Machine Involute Splines and Serrations with Rotary Broach Tools

By Peter Bagwell

Rotary broaching is not just for machining hexagon holes in screws. Here, you’ll learn more about the new product innovations and advanced techniques that continue to shape the broaching industry today.

Of the many ways to machine a form suitable for a gear, rotary broaching is not often the first considered. Precision grinding, broaching, EDM, and hobbing all have advantages in various features. Yet, innovation in rotary broaching tools is still alive and should be considered for various forms including small involute splines and serrations.

Rotary broaching tools were first patented more than 100 years ago by H.E. Warren in 1914. The concept involves using a machine to “wobble” a cutting tool from one corner to the next at a slow feed rate into a pilot hole. As the broach reaches the bottom of the hole, the complete form has been machined in a fast cycle time without a secondary operation.

In the 1950’s, commercial rotary broach tool holders were adapted into turning machines and screw machines. These tools were suitable for small hexagon, square, and polygon forms. However, interest began to grow and various other shapes, such as serrations and splines, were manufactured by rotary broaching.

Enter the 21st century and, now, rotary broaching tools for CNC machines have advanced features such as sealed bearings, pressure relief holes, and improved cutting tool steel. Ease of use has relaxed the skills needed to install the tools in the machine and more operators have become aware of their use. Today, rotary broaches are routinely used for making hexalobular and involute forms in precision-machined products in the standard lathes and mills found in nearly every machine shop.

However, the most significant challenge for rotary broaching has been the limited amount of material that can be removed in each pass of the broach. The average amount of material that can be removed with a rotary broach is approximately .025” per side. Improved techniques are helping to break through this barrier.

For example, if you have a half-inch diameter involute spline with tooth height of .025” per side, you should be able to rotary broach the form on your CNC machine. However, a one-inch diameter form with a .050” tooth height cannot typically be done due to the tooth height. New techniques are solving this problem and allowing more forms to be manufactured by rotary broaching.

One method is to use a new tool called a rotary broach brake. The brake attaches to the broach holder and holds the broach in position in between turning cycles. This tool allows the operator to remove the broach, drill out chips that are increasing pressure on the operation, and reinsert the broach into the hole in the same position it was removed.

The aligning of the broach to the partially broached hole could not be done previously because free turning rotary broach spindles do not include alignment features. The broach brake may also be used to align the involute form to another feature on the part. If there is a missing tooth in the form that is aligned with a perpendicular screw hole, the brake is manually adjusted to align the form properly.

The broach brake might also be used to align multiple broaches. Just as conventional broaches use multiple teeth to
cut the form in a part, multiple broach holders with brakes could be used to machine a part larger than .025” per side. The earlier example of a form with .050” material removal might be machined using three different broaches starting with the smallest and ending with the final form.

However, rotary broach brakes are not always the ideal choice for rotary broaching these larger gear forms. Manual adjustments and larger work envelope space may rule out its use. Another option is the use of a dog and guide post.

The dog is attached to the rotary broach holder spindle and will rest against the guide post when the tool begins turning. The guide post will always align the broach to the pilot hole in the same position and help keep it cutting straight in the hole. This fixture can often be assembled using standard screws and plates.

Setting up a rotary broach dog and guide post is more work and will take longer than setting up the rotary broach brake. However, the guide post is a more rigid set-up and can be relied on for longer sessions of unattended machining. The broach brake requires more attention, but can be set up to begin broaching very quickly.

Innovation in rotary broaching tools has not been limited to the tool holders. Many rotary broaches are now made with standard pressure

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relief holes to prevent hydraulic pressure from building in blind holes. New broach materials and coatings are constantly being tested to improve tool life.

Rotary broach forms are typically manufactured to a tolerance within .0005” and cut accurately. Limitations due to grinding and EDM may require .005” maximum radii in the sharp corners, but this area of the form is also removed from the part and is usually an acceptable compromise. Slightly oversize pilot holes for internal broaching and undersize diameters for external broaching needed to

**Case Study: Rotary Broaching for the Next Generation**

For more than 30 years, the Society of Automotive Engineers (SAE) has held an annual competition known as Formula SAE. The goal is to design and build a formula-style racing car, and then compete against similar race cars from all over the world. University of Washington Formula Motorsports students needed to make a hole to match the serration of one of their drive components.

The serration had a major diameter of 11.35mm, a minor diameter of 10mm, and 30 teeth. Students contacted rotary broach manufacturer Polygon Solutions Inc. to determine if the form was suitable. After confirming the suitable material removal per side and the shallow depth of the hole the custom serration broach was ordered.

An approval drawing was sent to the students to confirm all of the required dimensions and the broach was manufactured and delivered shortly after. The racing students achieved an early victory and were able to quickly and easily machine the complex form in a milling machine using a standard adjustment free broach holder and custom designed rotary broach. Future broaching projects are also planned with the new partnership developing between the students and engineers at Polygon Solutions.

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create individual chips often eliminate the radii portion of the form and make this limitation irrelevant.

Many customers wanting to make mating parts for spline shafts and other gear related forms often expect to find standard serrations and splines available off the shelf. However, the wide variety of international standards and standards between various trades makes this unrealistic. Most multi-toothed rotary broaches will be made to your custom dimensions within a short period of time. Some time may be required to generate working or approval drawings needed to manufacture the tools.

Some modification to the forms can be made after the broach is manufactured. Due to the back-taper needed to allow the broach to ‘wobble’ in the hole, rotary broaches are not typically sharpened. If the broach was sharpened, the form would drastically decrease in size.

If the internal form is at the high side of the tolerance, and the fit is too loose, the broach may be able to be slightly ground or dusted on the end resulting in a smaller form. When broached, this will result in a smaller hole and tighter fit. Sharpening and modifying the form by grinding the end of the broach should be done with caution as modern adjustment free versions of rotary broach holders designed for CNC machines rely on the fixed length of the standard broaches to keep the form on center.

Many of the limitations for rotary or ‘on-machine’ broaching are changing, and it may be worthwhile to revisit some manufacturing processes or product designs to see if your parts are candidates. Eliminating secondary operations and reducing cycle times are very effective means of reducing costs and utilizing idle turning machines. Contact your rotary broach supplier to see if you can machine your involute splines and serrations with rotary broach tools.

ABOUT THE AUTHOR: Peter Bagwell is a Rotary Broach Product Engineer at Polygon Solutions, Inc. in Fort Myers, Florida, and a board member of the Southwest Regional Manufacturers Association. Peter shares over 10 years of experience in broaching and expert technical support with thousands of Polygon customers and can be reached at peter@polygonsolutions.com.