KNIGHT MACHINE DIVISION

Product Information

The Cutting of Small Diameter Glass Tubes and Rods

KNIGHT
Tube and Rod
Cutting Machine

Document #FT1 Rev. 4

Product Information

The Cutting of Small Diameter Glass Tubing and Rod

The demand for cutting short lengths of small diameter glass tubing is very significant. Short lengths of small diameter glass tubing are used in large quantities in the manufacturing of lamp components, exhaust tubes, double-walled glass containers, automotive fuse bodies, blood capillary tubes, pharmaceutical ampoules, electrical insulators, thermometers, and many other applications. The specifications for length, edge quality, and end squareness are stringent and can be met only if the basic principles of glass cutting are applied. The design of a high production cutting machine must satisfy these stringent specifications, and meet industry requirements for speed, accuracy, yield, and versatility.

Glass Tube and Rod Cutting Machines

Industry Standard

To support the industry demand to cut large quantities of small diameter tubing, the Fletcher-Terry Company, America's largest carbide glass cutting wheel manufacturer, originally developed the technology and designed the early models of this machine. Since then, the Knight Company has kept the technology moving ahead to build and improve upon the tube and rod cutting machine, which sets the benchmark in the industry. Some of these technological improvements include: Programmable Logic Control (PLC), Automatic cutting with a built in Tilt-top for positive feed, Automatic control for piece length and piece count, Initial squaring-end trim-cut, Automatic rejection of residual tube end after last cut, Reliable mechanical cutting head drive and pneumatic feed system. This commitment to continuing development has resulted in improved operator control and efficiency, as well as machine accuracy and reliability.

Figure 1 - Glass Tube and Rod Cutting Machine

The standard Knight Tube and Rod Cutting Machine is designed to cut "Small" diameter tubing in the range of 0.75 to 7mm utilizing the "Score and Snap" process. It is uniquely versatile in that it can rapidly and accurately cut small diameter tubing and rod made of glass, quartz or ceramic materials, in round as well as hexagon or triangle shapes. The Knight machine (Fig. 1) does this at high speed and high yield.

Automatic Cutting Line

In addition to the standard cutting machine depicted above, Knight has developed a line of automatic equipment to further enhance the productivity of the cutting operation. There are three main pieces of equipment, which work together to feed and cut the "raw" lengths (canes) of tubing, as well as to receive and convey the cut lengths of tube.

Figure 2 Automatic Glass Tube Cutting Line

The initial machine in the system is the Knight Roller-bed Pre-load Table. This equipment not only provides the operator a table to pre-load the correct number of tubes for cutting, but also automatically advances the tube via a built-in, motorized roller system onto the attached cutting machine. The next machine is a specially developed Knight Roller-bed Tube Cutting Machine, which like the standard Tube and Rod Cutting machine utilizes the patented "Score and Snap" cutting process. The machines in this system are PLC driven and incorporate motorized rollers for glass advance. Adjoining the cutting machine is the Knight Orienting Transfer Conveyor. This piece of equipment receives the cut lengths of tubing from the cutter, maintains their orientation and conveys the pieces to the next process. The Orienting Transfer Conveyor also has the capability to scrap the first trim and end cuts.

The cutting and conveying system is truly automatic in that the operation is continuous with the exception of pre-loading and packing. The process informs the operator of low in-bound raw material and will place itself in a “pause” state if the operator does not respond before it runs out, and again informs the operator of its disposition. The Knight PLC based process management logic monitors and controls the loading, cutting and transferring, as well as the options to include the glazing, annealing and cooling processes. It informs the operator of out-of-bounds machine performance, and allows operator interdictions for inspection, set-up adjustments, breaks, and shut-downs.

