A CONTRIBUTION TO GLASS KNIFE BREAKING

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The quality of the glass knife used in thin sectioning for electron microscopy continues to be an onerous problem to many microscopists. Although a partly good knife edge is occasionally produced by almost any method, the conditions under which this occurs have been left undefined. For the purpose of the present paper I might define the "perfect knife" as one which is as straight as a diamond knife, usable from side to side with about 90 per cent of its edge free from any imperfections whatsoever. In intense edge lighting, such a cutting edge should only show parallel interference fringes. It should cut Araldite or Epon without even the faintest striations.

Although the present method has evolved over a period of about two years, it was the publication on glass knife breaking by André (1) which acted as final impetus to the satisfactory solution of the problem. André's paper should be consulted for discussion of glass types, glass cutter, and historical material. Both his and the present approach bear some generic resemblance to the method suggested by Tokuyasu and Okamura (2). Of the various factors which affect the production of a good knife, it is in the application of flexion to the score mark that the least progress has been made.

The first and most important step in putting the fracturing process on a more controlled basis consists of the elimination of all methods of breaking in which the force is applied in a non-reproducible fashion. Included in this category are approaches involving glowing glass rods, tension, torsion or flexion as applied with one or two pliers, and taped pliers. A pair of pliers taped in the manner described by André come closest to giving good results, especially when they are applied at a distance from the potential cutting edge. However, even this useful tool suffers from unsymmetrical taping, shifting of the tape, compressibility of the tape, and the basic flaw that the three pressure points are too close together. These difficulties were solved by the construction of a small device referred to by remote analogy as the "Nutcracker" (Fig. 1).[1]

The Nutcracker consists of two sturdy, hinged brass plates elongated into handles for increased leverage. The bottom plate is covered by a firm rubber mat and is penetrated by a screw as the bottom pressure point. The top plate has two pressure screws projecting through it, their distance apart depending on the size of glass square to be broken, a distance of about 2.5 inches being considered minimal. All three screws are bluntly pointed, hardened, and provided with lock nuts. The positioning of these pressure points is critical, with respect to both their symmetrical location to each other and their parallel alignment to the main hinge line. Lastly, a narrow longitudinal slit is milled centrally through the top plate to be used as an aiming device when a scored piece of glass is in position for breaking.

Accurate adjustment of the Nutcracker can only be accomplished by using the same type of glass out of which subsequent knives are to be made. A 2 inch wide strip of glass is given a ⅛ inch long score mark against its long edge. The strip is placed in the Nutcracker, score mark up and directly over the bottom screw. The top is lowered and the height of the bottom screw adjusted, until light pressure between two fingers at the end of

[1] In the course of development of the present technique the LKB Company demonstrated a glass knife making device at the Fifth International Congress for Electron Microscopy. This pliers-like instrument has some features in common with the device described here.

the handles breaks the glass with the sound of a faint "tick." The displacement of the two pieces of glass should be so slight that they remain adherent to each other and have to be separated by a gentle pull. A glass strip scored as above is also used for the adjustment of the top screws. One screw is locked while the other one is raised and lowered through a critical vertical range of about 30 μ, until a break originating at the score mark

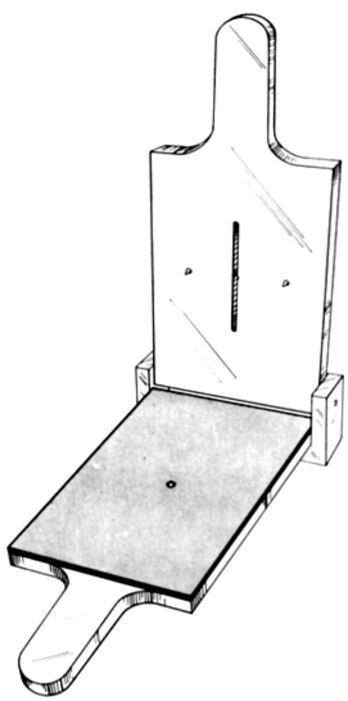

FIGURE 1 The glass knife breaking device ("Nutcracker"), as shown here, has the following dimensions: length, 9 inches; width, 4 inches; and distance between top plate and rubber surface, ½ inch.

travels straight across the strip. The break should be exactly parallel to the aiming slit and be perfectly straight when viewed on edge. This procedure completes the adjustment of the device for one type of glass only, other thicknesses requiring a different bottom screw setting.

The breaking routine presently to be described is apparently independent of the type of glass, the latter influencing primarily the durability of the edge. Since in previous methods the final fracturing step introduced enough randomness to cancel precautions taken in preceding steps, a certain amount of pedantry through the whole process greatly improves the yield of "perfect" knives, although in any case the great majority of knives will be straight and well above the norm of quality generally expected. Symmetry of breaks should be maintained throughout and strips with stress marked edges should be avoided. Hence, a maximum of "free breaks" is advisable.

