# *Notes on the cleaving and sawing of diamond.*

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IT seems to be a peculiarity in the history of the diamond that from time to time operations which have been known from time immemorial are ré-invented and claimed to be new. For instance, cleaving, which is said to have been known to the Indians, was discovered again by W. H. Wollaston. It is obvious, too, that cleaving was already known to A. B. de Boodt in 1604. The same applies to the sawing of gems by a thin rotating disk, which seems to be as old as the engraver's treadle lathe (earliest reference about 1520); but this art does not seem to have been applied to diamonds, as the first reference to diamond sawing with a thin rotating blade is that in 1874. All previous references seem to be to the sawing of diamonds with a thin wire moistened with a paste of diamond dust and oil, and otherwise designated as the Chinese method. Other gemstones were always sawn with thin disks on lapidaries' benches with vertical spindle. Similar remarks may be applied to bruting and drilling, but only polishing seems to have always been recognized as the main operation.

The octahedral cleavage is the one used in practice, but J. R. Sutton[1] also refers to dodecahedral and cubic cleavages of the diamond. I have to admit, however, that I have never yet convinced a cleaver to cleave in these directions.

The cleavage of diamonds not only represents a more or less easy means for dividing stones and removing external matter, it is also a dangerous property because in many industrial applications it is necessary to avoid the possibility of cleavages, as far as possible. The great technical difficulty is that this cannot be always altogether avoided, so that a compromise is necessary. Sometimes components which have already undergone considerable stress and strain in previous machining operations, for instance bruting, are shattered when they are dipped into a fluid, e.g. ether; such phenomena need further elucidation.

There are other instances where the cleavage is usefully employed. The edges of cleft pieces represent the so-called dodecahedral or two-point grain, and for this reason are considered to be very resistant, in the direction from one point to the other, but not so resistant, i.e. soft, in the direction perpendicular to the former. This may be explained by mentioning some applications. The glass-cutter diamond is used in such a way that it cuts with its slightly curved edge. The 'sharp' with which diamonds are grooved preparatory to cleaving is usually a cleft piece, and with the sharp edge of an angle of approximately 70° the groove is rubbed in the diamond, just in the same orientation. Another good example is the diamond used in a special brand of dental tools. They use crystals split along the lines of cleavage so that the edges exposed are able to scratch as sharply as possible. The abrasive action of diamond-impregnated tools, and in diamond dust of coarser mesh size, can be explained in a similar way, but the grains are generally not orientated. On the other hand, it can be said with some degree of certainty that the great abrasive action of diamond powder is due to the large amount of cleavage planes.

[1] J. R. Sutton, The diamond, a descriptive treatise. London, 1928, pp. 16–17. [M.A. 4–6.]

Some octahedral stones were recently sawn in the two possible sawing directions, namely, parallel to cube and dodecahedral faces, and the shapes thus obtained led to some consideration on the geometrical aspects of the problem.[1] In sawing diamond a surface roughness of generally about 15 micro-inch is obtained, and the optical interference method[2] proved to be useful for examination of the surface. Whereas in cutting wood, glass, and quartz the material to be sawn is fed through the sawing blade, in diamond cutting, and usually also with sapphire, the work is moved radially into the wheel.[3] Recently a hydraulic device was suggested as shock absorber for the stem attached to the work-holder, permitting adjustment.[4]

The sawing blades are of a special phosphor-bronze and the thickness is adapted to the size of the stone, being 0·002 inch for small stones and ranging up to 0·005 inch for larger stones. Usually the blade is trued in the machine by using a knife or a broken piece of a file, and is further trued from the side by two wooden sticks covered with emery cloth.

Recently also, diamond-impregnated blades have been tried out for the sawing of diamond. The thickness of such a blade is at present about 0·0035 inch, that is, seven times as thick as a phosphor-bronze blade. These blades, produced by Impregnated Diamond Products, Gloucester, are not so much interesting from an economical point, but they allow cross-grained stones to be sawn which hitherto could not be sawn at all.

Recently I was fortunate enough to obtain some actual records of sawing operations performed by a firm specializing in this trade. This firm has sawn 23,426 stones weighing 16,387 carats during a period of twelve months on about 24 to 44 machines, with the loss of only 558 carats, the average loss, therefore, being only 3·41 %. Details referring to a number of 2886 stones (out of the total production) are given in fig. 1. From this it can be seen that it is possible to foretell the diamond loss of a particular stone between the limits of $\pm 1$ %. The loss with larger stones is very small. That the data collected are really representative can be seen from the fact that the average is 3·38 %, compared with 3·41 % for the whole bulk. The determination of the weights was made to a commercial degree of accuracy, that is to say the second decimal point was estimated. For the total production of 16,387 carats, 1344·5 carats of crushing boart, mainly Brazilian, were consumed, or 8·2 % by weight. But since the weight lost is 3·40 % the total amount of diamond consumed in the process is about 12 %. For commercial considerations it can be said that with 1 carat of boart 12·2 carats of diamond can be sawn. This factor is interesting because in conjunction with others it gives an indication of the efficiency of production. When the works in question were started it was 12·5 % and at the present time it has been reduced to 12·15 %.

It would, of course, be of interest to obtain similar data from other firms engaged in sawing diamonds. In such data numerous factors enter, such as the

[1] P. Grodzinski, Diamond geometry. Industrial Diamond Review, 1944, vol. 4, pp. 49–53.

[2] J. F. Kayser, The micro-topography of diamond . . . Industrial Diamond Review, 1944, vol. 4, pp. 2–4, 72–75. Fig. 4, p. 73, shows the interference fringes on a sawn surface of diamond. [M.A. 9-49.]

