The Basics of Broaching

Chris Van De Motter

Broaching is one of the most productive and precise metal cutting operations performed today. It's also one of the most misunderstood.

Chris Van De Motter is president of Ohio Broach & Machine Company. He was recently promoted from vice president and general manager. Van De Motter has worked for Ohio Broach for the past 29 years and has held positions including broach grinder, broach machine operator and machine builder before specializing in engineering. He has presented seminars for SME concerning various aspects of broaching technology.

Broaching resembles planing or shaping in that the broach tool presents a sharp cutting edge to the workpiece and moves across it, removing a predetermined amount of material. The tooling used is what primarily distinguishes broaching from other metal cutting operations. A broach combines roughing, semi-finishing, and finishing teeth in a single line. Although many variations exist, the basic tool is an axial, multi-toothed rod, bar, or plate.

Broaching produces parts at a high rate, removes heavy amounts of stock, roughs and finishes in one pass, and permits the machining of complex contours and simple shapes alike.

Economical operation is another advantage of broaching. While initial tool costs generally are higher than for other metal cutting operations, the cost per finished part is lower because of the high production rates broaching permits. Coupled with automatic or semiautomatic parts-handling equipment, unskilled or semi-skilled operators can be employed, further reducing operational costs.

Broaches also make shallow cuts and perform finishing operations, often yielding smoother surfaces than can be attained with other metal-removal processes. Some broaches have burnishing sections that impart almost any finish desired, thereby eliminating the need for grinding. In terms of productivity, repeatability, accuracy, and surface finish, broaching surpasses milling in any one plane of a workpiece.

There are two basic types of broaches: surface (external) and internal. Surface broaches cut on the outside of the workpiece. Internal broaches enlarge or change the shape of an existing hole.

Surface Broaches

The simplest surface broach is the *slab broach*, used for cutting flat surfaces. Considered a general-purpose tool, it squares the ends of parts or provides a reference surface for additional broaching or machining.

In applications involving hard surfaces or heavy stock removal, *free egress* (or nibbling) *broaches* are employed. They have sets of narrow roughing teeth positioned at a specific angle to the centerline, and they quickly remove material. Full-width teeth follow the roughing section and make semi-finishing and finishing cuts.

Slot broaches cut slots of various depths and widths. In operations requiring high production rates, slot broaching is faster and more economical than milling. Two or more slots can be cut simultaneously with proper tooling and fixtures. It's easy for standard slotting broaches to cut slots in the ends or sides of a workpiece. But that's not the case when cutting a slot along the part's length. Often, heavier stock-removal rates are involved that demand application of a longer broach.

Contour broaches cut concave, convex, cam-shaped, contoured, and irregular surfaces to extremely close tolerances. This kind of operation requires parallel surfaces that also do not present obstructions in the broach's path.

Manufacturers of turbine engines often use *dovetail* (or "pine tree") *broaches* to create special forms in the compressor wheels that hold blades in turbine discs. This sort of broaching usually involves multiple passes, due to the heavy amount of stock removed and the complex forms involved.

Pot broaches cut precision external forms such as involute spur gears, splines, slots, and special tooth forms. Pot broaching allows the task to be performed in a single pass, making it an economical, high production process. It has replaced hobbing and shaping in the manufacture of many types of external gears. During pot broaching, parts are pushed or pulled through the bore of the pot-broach holder.

Straddle broaches incorporate two separate slab-broach inserts to cut similar (or identical) parallel surfaces on opposite sides of the workpiece in one pass. The advantage of straddle broaching lies in the fact that it maintains a more precise dimensional relationship between the two sides than would be possible with separate passes.

