Technical Guide for Glass Cutting

Section 1 - Two Basic Types of Cutting

Part 1 – Conventional Cutting

Basic Principles of Glass Cutting

This portion of Part 1 deals with those aspects of the basic principles of glass cutting that are common to all types of conventional glass cutting:

- Fissure Depth
- Lateral Vents
- Healing
- Score Line
- Stress in Glass
- Target Fissure Depth
- Wheel Contact Area
- Function of Wheel Diameter and Angle
- Wheel Operating Range

A carbide cutting wheel, rolling on a glass surface under the applied load of a cutting head, is elastically impressed into the glass surface creating a stress field under the rolling wheel. This stress field causes a fracture down into the glass that is called a fissure. As the wheel continues to roll a steady string of step-fractures occur producing an origin for plate separation by means of snapping or cut running. Looking at an opened score, the glass edge has a string of fractures or fissures and has a defined baseline. The distance from the glass surface to the base line of the fissures is termed the fissure depth. The wheel impression is only a small fraction of the fissure depth.

The rolling cutting wheel produces two other effects: the formation of lateral vents; and, a score line. Lateral vents are produced on either side of the scoring wheel and tend to extend away from the score. Under light wheel loads the lateral vents are only microscopic. As wheel load is increased the lateral vents can become progressively larger. Sharp angled wheels produce shallow vents that tend to emerge from the surface at high wheel loads. Blunt angled wheels produce somewhat deeper vents that tend to lead away from the score line but no emerge.

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Supposedly, the lateral vents on either side of the score line produce a wedging effect that puts the glass surface around the score line in tension. This tension is helpful for score opening either by snapping or cut running. If the lateral vents emerge to the surface they can pop out. This is a time related effect and, if the lateral vents do pop loose, the wedging effect disappears and the surface tension along with it. This effect is called score healing.

When the fissure is produced, a score line appears behind the wheel as a very distinct opening of the fissure to the glass surface. The visible shine under the score line is light reflection from the fissure. There usually is a fine line of glass dust on the score line as a result of the wheel/glass contact.

Even though glass is a brittle material, it is slightly elastic - enough so that, when it is annealed after formation, it has residual stresses that are helpful in the cutting and opening operations. The result of the anneal is a top surface and bottom surface compressive stress layer, each of which, is 18-22% of the glass thickness. The interior portion is in tension. This relationship holds for any thickness of commercial float glass.

Opening a score line is achieved by placing the top surface in tension by application of a bending moment about the score line. In snapping operations the bending moment is applied the entire length of the score line. In cut running operations the bending moment is applied only at one end. In either case, cutting practice has shown that the fissure depth has to be almost half way through the compressive layer. This defines a target fissure depth that is nominally 8-10% of glass thickness. Keep in mind that, as glass thickness increase, the top compression layer thickness increases and, consequently, the target fissure depth increase.

As mentioned earlier, a rolling cutting wheel elastically impresses the glass surface forming a contact area. A cutting force applied through a small contact area creates a high bearing pressure and a small stress field yielding shallow fissures. By enlarging the contact area, larger stress fields can be generated resulting in deeper fissures. Cutting wheel diameter determines the length of the contact area and cutting wheel angle determines the width of the contact area. Larger diameter wheels and higher wheel angles can generate deeper fissures.

For any given wheel there is a finite operating range. At the low end, light pressures generate shallow fissures - the range starts at a pressure that generates a fissure just deep enough to be opened - the range stops at a pressure that generates deeper fissures but begins to introduce defects in the score line. Generally, higher angle wheels have wider operating ranges—the same is true for larger diameter wheels.

With this background information: fissure depth, target fissure depth, the function of wheel angle and diameter, and the existence of an operating range—one can select a wheel for a given application from one of the charts supplied. The charts recommend one or more diameters with the wheel angles for each function of glass thickness. The angles shown are intended only to be starting points to achieve "target fissure depth" of 8-10% of glass thickness. Conspicuously absent are cutting pressures - because of all the differences in cutting installation support, rigidity, etc. The determination of cutting pressure is left to the user.

Product Quality Expectations

This portion of Part 1 deals with what is expected in the cut glass product.