Custom Cutting Machines and Lines

In addition to the cutting machines explained above, Knight can manufacture custom-designed equipment for special cutting applications and processes. Among some of the latest developments Knight has proven the viability to cut “Larger” diameters of tubing in the range of 7 mm up to 14 mm. This is a significant development for the cutting industry, which has typically cut this size range using wet-cut saws or thermal shock machines. The “Score and Snap” process represents a cleaner and more efficient method of cutting. In “wet-cut” operations it is necessary to clean and dry the cut product before the next process can proceed. Also, thermal shock cutting machines tend to have lower output, and are not able to cut quartz or other materials with very low thermal expansion properties.

Knight can design and manufacture custom transfer equipment, glazers (fire polishers), bottomers, flame annealers, annealing lehrs, cooling and inspection stations according to the customer’s product and process requirements. This type of equipment can be added to the central cutting and conveying line in order to produce a completed cut, glazed and annealed product, ready for packing or another process.

The Process

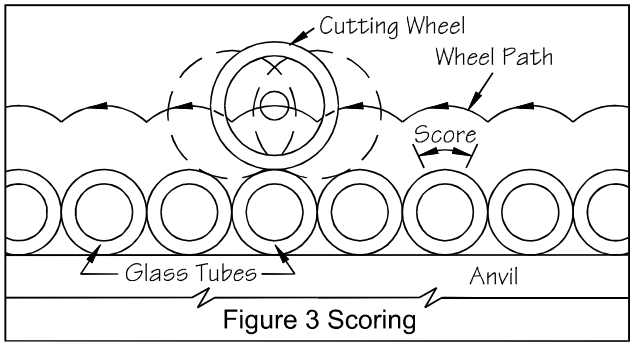

Figure 3 Scoring

Fig. 3 shows the carbide cutting wheel rolling over the tubes to score a fissure into the top surface of each tube. This initial fissure is a clean shallow fracture. It must not be a scratch or gouge. After scoring and in order to achieve a clean square end the break-out must be the technique of progressively propagating the initial clean fissure to a full fracture. When the correct cutting force and "down position" are set, the wheel will score a proper fissure, which is progressively propagated by the break shoe that follows. The "down position" of the break shoe and the force applied must also be correctly set. (See Fig. 4)

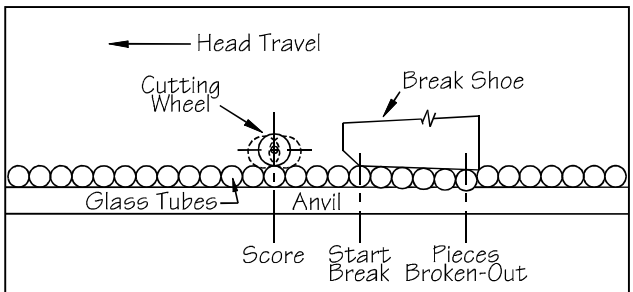

Figure 4 Score and Progressive Break-Out

The tapered shoe gradually forces each measured and scored piece to the critical angle of bend for correct break-out. The pieces are not parted with a sudden explosive snap. Residual stresses in the glass must be overcome gradually to achieve good end surfaces.

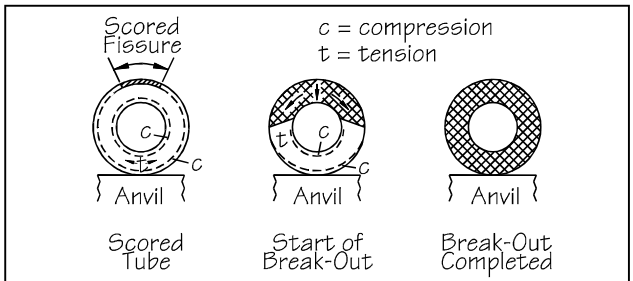

Figure 5 Progressive Break-Out

The Knight Tube and Rod Cutting Machines combine the critical elements required to properly score and break small diameter glass or ceramic tubing or rod. The anvil is located below the line of score. The cutting head is adjusted so that the cutting wheel scores the tubes directly over the center of the anvil. This position my vary depending on the material and on the annealed quality, if the material is glass. The feed bars serve as clamps to hold the canes to the bed and the break shoe gradually forces the measured and scored pieces to the critical angle of bend. Scored glass breaks when bent to an angle of less than 1º.