Internal Broaches

The *round-hole broach* is the simplest

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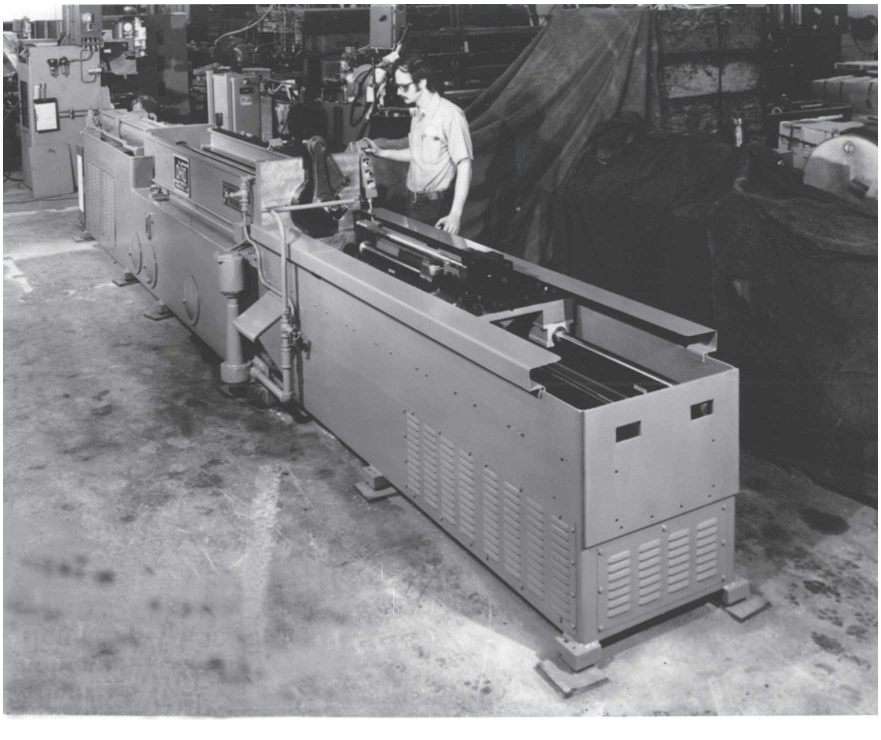
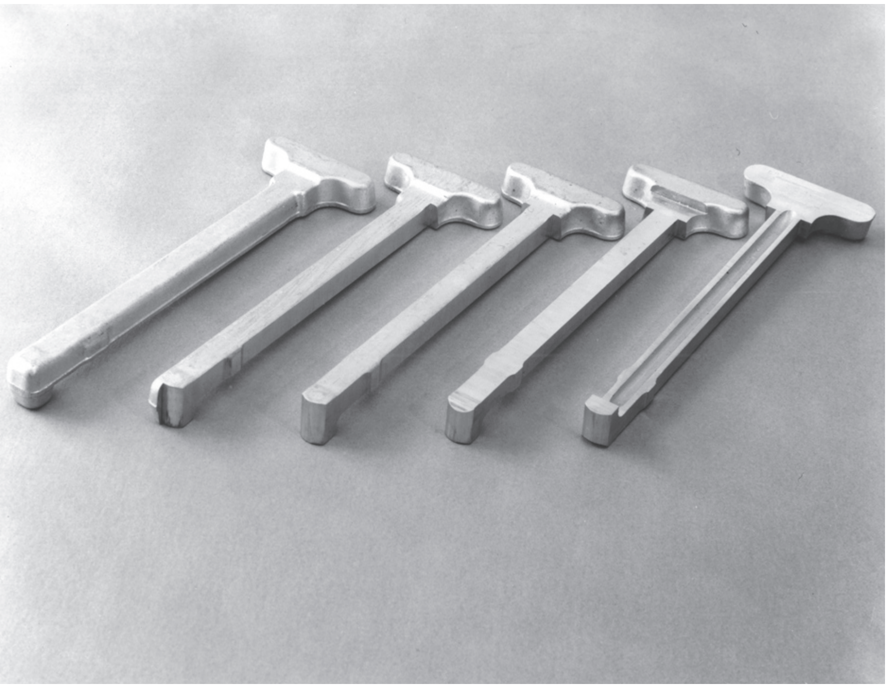


of the internal broaches. It produces close-tolerance parts and smooth surface finishes in high production applications.

The round-hole broach has a series of teeth that fully encircle the tool. Each tooth cuts on its entire outer edge.

When broaching ductile materials, round-hole broaches that incorporate chipbreakers are recommended because of their ability to effectively break the stringy chips that form.

A variety of hole shapes can be broached, in addition to round ones. Internal broaches cut square, rectangular, octagonal, and hexagonal holes as well as any other internal shape. All that's required is the proper starting hole for inserting the tool. One of the most common internal broaches is the keyway broach, which resembles a slot broach. A fixture called a "horn" usually supports the broach, locating the part in the hole where the keyway is to be cut.



An *internal gear broach* cuts internal gear forms. Its tooth pattern gradually "nibbles" away at the workpiece's internal surface, generating the desired gear profile. A full-form finishing broach may be needed to ensure accuracy and provide the optimum surface finish.