- Score Line Quality
- Opened Edge Quality

Score Line Quality

Examination of a score line before snapping or cut running can usually predict the quality of the opened cut edge face. The score line should be a fine line with no flaking or chipping. Beneath the surface should be bright line of fissures of uniform depth.

The right combination of wheel diameter, wheel angle, wheel tip line finish and cutter pressure will produce this score line. The resultant fissure will facilitate easy snapping or opening.

Opened Edge Quality

Examination of the glass edge after opening will reveal the quality of the glass processing operation that produced that edge. The face of the edge should be flat and square with the surface. The fissure depth should be no deeper than necessary and be of uniform depth. The scored edge should have very minimal lateral vent structure. Also, there should be no evidence of surface crush at the scored edge.

Opened edge defects that can be associated with scoring will be concentrated at or start from the top surface. The bulk of opened edge defects are usually associated with score opening and would be located below the fissure line.

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Influences on the Quality of Cutting

This portion of Part 1 deals with seven aspects of the cutting equipment that affect product quality:

1. Cutting Support System
2. Cutting Wheel Assembly
3. Cutting Wheel
4. Cutting Wheel Finish
5. Cutting Wheel Speed
6. Glass Cutting Fluids
7. Cutting Wheel Life

Every cutting installation has to be treated as a system and each component contributes to the performance of the system. It is therefore important to pay attention to each component.

1. Cutting Support System

Regardless of the cutting application - on-ribbon crosscutting or slit cutting, or off-line cutting - the process must have firm back up support. The purpose of the firm support is to prevent the glass from deflecting under the applied load of the cutting head. This is most critical with thinner glasses.

A companion component of the cutting support system is the rigidity of the cutting head support. The purpose of the rigid cutting head support structure is to prevent the head from moving upward in reaction to the applied load of the cutter head.

The combination of the firm support under the glass and rigid cutting head support will yield predictable fissure depths in the glass at known applied loads. If either or both components are not adequate, the score quality will be substandard.

If the back up firmness is variable, then the fissure depth will be variable. If the cutter head deflects upward the cutter will no longer be plumb to the glass and will not allow the pillar post to swivel and caster correctly resulting in any number of score defects.

On-ribbon crosscutters usually traverse the ribbon at approximately a 7-degree angle to the conveyor rolls. Ribbon support, in this case, can be accomplished by nesting donut rolls under the cutter path and even between conveyor rolls.

On-ribbon slit cutters are normally positioned then re-positioned periodically to accommodate order cut sizes. In this case a solid roll across the conveyor and centered with the cutting wheel provides good support.

Off-line cutting machines typically use a belt or an air cushion to transport glass into the cutting station. In the cutting station the belt is typically very think and is backed up by an aluminum (or other rigid material) bed. In the case of air cushion transport the cutting bed is usually dense felt supported by aluminum.

In almost all of these applications the cutting heads are mounted on the side of a very rigid structural member with the working of the cutting head mounted as close as reasonable to the glass.

Still, there are two extraneous factors that affect the support system: ribbon or plate warp and scoring over voids. In the case of ribbon warp or plate warp, some provisions have to be in place to either flatten the glass (thin glass) or to ride with the warp (thicker glass). Warped glass is normally cut with the bow concave down. This allows the weight of the ribbon or plate to tend to flatten the glass, which places the surface to be scored in compression rather than in tension. Scoring with the surface in tension could result in uncontrolled fracturing. In some applications, thinner glasses are held flat by using vacuum belts or vacuum chucks.

Never score over or across a void. If this is unavoidable, try to minimize the size of the void as much as possible. The thinner the glass the more sensitive it is to deflecting downward into a void resulting in shallower fissures or possible puncture.

2. Cutting Wheel Assembly

In order for the cutting wheel to successfully score the glass, both with quality and consistency, it must both swivel and track in all applications. The cutting wheel assembly design provides these two functions as well as keeping the cutting wheel plumb to the glass. Failure of any one of these three elements will result in substandard scores or worse.

