Rotary Engraving

Description

Rotary engraving is the term used to describe engraving done with a rotating cutting tool in a motorized spindle. The tool, or cutter, cuts into the surface of the material to a predetermined depth and produces a groove of the same shape and dimension of the cutter. Rotary engraving can be performed on a wide variety of materials with plastic, brass, and aluminum being the most common in the awards industry.

Rotary engraving can be done using the simplest pantographs to the most complex computerized engraving machines. The principles are the same on all. On a pantograph, the operator lowers the cutter into the material and then forms the character by tracing a master (copy type, template, etc.). On a computerized machine, the cutter spindle (Z-axis) is lowered mechanically and then is moved laterally (X-axis / Y-axis) by stepper motors to form the characters.

Engraving Cutters

The tools used for rotary engraving are generally referred to as “cutters.” Cutters are manufactured from different materials and are produced in a variety of configurations specific for certain applications and materials. Most engraving cutters are “half-round” tools which means the blank is split or halved on center producing a “single-lip” tool which is one of having only one cutting edge. This configuration affords a significant amount of clearance and allows the tool to run at relatively high speeds to maximize material removal and produce good finishes. Some cutters are also made as “quarter-round” tools which allow even greater clearance, but they are inherently weaker and are recommended for specific applications.

The majority of the engraving machines used in the awards and engraving industry have spindles that use “top-loading” cutters. These are cutters that are inserted into the spindle from the top and are typically held in place by means of a threaded knob. This arrangement allows for easy cutter adjustments and changes. Top-loading cutters are most commonly available in 1/8”, 11/64”, 1/4”, 4mm, and 6mm shank diameters. Cuter lengths vary to accommodate machine spindles and accessories (burnishing attachments, vacuum chip removers, etc.).

Some machines, particularly industrial ones, utilize collet spindles. The cutter is inserted into the top or the bottom (usually the bottom) of the spindle and is held in place by a collet. A collet is a segmented, clamping device somewhat similar to a drill chuck. By means of a “drawbar,” the collet segments are tightened against the shank of the tool, holding it securely in place. This arrangement is more rigid and precise than the top loading spindle, but does not offer the ease of cutter change and adjustment.

Most engraving cutters are manufactured from carbide or high speed steel (HSS). Carbide is an extremely hard and abrasion resistant material and is recommended for the majority of engraving applications due to its toughness and durability. Generally speaking, carbide cutters will outlast HSS cutters by a factor of 5-10 times depending on the material being cut.

Cutters manufactured from high speed steel do not have the hardness or strength of carbide. Therefore, they become dull more quickly than carbide tools. On the other hand, high speed steel cutters are not as brittle as carbide, and tend to be the best choice when making deep, fine cuts in metal such as those required for making seal dies.

Terminology

While there is a seemingly infinite number of cutter sizes and shapes, engraving tools fall into two basic categories - conical and parallel. Conical cutters have an angled cutting edge and produce a “vee” shaped, flat-bottomed cut. Parallel cutters have a straight cutting edge that is parallel to the cutter’s axis of rotation and produce a cut with straight walls and a flat bottom.

Cutter Geometry

The various angles on a cutter are referred to as its geometry. Each angle plays an important role in how well a cutter performs for a particular application.

The CLEARANCE ANGLE refers to the angle of the cutting edge with respect to the face of the cutter. This angle allows for chip clearance and determines how fine the cutting edge is. The clearance angle is determined by the properties of the material being engraved. Generally, softer materials require a larger clearance angle for chip removal than that needed for hard materials.

Most cutters fall into one of five Antares clearance classifications: ACR (acrylic)
FLX (soft plastics - flexible engraving stock)
PHN (rigid plastics - phenolic)
BAL (soft metals - brass, aluminum)
SSS (harder metals - steel, stainless steel)

A cutter for flexible engraving stock has a high degree of clearance and a correspondingly fine edge. If this cutter were used to engrave hard steel, it would be dulled rather quickly. Conversely, a cutter sharpened with a smaller clearance angle for harder materials will not produce clean, quality cuts in softer materials.

The CUTTING ANGLE is the angle formed between the cutter’s axis of rotation and its cutting edge. This determines the shape of the cut. Higher angles produce stronger tools and broader cuts and are recommended for harder materials. As a generalization, the standard cutting angle for most materials and applications is 30°. For harder materials like steel and brass a 40° angle is recommended and 20° would be choice for extremely fine or delicate work in soft materials.

The TIP is the flat at the tip of the cutter which determines the width of the cut. Since an engraving cutter needs to be “end-cutting” as well as “side-cutting,” the tip is actually a cutting edge. It is formed by two angles that provide clearance and are selected based on the material being engraved. Tip width is most accurately defined and measured as the as twice the distance from the tool centerline to the cutting edge. The width of cut is most correctly defined as the width produced at the bottom of the cut. (Note: even though the flat at the cutter tip is angled for clearance, the bottom of the cut will be flat - not angled.)

Cutter width is selected based on character height and font style. In general, single stroke characters should have a width that is approximately 12% of the character height. For example, a quarter inch (.250”) letter should have a .030” tip (.250” × .12 = .030”). It may be desirable to decrease tip width on condensed fonts and increase it on extended ones. On multiple line fonts, the cutter width should be such that there will be slight overlap on each pass.