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In order to prevent end chipping, the measuring bar retracts to clear the tube ends during the score and break.

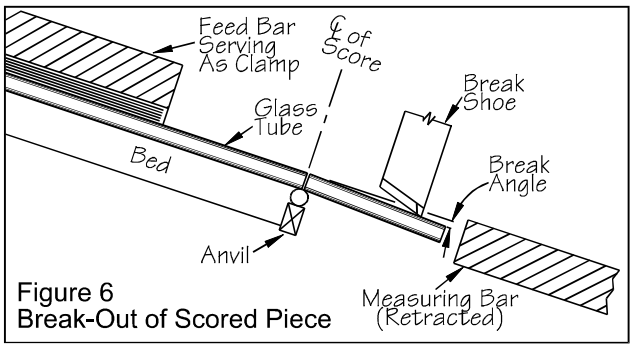

Figure 6
Break-Out of Scored Piece

As mentioned before, the Knight machine will cut tubing and solid rod made of glass, quartz, ceramic, carbon, or other brittle materials. The shape does not necessarily need to be round. The technique used will also successfully cut other cross-sectional shapes. However, if the specifications call for square ends to close tolerances, then there are well defined limitations regarding the largest diameter and the shortest length which can be cut by the score and break technique.

The Principles

Maximum Diameter

On the Knight standard cutting machines, the maximum diameter which can be cut and achieve square ends is 7 mm. On specially designed machines, the maximum diameter can be increased to about 14 mm. This may vary somewhat depending on the type and anneal of the glass. The determinant is the path of propagation of the fracture. See Fig. 5. The development of the full fracture starts downward and then must travel laterally around the bore.

Minimum Length

The minimum length of tubing or rod which can be cut and achieve square ends is related to the diameter. The minimum length is about 7 times the diameter. The reason for this is the nature of the forces developed at the score line during the break-out operation. Glass and brittle materials are weak in tension. The feed bars (serving as clamps) and the break shoe act to bend the scored tube about the anvil. See Fig. 6. The longer the distance is from the anvil to the break shoe the more the tube will tend to bend, and the greater will be the tension transverse to the line of score. With tension applied the fracture will propagate easily. However, the forces appearing at the line of score are tension **and** shear. The component of shear affects the path of fracture propagation. As the point of application of the break shoe is moved closer to the anvil to shorten the length of cut, the tensile force applied to the score diminishes and the shear force increases. When the length of cut is less than 7 times the diameter, the path of fracture propagation tends to deviate from true squareness.

Lengths having a length to diameter ratio of less than 7 to 1 can be cut on the Knight machines, but the ends may not be exactly square. Lengths cut from tubing up to 5 mm in diameter are being cut to lengths of 1.5 times the diameter for wire insulation beads.

The Cutting Wheel

It is best to use tungsten carbide cutting wheels and axles. The Fletcher cutting wheels and axles are made of specially formulated tungsten carbide. For tube cutting, the Fletcher wheel is honed to angles of 88º, 94º, 104º, 114º or 120º. These are quite sharp for flat glass cutting, but are best for tube cutting. The C245-055-94 is the most popular for soda lime and borosilicate materials. Quartz tubing is generally cut with the C245-055-114 or 120, while some thin wall tubes are best cut with the C245-055-88 wheel.

It is most important that the cutting wheel rolls freely and consistently as it scores. Our cutting machines come equipped to use Fletcher-Terry carbide wheels and axles. All Knight machines are easily and fully adjustable to allow the operator to set-up for optimum performance.

N.M. KNIGHT CO., INC.
P.O. BOX 1099, MILLVILLE, NJ 08332 U.S.A.
PHONE: 1-856-327-4855 FAX: 1-856-825-9142 www.nmknight.com