TECHNICAL METHODS

The Sharpening of Microtome Knives

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The regular production of a satisfactory edge on a microtome knife for the cutting of sections as thin as $2\ \mu$, which are free from scores and other blemishes, is a serious technical problem in histological laboratories. Even when a good edge is produced on a knife, its life is generally limited because contact with any hard material in the specimen may damage the delicate edge, causing it to score subsequent sections.

A knife edge is formed by the intersection at an appropriate angle of two smooth surfaces (Fig. 1). It is well known that if the surfaces are flat, the edge formed by their intersection will be straight; if they are not flat, the edge will be curved. If the surfaces are not smooth, the edge formed by their intersection will be ragged and unsuitable for fine work.

The procedure described in this paper has been developed by applying to the preparation of the facets forming the edge techniques used for the production on steel of optically flat surfaces having a surface roughness of the order of $0.01\ \mu$.

Conventional Methods of Sharpening

The hand sharpening technique which has been used for many years may be described as follows.

A cylindrical metal back of the same length as the knife is clamped to the back of the blade, and the handle is fixed to one end of the blade. The knife is laid on a fine hone, liberally coated with water, and then moved, with the edge leading, over the surface of the hone under a very light pressure. The purpose of the metal back on the knife during sharpening is to produce the desired angle on each of the facets forming the edge.

If the bearing surfaces on the back lie in a plane through the knife edge, it will be possible to produce a flat facet. In general, however, this edge will not be parallel with the bearing surfaces on the back, and if, during sharpening, it is lying along the surface of the hone, the back will be in contact with only one edge of the hone and a facet of varying angle will be produced. Further, as the length of the blade is generally greater than the width of the hone, more work will be done on the central zone of each facet and concave facets and a curved edge will result.

FIG. 1.—(a) Straight edge formed by intersection of flat facets.
(b) Curved edge formed by intersection of concave facets.

2 B

FIG. 2.—Experimental sharpening of a knife by lapping.

When it is considered that a suitable finish has been achieved on each facet, and the edge is free from gaps, the knife is given a few very light strokes over a leather strop.

Preparation of Knives by Lapping

Preliminary Experiments.—When the problem was first examined it became clear that the first step would have to be to develop some better means for locating the knife on the sharpening medium than that achieved by the conventional type of back. If a knife is placed on a flat surface and the back of the knife is supported close to its midpoint, then the edge of the blade will lie evenly on the flat surface. To secure this geometry a narrow band of hard steel was fixed to the middle of the conventional back which was clamped to the knife (Fig. 2). Then, when the knife was placed on a flat surface, it rested, in general, at the midpoint of the back and at two points on the edge, unless the form of the facet happened to match exactly the contour of the surface.

The knife, mounted in this way, was sharpened by lapping on a flat bronze plate impregnated with fine abrasive powder. The surface of the plate is chequered by two sets of parallel grooves at right angles to each other. Their purpose is to prevent the accumulation of debris on the surface and to stop the formation of a "wire edge."

The lapping plate is liberally wetted with a suspension of abrasive (Al_2O_3) in a suitable medium (see Appendix), and the knife in its holder is worked over the plate with a circular movement, care being taken to avoid bringing the edge parallel with either set of grooves. As the knife is moved over the plate, metal is abraded off those parts of the blade (and the back) which are in contact with the surface of the lap. As the work continues, a point is reached where the whole of the lower facet of the knife is in contact with the plate and metal is being removed uniformly from all parts of this facet. The knife is turned over and the same process repeated on the second facet. During this initial sharpening process it may be necessary to add further abrasive suspension to the plate.

When this stage has been completed and the lap is cutting evenly over the whole of each facet, the surfaces will present a slightly matt appearance. To produce the fine surface finish on the knife a small quantity of abrasive suspension is poured on to the plate and worked over with a hardened flat steel disc, which pushes the tiny grains of abrasive into the soft surface of the bronze. After about two minutes' work with the steel block, the plate is flooded with a solution of detergent in water and scrubbed with a stiff brush to remove all loose particles of debris and abrasive. The plate is rinsed several times with tap water and dried with absorbent paper.