Broaching gun-barrel bores necessitates a *rifling broach*. This special tool is very long, so it can traverse the barrel's full length. It has relatively few teeth, as barrel grooves are only a few thousandths of an inch deep. The broaching machine pulls the broach through the bore while simultaneously rotating it to produce the spiral pattern.

In some spline-broaching applications, the pitch diameter must be precisely concentric with the part's minor diameter. A *concentricity broach* ensures this because it has a full-form finishing section possessing alternating round and spline teeth that shave the minor diameter and spline form.

Cutting splines in thin-walled parts can be a problem. During the operation, the walls expand with the broach's passage, but then spring back, leaving improperly cut splines. A *cut-and-recut-broach* solves the problem. It has a "breathing area" behind the front cutting section that prevents part shrinkage. The front of the tool cuts the spline, and then another cutting section at the broach's end re-cuts it to precise tolerances.

Horizontal vs. Vertical Machines

The two most important factors to consider when selecting a broaching machine are the type of broach required for the application and the number of parts to be produced. Machine size is determined by broach length, how much force will be exerted on the tool, whether it's a push- or pull-broaching operation, and available floor space.

Horizontal machines are utilized primarily for pull-through applications. One-way (cutting in one direction) and two-way (cutting in both directions) models are available.

The automotive industry makes extensive use of large horizontal surface broaching machines to remove heavy amounts of stock. These machines cut surfaces on large parts like cast engine blocks, cylinder heads, manifolds, and bearing clusters. With a carbide insert, stock-removal rates of ¼" or more are possible.

Formerly, most broaching was done on horizontal machines. Today, they represent just 10 percent of all the broaching machines purchased. Vertical broaching machines have become more popular because they take up less space. This is an important consideration in plants where floor space is at a premium.

A drawback to vertical machines, though, is that they require a higher ceiling than horizontal models. In plants with low ceilings, horizontal machines still are used, and they also find use as special, low-profile equipment for transfer lines and short-run applications.

Vertical machines typically are used for surface broaching. In operation, the broach tool either passes over the workpiece or remains stationary while the part moves.

Workpiece Materials

Almost any metal alloy is broachable, including soft materials like brass, bronze, and copper. Nonmetallic materials—graphite, hard rubber, wood, composites, and certain plastics—can also be successfully broached.

Free-machining materials are easier to broach than tough, hard ones. In steels, machinability is closely related to hardness. Steels with hardnesses in the range of Rc 16–24 are ideal. Usually, steels harder than Rc 35 dull broach teeth too quickly, forcing frequent tool changes and regrinds.

Cast and malleable irons allow more stock to be removed per tooth than steels, as do brass and bronze.

Exercise caution when determining stock removal rates. Too heavy a cut will cause the broach to overload.

Broach hook angles vary between 0–20°, depending on workpiece ductility. Brittle materials, such as cast iron, require a smaller hook angle, usually 5–10°. The softer alloys of aluminum and rolled steel pose special problems because they may adhere to the broach teeth during cutting. This can be controlled with proper sharpening, the right cutting fluid, adjustment of the cutting speed, and altering the step per tooth and tool geometry.

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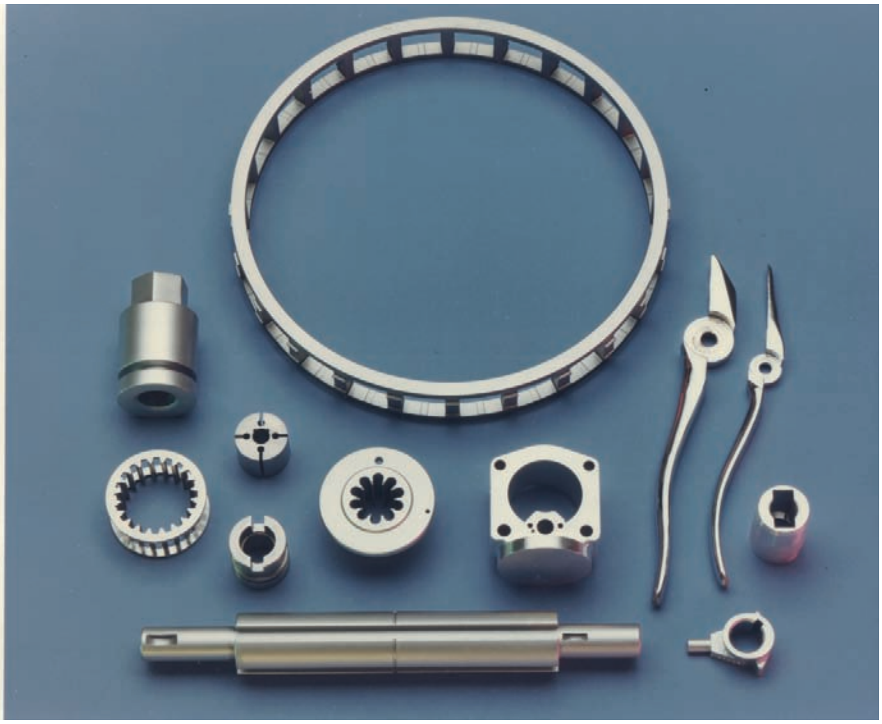