[3] New quartz sawing machine. Industrial Diamond Review, 1944, vol. 4, pp. 63–64.

[4] P. Grodzinski, Provisional Patent Application, 21704, 1943.

skill of the operator, the condition of machines, and so on. Such information, however, is not usually very readily available.

*Sawing time.*—Very important from a production point of view is the time necessary for sawing an individual stone. Also in this case the data given in the literature are not very concise, and of course they vary according to the size of the stone, the sawn area (not usually taken into account), the condition of machine used, the preparation of the sawing blade, and the skill of the operator. I obtained

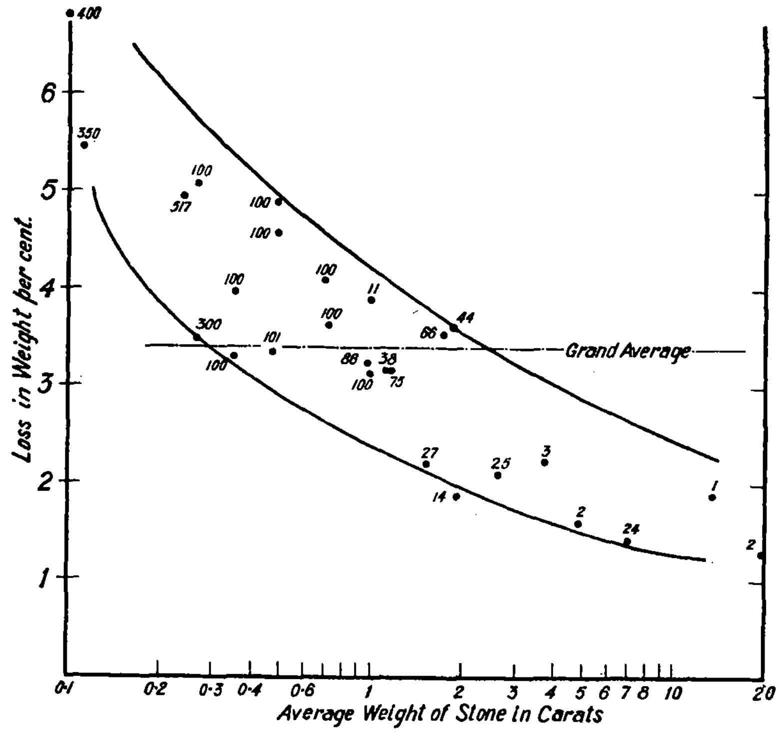


FIG. 1. Loss in weight during sawing of diamond, based on records from 2886 stones. (The numbers against the plotted points give the number of stones in each batch.)

confirmation that an expert diamond sawer can saw a 1-carat stone in $2\frac{1}{4}$ hours; of course the man can operate about 11 to 16 machines. Another record states that a young boy (trainee) sawed 140 stones of $\frac{1}{4}$ carat each during a shift of 9 hours on 11 machines; thus the sawing of one stone was approximately $(9 \times 11) \div 140 = 42$ minutes, not taking into account any idle time for resetting. The setting and taking-off time for each stone in such instances would be one to two minutes. Since the cross-sectional area of the small stone is about 0·4 that of the larger stone the sawing time of the small stone should have been 0·9 hour. This difference shows that there is no visible correlation between these two data, and of course the technical analysis of the sawing operation is not an easy one, as the cross-sectional area varies during the cut, and as the load is constant the specific sawing pressure varies from a maximum to a minimum, and is then increasing again, assuming that the stone exhibits always the same resistance against cutting, which as a matter of fact it does not. The data indicate that diamond can be sawn at a rate of 10 to 15 sq. mm. per hour, the length of cutting surface necessary to perform this work being about 60 miles per hour.

It may be of interest to compare these data with sawing results obtained with other materials (table I). Of course, these data were obtained with another type of machine and with another diamond grade, and are therefore not strictly comparable, but all tests are representative for the best commercial practice.

TABLE I. Results of sawing of various hard materials.

| | Cross-sectional area in sq. mm. sawn per min. | Sawing time in min. for one sq. mm. | Ratio of resistance to sawing | |
|---|---|---|---|---|
| | | | Corundum = 1. | Diamond = 1. |
| Diamond | 0·166–0·200 | 6–5 | 310–260 | 1 |
| Sintered carbide | 13–28·5 | 0·0765–0·035 | 40–18 | 0·15–0·06 |
| Natural sapphire (Australia) | 168 | 0·00595 | 3·1 | 0·011 |
| Natural sapphire (Ceylon) | 450 | 0·00222 | 1·16 | 0·004 |
| Synthetic corundum (white) | 520 | 0·00192 | 1 | 0·0035 |

The comparison shows that it takes nearly the 100 to 300 fold time to saw through diamond than through sapphire, the material which is next to diamond on the Mohs's scale of hardness.

For gem cutting there is a special arrangement for sawing one diamond into a larger and smaller part, thus obtaining a larger and more valuable stone besides the smaller one.[1] The general practice of to-day, however, seems to be to divide a stone into two parts of equal size by sawing just through the biggest cross-section of the stone. A good practice is to start the sawing cut with a thicker blade and then to continue the operation with the thinnest possible blade—this method obviates rubbing of the side faces. The power consumption per machine is estimated to be about 1/16 horse-power.

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[1] P. Grodzinski, Diamond and gem stone industrial production. London, 1942. [M.A. 8-266.]