To complete the sharpening process, the plate is wetted with a suitable lubricant (see Appendix) and the knife worked over the plate exactly as before. An examination of the facet after only a very short

period of lapping (two or three minutes) shows a beautiful specularly reflecting surface developing on the facet as the scratches due to the loose abrasive are removed. Each facet is lapped in this manner and the final finish is obtained by drawing the knife across the plate about six times with a straight stroke at right angles to the blade with the edge trailing.

Each of the facets formed in this way is accurately flat and the edge is very straight. In a blade of good quality steel, a microscopic examination of the edge at a magnification of 100 generally fails to reveal any imperfections, and at a magnification of 400 very few imperfections and departures from straightness can be detected.

When this method is employed, the initial sharpening of a used knife with curved facets may take two or three hours, but the resharpener of even a seriously damaged blade takes less than 30 minutes, providing that the back is correctly placed on the knife.

Final Form of Apparatus.—During the preliminary experiments several disadvantages became apparent.

The most serious was the behaviour of the band of hard metal fixed to the back of the knife. This band failed to give a completely satisfactory location of the blade and to determine the angle of the facet. Metal was, of course, removed from this supporting band and in time it had to be replaced. Also, from the nature of the support, it was impossible to vary the angles on the facets. It was also found in lapping a stellite knife that material was removed from the support more rapidly than from the blade, with the result that a good edge could not, therefore, be obtained.

The fixture finally developed for holding knives for sharpening consists of a steel block with a tapered slot carrying the knife which is locked into the fixture by means of two screws bearing against the back of the knife. The feet of the fixture, which are in contact with the lapping plate, are each made of a tungsten carbide pad fixed to a self-aligning bearing which is fixed to the end of a screw passing through the fixture. Tungsten carbide is a very hard material which is not lapped away by the abrasive used for sharpening the knives, so troubles due to wear of the supports are eliminated. The use of a self-aligning bearing to hold each pad ensures that the surface of the pad lies flat on the surface of the lapping plate. The angle of each facet is controlled independently by the adjusting screws, each of which is fixed in position during lapping by means of a lock nut. The dimensions of the experimental fixture are such that the facet angles can be continuously varied from about $12\frac{1}{2}^\circ$ to 20° , corresponding to cutting angles of 25° to 40° .

The use of a fixture giving a controllable facet angle greatly extends the useful life of a blade and facilitates resharpener. When a knife is sharpened initially the jig is set to give a minimum cutting angle. Each time the knife is resharpened with the same cutting angle the width of the facet is increased, as

FIG. 3.—Sharpening a knife on a spirally grooved lapping plate.

also the amount of material which must be removed from the facet to obtain a sharp edge. When a stage is reached where sharpening takes an unduly long time, the facet angles are increased by advancing each adjusting screw by about half a turn so that on lapping a new pair of narrow facets is produced and the sharpening time kept within reasonable limits.

The second modification was made to the lapping plate. It is essential for the production of a high quality flat facet that the surface of the lap should be grooved. For most of the work for which these laps are used, two sets of straight parallel grooves at right angles are quite satisfactory. However, when a knife with a narrow facet is worked on such a lap, disastrous results will follow if, during lapping, the edge becomes aligned with either set of grooves. The form of grooving adopted was spiral in the surface, having a width and depth of $\frac{1}{16}$ in. and a pitch of $\frac{1}{2}$ in. The main reason for choosing this form of grooving is that it is easy to produce in a lathe; concentric circular grooves are also satisfactory.

A knife mounted in the fixture and resting on a spirally grooved plate is shown in Fig. 3.

Results

Two entirely different methods were used for assessing the quality of a knife. In the first, the knife was examined under a high-power microscope and a search made for any defects in the edge. The facets were also examined under an interference microscope (Linnik type, by Hilger & Watts) which gave a good assessment of the surface texture or roughness and of the flatness of the facet in the immediate neighbourhood (within 0.002 millimetre) of the actual edge.

In the second method the knife was used to cut serial sections of a variety of types and its quality estimated by the number of satisfactory sections which were cut.

The results of the microscopic examination are shown in Figs. 4 to 7. Each figure comprises an interferogram (a) and a photomicrograph (b) using vertical illumination. In all the interference photographs the interference bands are closely at right angles to the edge. The dark bands are "contour lines" of the surface of the facet, the contour interval being 0.25μ . Thus, if the surface is perfectly flat and free from imperfections, the bands would be smooth and straight. Surface imperfections show up as irregularities in the bands, and departures from flatness of the facet are shown by curvature of the bands.

