If specific load within the outline contact area of an abrasive tool sample and a counterbody equals 0.01; 0.005; 0.05 MPa, correspondingly, its wear increases linearly as the wear time increments (figure 3). It indicates high stability of the conditions selected for wear testing of the samples. The following parameters were selected as constant test conditions:

- Abrading body — boron carbide with grit size F80.
- Sample weight — 0.04 ± 0.01 g.
- Specific load of sample wear — 0.01 MPa.
- Lapping of samples before testing — 5 min.

![Figure 2](image1.png)  
**Figure 2.** Relationship between linear wear $U$ of the tool samples and sample weight $P$ at various wear time values of the abrading body (boron carbide with grit size F80, specific load — 0.01 MPa).

![Figure 3](image2.png)  
**Figure 3.** Relationship between linear wear $U$ of the tool samples and wear time $t$ at various specific load values.
To estimate correlation between relative durability of the tool samples and the tool parameters during operation, wear of the wheel materials and metal removal over efficient life $1$ of $500 \times 125 \times 305$ wheels made of ceramic-bonded fused alumina $14A$ and $91A$ with grit size $F40$, hardness $K-P$, was studied with consideration of preliminary grinding of the bearing roller generatrix at the grinding rate of $35 \text{ m/s}$. After the operation tests, samples would be cut out of the tool cutting head by a diamond wheel and wear-tested as per the described procedure. The analyzed test results reveal the following.

A clear direct linear relationship between wheel wear is observed during laboratory and operation tests in most cases (figure 4). Besides, it should be noted that the relationship between sample wear and metal removal of the processed item is more complicated, though the general dependence trend exists.

To estimate the effect of the wheel hardness and grit size on sample wear, samples ($22 \times 22 \times 5 \text{ mm}$) cut out of wheels made of ceramic-bonded white fused alumina $24A$ with grit size $F40$ and hardness $I-M$ were tested. The results of studying sample wear vs. sample hardness are given in figure 5. They indicate that sample wear increases as hardness decreases. Yet wear hardly depends on the grit size.

Thus, the analysis results make it clear that the suggested procedure, involving a device for monitoring of sample wear, is quite sensitive to the tool parameters, process and operation factors. The obtained results can correlate with the results of actual tool operation; the procedure can be recommended for rapid quality analysis of grinding wheels and other abrasive tools in the process of production and operation, as well as for preliminary and comparative tests of new types of tools.

Figure 4. Metal removal $G$ and grinding wheel wear $U$ during laboratory and operation tests.

Figure 5. Relationship between linear wear $U$ of the grinding wheel samples and grinding wheel hardness.
References

[1] Garshin A and Fedotova S 2008 Abrasive Materials and Tools. Manufacturing Procedure: Instructional Aid (SPb.: Polytechnic University Press)

[2] Kovalchuk Yu 1984 Design Basis and Manufacturing Process of Abrasive and Diamond Tools (M.: Mashinostroyenie)

[3] Ovchinnikov A 2013 Materials for Abrasive Tools. Review Science and Education 7

[4] Bivdenko Yu 1998 Obtaining Target Durability – Part of Ensuring Functionality of Components Being Restored Friction and Wear 4 529-34

[5] Vinogradov V, Sorokin G and Kolokolnikov M 1990 Abrasive Wear (M.: Mashinostroenie)

[6] Safonova M 2012 Criteria for Selection of the Abrasive Grain Geometric Model New of the Samara Scientific Center of the Russian Academy of Sciences 14 432-4

[7] Nazarenko V, Berdikov V, Leonidov L, Arkhippev V, Lavror I, Finogenov G, Pushkarev O, Chistyakov V, Kolnoguzenko V and V. Polyansky V 1982 Pat. of the USSR No. 905734 Material Wear Testing Device Published in the Bulletin of Inventions 6

[8] Berdikov V, Diulin A, Efimchuk V, Pushkarev O and Finogenov G 1986 Device for Studying Durability of Materials Plant Laboratory 7 78-81

[9] Pushkarev O and Schumyacher V 2004 Methods and Equipment for Monitoring of Abrasive Materials’ Physical and Mechanical Characteristics: Monograph (Volgograd: VolgGASU)