Sheets of glass are obtained in such dimensions that consecutive halving of its long side yields the desired strip width, while the short side should be a multiple of the width of the final strip. For example, a 20 × 10 inch sheet will yield 2½ inch squares by symmetrical breaks. The sheet is broken into strips without scoring by making one small nick at the half-way mark against one edge, supporting the nick and the opposite side of the sheet with two short applicator sticks, and breaking by applying pressure with two thumbs at the extreme right and left ends of the sheet. Use of the palm tends to cause skewed breaks due to unsymmetrical loading. The broken surface should be flawlessly smooth. For the last break in which thumb pressure is not sufficient, a stiff, 12 inch wooden ruler is placed symmetrically across the nicked end of the strip and pressure applied to the ends of the ruler. The strips are nicked along one side at appropriate intervals to yield squares. They are broken by the Nutcracker in the previously described manner, yielding squares with two "free broken" right angle corners except for the terminal squares, which have only one such corner.

The squares are scored diagonally in the manner described by André, aiming at a corner with two "free broken" sides. However, since with a well adjusted Nutcracker all depends on the score, more accuracy is required. The André scoring turntable can be considerably simplified by having a stationary guide rail above a rubber mat provided with a recessed mirror with cross-hairs. This arrangement allows accurate positioning without parallax of the corner to be scored. The rail is provided with adjustable front and back stops to limit the travel of the glass cutter. Suitable lateral adjustment of the rail and shifting of the stops allows one to make repeatable scores very accurately into the corner, starting within a millimeter or less from it. The square is broken in the Nutcracker, with particular attention to be paid to the accurate alignment of the score both over the bottom pressure point and under the aiming slit.[2] If one starts with a large enough square, the resulting triangles can again be bisected, a method to be particularly advocated with thicker glass, since the triangles break more easily. If the break occurs at a readily visible distance from the corner, the knife is best used for trimming. The quality of the knife increases the closer to the edge it breaks. The percentage of flawless edge lies around 90 per cent at a 100 μ distance (Figs. 2 and 3), 60 per cent at 150 μ, 40 per cent at 200 μ, and varies between 10 per cent and 40 per cent at greater distances. "Cross-over" knives are good only if the angle of intersection between the break and the corner is a very acute one. Consistent crossing-over is indicative of Nutcracker maladjustment. The usual "roll-over" of the cutting edge, that is, a turning in the breaking surface near the edge to form a more obtuse angle, is also markedly decreased when the knife breaks close to the corner. The reason for this improvement may lie in the fact that the fracture separates the two glass pieces only minimally, hence not compressing the future edge before the break arrives. Secondly, the two pieces of glass immediately adjacent to the cutting edge may flex symmetrically away from each other, while this possibility is precluded if the triangle bearing the corner is significantly more massive and, hence, stiffer.

The break, as produced by a well adjusted Nutcracker, has a tendency to run straight between the pressure points. This feature can be put to use if, for example, inspection of a score reveals that the break is likely to fall too far to the right. In that case the square can be turned slightly clockwise over its bottom pressure point, at most 1 or 2 degrees of arc, which maneuver tends to force the fracture slightly to the left, that is, closer to the corner.

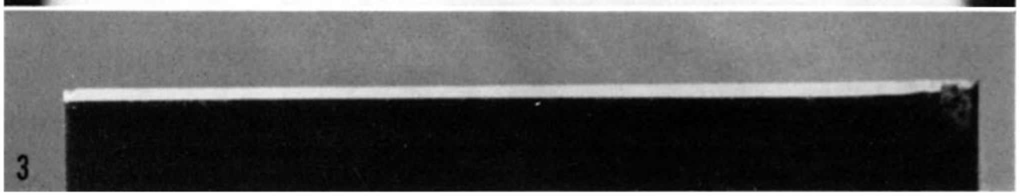

FIGURE 2 A ¼ inch long knife edge. Note absence of check marks, serrations, and fracture ridge. The irregularities at the right side near the bottom of the picture indicate the start of the score, 0.6 mm from the edge. × 19

FIGURE 3 The companion triangle to the knife shown in Fig. 2. The distance of the break from the corner is about 100 μ. Deviation from parallelism is minimal. × 19

Since "chatter" in its broadest sense (3) depends among the other factors on an interaction of block consistency, face size, section thickness, cutting speed and knife angle, the knives made by the present method will not meet all needs, but may have to be replaced by knives with a more acute angle (and an inevitable spur) or by a diamond knife.

SUMMARY

Straight and 90 per cent flawless glass knives can be produced by bisecting a right angle corner in such a manner that the break falls parallel to the corner at a distance of about 100 μ. A method to accomplish this end has been described.

I am indebted to Mr. Guenther Knoll for the construction of several Nutcrackers and to members of the Department for many suggestions and for main-

[2] Squares too small to fit under the pressure points can be broken by placing a 1½ inch wide glass strip across the square. Both pieces are oriented in the "Nutcracker" with particular care.

taining an uncompromisingly critical attitude toward "perfect" knives. The work was pursued while the author held a Postdoctoral Fellowship (41044) from the National Science Foundation.

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