Fig. 4 shows a facet of a knife sharpened in the conventional manner on a fine hone followed by very light stropping on canvas impregnated with abrasive powder, and finally on a leather strop mounted on a wooden bat. The interference bands are straight to within a short distance, about 0.03 mm. of the edge, and then curve off smoothly by about 0.5μ , showing a distinct rounding of the edge. The surface of the metal is fairly smooth, but shows a characteristic smeared appearance where the stropping has flawed the surface of the metal. The edge, however, is straight, free from "nicks" and gaps, and should be suitable for cutting sections.

(a) Interferogram.

(b) Vertical illumination.

FIG. 4.—Photomicrographs ($\times 360$) of a honed and stropped facet of a knife.

FIG. 5.—Photomicrographs ($\times 360$) of a facet of a knife sharpened in a commercial sharpening machine.

FIG. 6.—Photomicrographs ($\times 360$) of a lapped facet of a knife.

FIG. 7.—Photomicrographs ($\times 80$) of a knife, showing new and old facets.

A facet of a knife sharpened on a commercial knife-sharpening machine is shown in Fig. 5. It will be noted that the surface is crossed by a number of relatively deep scratches, and that the edge is somewhat ragged but is not perceptibly rounded.

Photographs of facets of knives prepared by lapping are shown in Figs. 6 and 7. The interference bands show no rounding off at the edge in Figs. 6 and 7. In each case the surface of the facet is very smooth and the edge of the knife is free from "nicks" and gaps and is quite straight.

In Fig. 7 is shown the result obtained when the angle of the facet is increased slightly from that originally on the knife. The straight bands normal to the edge (Fig. 7 a) are on the new facet and the inclined bands are on the original facet which is heavily scratched. The angle between the new and old facet is approximately 80 minutes and the width of the new facet is approximately 0.1 mm. It is of interest to note that the total time taken for mounting and lapping the knife to form the new edge was less than 10 minutes.

It will be seen from Figs. 6 and 7 that the edges prepared by lapping have all of the desirable features required of a good knife: a minimum of rounding on the edge, freedom from "nicks," and very smooth facets.

The results of the performance tests on these knives may be summarized as follows:

(1) A single portion of a blade was used to cut 850 frozen sections from a number of specimens before any deterioration was noticed.

(2) Another knife was used to cut 550 sections from a specimen mounted in pure celloidin before any deterioration was noted.

(3) The same knife, after resharpening, was used to cut 2,850 paraffin-mounted sections before any deterioration was noted.

(4) In another case a knife, prepared by lapping, was used to cut serial 8 μ sections from large specimens of brain embedded in celloidin.

An overall measure of the efficiency of the method is shown by a comparison of the times spent on sharpening in a large hospital laboratory, where approximately four man days per week were spent in preparing knives by conventional methods. The applications of the lapping technique has reduced this time to approximately three man hours.

Summary

Improved techniques and equipment are described for the sharpening of microtome knives. The knife is sharpened by lapping on a grooved flat plate using fixed abrasive. The knife is held in an adjustable fixture which ensures correct presentation of the blade to the lap and the cutting angle is readily adjustable over a wide range. Two methods of assessing the quality of a knife are described, and it is shown that the methods described are quicker than those generally used and produce a better edge.

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APPENDIX

A suitable lubricant for lapping work consists of an emulsion of

Mineral white spirit	...	...	...	400 ml.
Water	...	...	...	1,000 ml.
Ethyl (or power) alcohol	...	...	...	1,000 ml.
Turkey red oil	...	...	...	45 ml.

This is not a permanent emulsion and must be well shaken before use.

The abrasive suspension is prepared by adding approximately 2 ml. of abrasive powder to about 50 ml. of the emulsion. The abrasive is well graded aluminium oxide grain 4 μ diameter.

If, in warm weather, the lapping plate tends to become sticky due to the rapid evaporation of the volatile components, a small amount of white spirit should be added to the plate during lapping to enable the work to be moved smoothly over the plate.