ABRASION TESTS ON DIAMONDS

Directional Properties

VARIATIONS in the hardness or wear resistance of diamond surfaces are well known[1], and attempts have been made to explain them from the crystal structure[2]. Diamond is normally assumed to have the highest symmetry in the cubic system. There is, however, some evidence from the working of diamond that it does not possess this full symmetry[3].

In order to investigate the hardness directional properties, micro-indentation or micro-abrasion tests may be used. Although the National Bureau of Standards, Washington, has succeeded in making a number of indentations with the Knoop indenter (elongated pyramid) into the cube plane of an octahedral diamond[4], no variation with direction was revealed. We have tried to obtain indentation with a double-cone diamond indenter pressed against a diamond face; but no indentations were observed. Only elastic flattening of the diamond indenter itself was detected.

Interesting results have now been obtained with a new micro-abrasion tester, which consists of a 1-in. diameter (110° included angle) cast-iron wheel of double conical shape provided with fine diamond powder 0–2 micron size and rotating at about 10,000 r.p.m. Against this the diamond surface to be tested is lightly pressed. Well-pronounced abrasion marks were obtained in a number of directions on the diamond, these being known as 'preferred' directions. In the 'non-preferred' directions no abrasion marks were obtained on good diamond crystals; but marks did appear in the single instance of a very low-grade stone of crushing boart quality. Without exception the abrasion marks in the preferred direction had a well-polished surface permitting investigation of their forms by interferometric methods.

Fig. 1 shows the preferred directions in the cube plane of an octahedral diamond. According to crystallographic views, there should be four preferred directions parallel to the two diagonals which coincide with the directions of two crystal axes; but the usual view of the diamond polisher is that there is only one preferred direction parallel to one diagonal. The results of our own investigations on two different diamonds, one an alluvial and one a so-called 'glassy' octahedron with almost plane faces, suggests that there are only three good grinding directions, and a fourth very poor one. In the dodecahedral plane the conditions are somewhat simplified as there can be theoretically only two preferred directions parallel to one crystal axis, whereas the diamond polishers actually maintain that there is only one preferred direction in this plane. We find that the alluvial stone accepted an abrasion mark in two directions, whereas the glassy stone could be abraded only in a single preferred direction.

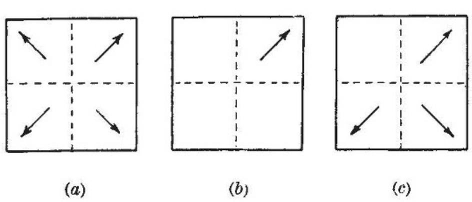

Fig. 1. Schematic representation of the cube plane of diamond; arrows indicate preferred direction, dots indicate 'non-preferred' direction. (a) Theoretical assumption; (b) assumption of diamond polishers; (c) condition revealed by tests (see Figs. 3a, b). Arrows parallel to crystal axes

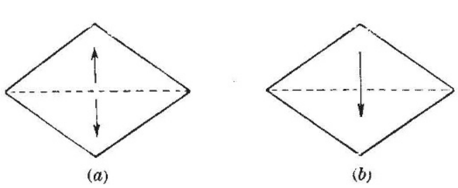

Fig. 2. Schematic representation of dodecahedron plane of diamond, designations as for Fig. 1. (a) Theoretical assumption; (b) assumption of diamond polisher. The existence of both assumptions has been confirmed by test. Arrows parallel to crystal axis

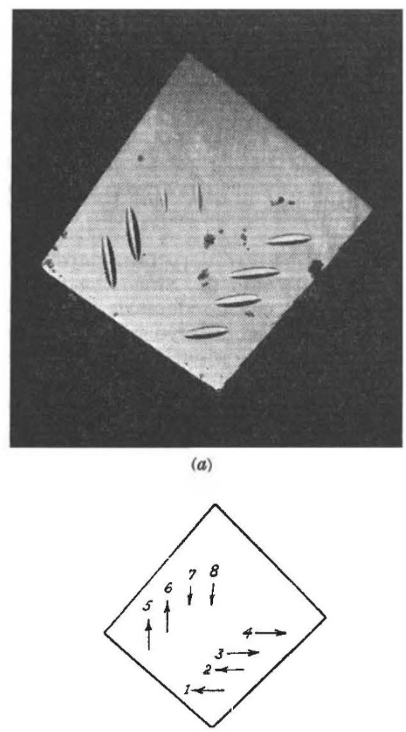

Fig. 3. (a) Photomicrograph of polished cube plane of glassy stone with abrasion marks 1–8; (b) order and direction of abrasions

Abrasion tests were made with the glassy stone on octahedral planes, both natural and cleft; but on these no abrasion mark could be detected under the microscope even at 750 × magnification. The stones have also been under examination by multiple-beam interferometry (Prof. S. Tolansky); but no traces of abrasion marks could be found.