Cutting heads that provide the up and down elements and the pressure application elements require a complete wheel mount assembly. This assembly consists of a housing that is locked into the cutter. The housing also provides the necessary bearings or bushings for the pillar post. When assembled in the housing, the pillar post can have unrestricted free swivel or restricted swivel. The pillar post assembly is held in the housing by a radial bearing or bearings. A thrust ball mounted between the housing and the top of the pillar post absorbs and transmits the vertical loading applied by the cuter to the wheel. The pillar post contains the cutting wheel and axle in an insert at the base of the post. The wheel centerline is offset from the cutter head centerline and enables the cutting wheel to caster, maintaining perfect alignment while scoring. This complete wheel mount assembly is called a unit.

The guts of the assembly are the tungsten carbide cutting wheel, tungsten carbide axle and the hardened steel insert or pillar post. The cutting wheel rolls on the axle and is maintained vertical by the fit of the axle and the clearance in the wheel slot in the insert or pillar post. This assembly must be mounted and maintained plumb. The wheel slot clearance is only as large as cutting experience has dictated necessary. This assembly should be kept clean and lubricated with light oil.

When selecting a unit, consideration should be given to type of operating conditions, type of cutting (straight, pattern or combination), amount of offset, lubrication feed, housing attachment to the cutting head and dimension of the pillar post block. In this case, consideration should be given to post shaft dimensions, lubrication feed, amount of offset (caster) and dimension of the pillar post block. Many off-line cutters require only the pillar post and insert. In this case, consideration should be given to post shaft dimensions, lubrication feed, amount of offset (caster) and dimension of the pillar post block. Many of the off-line cutters have an integrated pillar post and require only an insert.

The life of the assembly is maximized by the use of light lubrication oil and by cleaning the insert slot at every wheel change. Both the axle and the insert slot will eventually wear and need to be replaced. Assemblies should be checked for visible wear or excessive wheel play during wheel change. Failure to recognize this wear after reasonable running time can result in substandard scores. Hard, abusive cutter set down can result in axle breakage and immediate scoring failure.

3. Cutting Wheel

The cutting wheel is the heart of any glass cutting application. The function of the cutting wheel is to transmit the applied load to the wheel tip line and contact the glass in such a way that the load is transmitted uniformly through the contact area. This bearing pressure generates the stress field beneath the glass surface that in turn causes a step fracture (or fissure).

With the commercial availability of micro-grain tungsten carbide came a new level of quality in the tungsten carbide product. This higher quality is reflected in more durable, consistent and longer lasting cutting wheels. This is also reflected in both score line quality and opened edge quality. All cutting wheel surfaces are precision ground using high quality diamond grinding wheels. All dimensions are held to exacting tolerances with great emphasis on product uniformity. Wheel side walls are ground flat and parallel. The wheel axle hole is ground perpendicular to the side walls. The wheel tip line is ground concentric to the axle hole. The wheel angle is ground so that the wheel tip coincides with the centerline of the wheel thickness and so that the angles on either side of the lip are equal. The finish of the wheel lip is ground to the selected smoothness. Each of these steps is critical to the performance of the wheel and quality of the score line and opened edge.

The tungsten carbide axles are centerless ground to insure that the wheel will rotate smoothly on the axle. The wheel slots in either the insert or pillar post are precision ground to exacting dimensions and tolerances to insure that the vertical slot centerline is in line with the pillar post centerline.

All these elements taken together result in excellent score lines and high quality opened edges.

4. Cutting Wheel Finish

An enormous amount of development work has been done to bring the best quality tip line finish to the user. Improvements in the uniformity of grain size in the metallurgy of the carbide, in grinding methods and in diamond grinding wheels have all contributed to this quality. After all, only the very tip of the cutting wheel contacts and indents the glass. The tip line is the intersection of grind lines.

The regular grind finish (220x) represents a finish that will provide enough traction with the glass surface and still produce an excellent quality score line. The polished finish has reduced traction with the glass surface but produces superior quality score lines. The coarse grind finish (180x) is used on glasses that require greater traction. (textured surfaces, shaped surfaces, etc.)

The important quality feature of tip line finish is that the grind lines on either side of the tip have uniform spacing and uniform height. These characteristics insure that the rolling wheel tip line indents the glass surface and transmits the cutter load uniformly throughout the contact area. This results in a well-defined stress field beneath the glass surface. This stress field will then produce an edge having uniformly spaced fissures and fissures of uniform depth.