The finishes on the cutting surfaces are also very important in terms of the quality of the cut and the durability of the cutter. A grinding wheel contains abrasive particles (grit) that act like miniature cutting tools and produce a series of grooves in the surface of the part. The finer the grit of the wheel, the smaller the grooves and the better the finish.

The cutting edge on an engraving cutter is the junction of the face and the back of the cutter. If either of these surfaces have grinding marks produced by coarse grits or improper grinding procedures, the result will be a cutting edge that is irregular and serrated. Depending on the severity of the marking, it can lead to rough and burred cuts with poor surface finishes. Additionally, each serration is a weak point that can quickly dull or break off, exaggerating the problem further. All Antares carbide tipped and solid carbide cutters feature our exclusive Microedge® finish that provides optimum performance and tool life.

During the engraving process, the cutter rotates and moves through the material. The actual cutting is produced by a shearing action between the cutter and the material. As the cutter engages the material, the cutting edge meets with resistance and slices off a piece of the material.

Speeds and Feeds

The rate of the cutter rotation is referred to as the cutting speed, and the lateral movement is the feed rate. Each has a profound effect on the quality of the finished cut. The cutting speed is actually the measure of the distance traveled in surface feet per minute (sfpm) by the cutting edge and varies proportionally with tip size. For example, a .030" tipped cutter turning at 10,000 rpm has a speed of approximately 75 sfpm while a .060" tipped cutter rotating at the same speed generates about 150 sfpm. It is apparent then, that small cutters need to turn faster to achieve the same results as larger ones and vice versa. Cutter speed is determined primarily by the material being engraved. The following table and graph can be used as a guide.

Cutter Speed in Revolutions Per Minute

	Cutter Size - Measured at Tip						
Material	.015"	.030"	.060"	.090"	.125"	.171"	.250"
Plastic Engravers Stock (FLX)	15,000 to 20,000rpm					12,000rpm	10,000rpm
Engravers Brass	10,000 - 15,000rpm			13,500rpm	9,500rpm	6,500rpm	5,000rpm
Free Cutting Aluminum	15,000 - 20,000rpm				7,500rpm	10,000rpm	14,000rpm
Mild Steel	15,000rpm	10,000rpm	5,000rpm	3,500rpm	2,500rpm	1,500rpm	1,200rpm
Hard Steel / Stainless Steel	12,000rpm	6,000rpm	3,000rpm	2,000rpm	1,500rpm	1,000rpm	750rpm
Wood	20,000rpm						

Cutter speeds can vary greatly based on factors such as feed rates, depth of cut, and the use of cutting fluid. The above chart is intended to serve primarily as a comparison if cutter speeds in various materials.

Feed rate should be proportionate to cutter speed and is dictated by material properties, horsepower, and torque. At a given cutter speed, a slow feed will produce more, smaller cuts and finer finishes. A higher feed rate will produce fewer, larger cuts and rougher finishes. Due to its single-lip design, an engraving cutter makes an "interrupted cut" which means the cutting edge is not continually engaged in the material. At each rotation, the cutting edge hits the material as it starts the cut. On harder materials, the shock created by this impact can damage the cutter and quickly destroy its edge, thus slower feed rates are dictated.

While the above situation not as dramatic and detrimental when involving softer materials, a cutter still needs time to cut. Too high a feed rate tends to tear the material rather than cut it cleanly, resulting in rough, burred cuts. As a rule-of-thumb, the feed rate should be adjusted to allow maximum engraving speed without sacrificing the quality of the finished cut.

On softer, free-cutting materials like flexible engraving stock, one pass is generally sufficient to produce a good, smooth cut. On harder materials such as steel, brass and even acrylic, two or more passes are recommended. The first does most of the cutting, while the second cleans out the chips and removes the burrs. One problem inherent to some machines common to the awards and engraving industry is their lack of power and torque at lower speeds. If the cutter speed is reduced appropriately for harder materials, there is insufficient power to produce a quality cut. Engraving machines are not milling machines and care must be taken to not exceed their capabilities.

Cutting Fluids

Many of the materials common to the awards and engraving industry can be cut effectively without the use of cutting oils or lubricants. Flexible engraving stock, phenolic, engravers brass, and aluminum all fall into this category. There are many other materials, however, that must be cut with a cutting fluid to achieve satisfactory results and maintain reasonable cutter life. Cutting fluids keep the cutter cool and prevent chips from adhering to the cutting edge.

The subject of cutting oils is very specific and complex, but the following are generalizations that may be helpful as guidelines.

All steels should be engraved using an appropriate cutting fluid to improve the cut and extend tool life. Soft aluminum that is not “free-machining” can usually be engraved effectively using kerosene or a tapping fluid specifically formulated for aluminum. Plastics that tend to melt when engraved can often be engraved very successfully with the use of a water-soluble cutting oil. Engraving acrylic is a good example of this. The use of cutting fluids, even on materials that can be cut dry, will often improve the finish of the cut and extend tool life.