For the evaluation of the abrading, the volumes of the abraded material should be determined. Fig. 3b shows the abrasion marks in the cube plane of the glassy stone, all eight tests being carried out in possible good running directions, and using the same number of revolutions, to within a few per cent. The numbers indicate the sequence of the test runs. Marks 3 and 4 are a good repetition of the marks 1 and 2, but are made from the opposite direction;

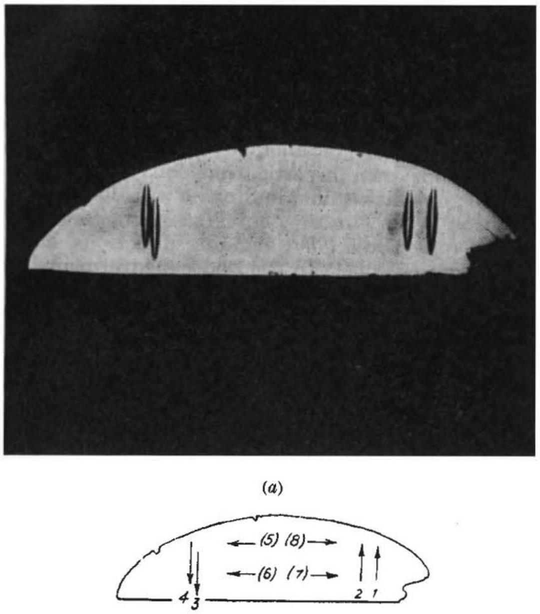

Fig. 4. (a) Photomicrograph of polished dodecahedron face of alluvial diamond with abrasion marks, some of them invisible; (b) order and direction of abrasion marks 1–8. Marks 5–8 not visible in photomicrograph

marks 7 and 8, which are very faint, are opposite to the good direction 5 and 6. Since the faint mark 7 immediately follows the good mark 6, the abrading quality of the wheel cannot have suffered appreciably. Fig. 4*b* shows the abrasion marks on the dodecahedral plane of the alluvial stone. Here all cuts 1–8 in four directions (two good ones and two bad ones) were repeated. Marks 3 and 4 are almost as good as marks 1 and 2, indicating no deterioration of the grinding wheel. Cuts 5–8 in the non-preferred direction did not leave any visible trace.

No general conclusions as to the relative abrasion-rate in the different planes can yet be drawn with certainty, particularly as the condition of the grinding wheel may have been varied slightly in the course of the tests.

In comparison with abrasion methods in which only a surface layer parallel to the original surface of the substance to be tested is removed, the method described here permits the carrying out of many abrasion tests in the same surface layer without always removing the evidence of the previous tests.

This new testing method (originated by one of us, namely, P. G.) allows very small specimens of hard materials to be tested, and it removes only very small amounts of material from the surface, which is in marked contrast to abrasion tests made on flat disks or cylindrical drums.

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[1] Tolkowsky, M., doctoral thesis, University of London (1920). Drane, H. D. H., *Research*, 1, 191 (1948). Grodzinski, P., *Indust. Diamond Rev.*, 3, 7 and 13 (1943).

[2] Nat. Phys. Lab. Collected Researches, London, 24, 1, etc. (1931); *Amer. Mineral.*, 24, 661 (1939).

[3] Eppler, W. F., and Rose, M., *Zentralbl. Mineral.*, A, 251 (1925). Raman, C. V., and Ramaseshan, S., Second Symp. on Structure and Properties of Diamond (Bangalore, 1946).

[4] *Indust. Diamond Rev.*, 5, 103 (1945).

Interferometric Examination

We have applied multiple-beam interference methods to the study of abrasion test marks cut in diamond surfaces prepared for us by a new method due to P. Grodzinski (see above note). In this abrasion test the directional mechanical properties of the diamond are revealed by the sizes of the cuts produced in the various directions by (as near as possible) the same number of revolutions, under constant load, of a sharp grinding wheel charged with diamond dust. The accompanying illustrations are interferometric studies made on the cube top face of a truncated pyramid of a 'glassy' diamond, the same face, in fact, as that described in the preceding note by Grodzinski and Stern.

(a) (b)

(c) Fig. 5

Fig. 5*a* shows multiple-beam interference fringes using green mercury light with the various abrasion cuts described as Fig. 3*a* by Grodzinski and Stern (× 20). It has been necessary to over-expose strongly the fringes on the flatter regions in order to secure sufficient intensity within the cuts, hence the apparent excessive fringe broadening in these regions is not genuine, merely photographic. Fig. 5*b* shows four of the cuts at a higher magnification, taken from a different photograph.

Owing to the very sharpness of the fringes, it is not possible with Fizeau fringes to secure a profile of a depression which is of the order of only half a light-wave deep, unless a number of different wave-lengths are employed. For such a depression the white light fringes of equal chromatic order are peculiarly admirably suited, and in Fig. 5*c* are shown such fringes for the shallowest cut of Fig. 5*a*. Such fringes reveal precisely the true profile, and the section selected here is the minor axis of the elliptical abrasion mark. The depth is a little less than half an order.

Four principal features may readily be recognized from these sensitive interference fringes, namely:

(1) The polish of the diamond surface within the abrasion cut is so good that high-definition fringes appear within each depression. The abrading wheel therefore polishes while removing material, and this is true for all the directions illustrated.