Applications

Each broaching operation is different. But there are five areas where broaching excels: on parallel, multiple surfaces; when fast cutting is needed; automated operations; large production runs; and tough materials.

The following examples of typical broaching applications illustrate broaching's versatility.

Broaching has been used to manufacture a firing-pin locking bolt for a large-caliber gun. The part was broached on all sides with a combination flat/contour broach fitted to a 48"-stroke, dual-ram surface-broaching machine. With hand loading and automatic clamping, the machine completed 60 parts per hour.

The picture on page 28 shows another example of multiple-surface broaching. It involved machining four surfaces on an aluminum forging. Employing a common fixture, only the adapters had to be changed prior to broaching each side of the part. A 48" stroke, vertical machine was loaded and clamped by hand. The result was 240 parts per hour.

Openings in combination wrenches have also been broached, with sizes varying from ¼" to 1". The wrenches first were loaded by hand into one of two adjustable magazines. The operation ran completely automated afterwards, with parts being fed into position, clamped, broached, unclamped, and then ejected. Production varied from 800–1,000 parts per hour, depending upon the wrench's size.

Slot cutting is another common broaching application. The clutch shown below is a rough-turned pearlitic casting. The fixture automatically indexed the part, permitting 12 slots to be broached on the part's OD. Ninety of these complex workpieces were produced per hour.

To cut the teeth in three brass styling combs, the parts were hand-loaded into a magazine, automatically positioned, clamped, broached, and then ejected. The slots measure 0.047" wide and 0.687" deep. Depending on the part size and style, between 800 and 1,000 parts were broached an hour.

Considerations

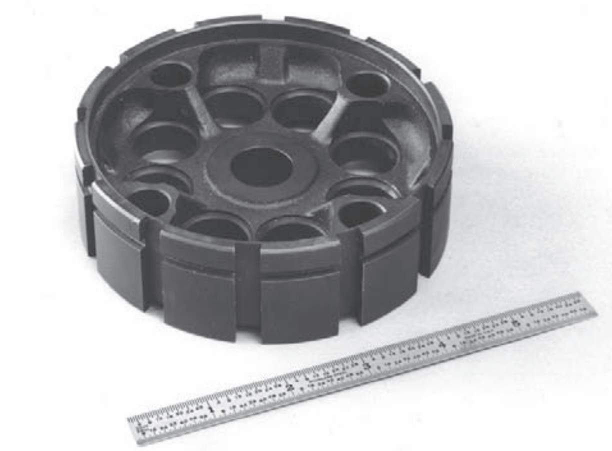
Broaching is not suitable for every situation. Like any machining operation, it has limitations. Several of these must be taken into account before determining whether broaching is right for a certain application.

The first consideration is the workpiece surface. If the surface to be broached isn't parallel to the direction the workpiece or tool travels, broaching may be inappropriate. Also, if the broach's passage over or through the workpiece is obstructed, another method should be sought.

Complex, contoured surfaces having curves in two or more planes can't be formed in a single broaching pass, except in the case of surface broaching helical gear teeth. In helical surface broaching, the broach and gear teeth are uniformly rotated in relationship to each other. The gear and broach must rotate at the desired helix angle as the broach is pulled through the piece to obtain the proper relationship.

Finally, the broached part must have sufficient strength to resist the forces exerted by the broach. Likewise, these forces also demand that machines and fixtures be rigid. Parts with thin walls or cross sections may prove too fragile for broaching. This is true for narrow slots as well, because the broach tools would have excessively thin cross sections.

Broaching won't solve every metalworking problem. But if the workpiece design and production volume lend themselves to it, broaching could prove to be the most efficient, least costly way to make top-quality parts. ■



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