The regular grind wheels are used extensively through almost all machine cutting operations. These produce high quality cut edges and still allow for complete intermittent scoring (alternate layouts on float lines or different layouts on single plates on off-line machines),

Polished tip wheels are used by some customers to produce the highest quality, highest strength edges on solar glasses or heat absorbing glasses.

Coarse grind wheels find their application primarily with textured surface glasses.

5. Cutting Wheel Speed

In conventional cutting the performance of a cutting wheel does not change in regard to score quality or fissure depth over the entire range of cutting head velocities. This is true even with the very high velocities used on the thin float glass ribbon crosscutters.

It is very important however, that the cutting wheel and the wheel mount be kept clean and lubricated especially for the higher speed applications. Periodic inspection of the wheel mount (insert/axle/wheel assembly) is recommended to insure that the wheel slot clearance be maintained by disassembly and cleaning. Foreign substances such as glass dust, debris, interleaving powder, etc. can rapidly build up and limit or restrict the free rotation of the cutting wheel. This can cause the cutting wheel to skid rather than rotate and score. After cleaning the assembly should be lubricated with a light lubricating oil.

The cutting wheel and mount should be treated like the precision tool that it is and, with proper maintenance, will perform at any required cutting speed.

The quality of the score line and the quality of the opened edge should be constant throughout the entire cutting speed range.

6. Cutting Fluids

The primary purpose of a cutting fluid is to retard healing in the time period between scoring and snapping. A secondary purpose is to exclude atmospheric moisture from the score line. Why? In extreme wareroom conditions, such as a cold wareroom with a humidity level at or near the dew point, glass without a cutting fluid will not score as expected. In these conditions a 140-degree wheel will score as if it were a 115-degree wheel, which at the scoring pressure required for a 140-degree wheel, will destroy the score. Most warerooms would never experience this kind of condition.

If the cutting fluid is a lubricant, it can be run through the wheel assembly and serve a dual purpose of lubricating and flushing the wheel assembly and lubricating the score line. If the cutting fluid is not a lubricant it should not be applied to the glass through the wheel assembly.

The use of, and type of, cutting fluids are left to the discretion of the user.

The practice of cutting without using any cutting fluid has been demonstrated to be very effective. It offers the advantage of allowing the line operator to examine score line quality without being masked by a fluid. This enables the operator to optimize score line quality. A secondary advantage is that dry cutting does not require washing for most products. However, the cutting wheel assembly should still be lubricated.

Which practice is best from the standpoint of quality edges? Cutting with or without a fluid? If the wareroom process is such that a time delay is normal between scoring and snapping, then scoring with a cutting fluid might be best to prevent healing. If the process is straightforward with little delay between scoring and snapping, then scoring without a fluid might be best if the line operators do optimize the scoring. Cutting fluids are still used extensively throughout the industry.

7. Cutting Wheel Life

"How long will a cutting wheel last?" - a frequent question with a difficult answer. A wheel will wear on the tip line over a long period of time. Normal wear is essentially a change of shape of the tip to a slight radius. However, the cutting application itself will dictate wheel life. Wear is accelerated by constant intermittent set down onto the glass such as with a float line crosscutter or on-line slit cutters. Wear is further accelerated by abusive, set downs. The practice of having a cutter climb an edge or run off an edge such as allowed on float line crosscutters or on off-line machines are examples.

Cutting wheels should be kept on their wire until put into use. The practice of removing several wheels from a wire and storing them in a small plastic bag or paper envelope allows the wheels to make tip to tip contact which can be damaging. This damage can produce a discontinuity in the score line on every revolution.

Depending on cutting application, operation or handling, wheel life can be measured in length of quality scoring from as high as miles to as low as feet. How does wheel wear affect edge quality? Over the normal life of a cutting wheel there should be no measurable decrease in cut edge quality. The carbide tip line is a shaped solid consisting of micrograins of tungsten carbide encapsulated in a cobalt binder. Wear takes place as the tungsten carbide micrograins slowly come out of matrix in the binder. This is so microscopic it has no effect on the interface contact area between wheel and glass.

When a tip line is damaged, chances are this damage will be transmitted to the score line.