An Update on Broaching Technology

By Dwight Smith

Advances in both broach tools and broach machines have progressed the state of the art in broaching.

The world of broaching has certainly changed since the 1850s when it emerged as a viable production metalworking process. Advancements have been made in machine technology, processes to increase performance, and specialty coatings to improve tool life.

Broach tool advances

Most manufacturers seek higher productivity and lower costs as ways to improve profitability. The cutting tool industry is constantly being challenged to improve tool life and re-sharpening accuracy.

A recent advancement in broach tools is the use of specialty coatings. By applying the super-hard Nanodynamic coating, broach tools are being produced with finer surface finish. This improved surface finish, along with the hardness of the coating, can produce better tool life.

The broach tool surface finish is significantly improved over an uncoated or TiN-coated tool as shown in Table 1.

<table>
<thead>
<tr>
<th>Nanodynamic</th>
<th>TiN coated</th>
<th>Uncoated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ra 0.03mm</td>
<td>0.04mm</td>
<td>0.33mm</td>
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</table>

Table 1

Testing has revealed superior edge retention and tool life in real-world broaching applications. It has been observed that workpiece flaking is reduced and burr sizes are one-seventh the size created by conventional broach tools.

In broaching, it is edge wear that ultimately governs tool life as well as the number of pieces that are cut before sharpening is needed. Real-life performance has shown that Nanodynamic coating greatly delays the onset of edge wear, thus extending the working life of the tool.

Table 2 is a comparison of edge wear measurements both with and without Nanodynamic coating. It shows that the wear on the coated tool at 10,000 pieces is the same as the uncoated tool at 5,000 pieces. This represents twice the number of parts. If the obtuse edge wear of .101 mm produced parts in tolerance, then the tool could produce three times the number of parts compared to an uncoated tool.

<table>
<thead>
<tr>
<th>Broach tool data:</th>
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<tbody>
<tr>
<td>Body: 125 cutting teeth, two starts, length 2,286 mm, material: PM-M4</td>
</tr>
<tr>
<td>Shell: 18 cutting teeth, four starts, length 254 mm, material: PM-M4</td>
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</tbody>
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<table>
<thead>
<tr>
<th></th>
<th>Uncoated</th>
<th>Nanodynamic Coated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pieces cut</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>10,000</td>
<td>10,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Acute Edge Wear (mm)</td>
<td>0.050</td>
<td>0.050</td>
</tr>
<tr>
<td>Obtuse Edge Wear (mm)</td>
<td>0.076</td>
<td>0.076</td>
</tr>
<tr>
<td>0.101</td>
<td>0.076</td>
<td></td>
</tr>
</tbody>
</table>

Table 2

Hard broaching

Continuous improvements in automotive powertrain applications have driven most gear manufacturing to hard finishing operations to ameliorate the effects of heat treat distortion. Gear grinding and honing are utilized for nearly new transmission projects. Analogous to this is the use of hard broaching to improve part geometry after heat treatment. This need is being met on internal spline applications by the use of hard broaching.

After a “green” (pre–heat treatment) broaching process, the components are typically carburized and hardened to a hardness of Rc 58-62. Cutting speeds generally range from 60 to 63 meters per minute. Two methods of hard broaching are considered for each application. If the removal of distortion is the only goal, and “no cleanup” is acceptable, then the part can be broached to the finished size and then heat treated. After heat treatment, the hardened parts can be hard broached — again, to the finished nominal size. This will remove only the material that was displaced by the heat treatment distortion.

The other method, defined stock removal, requires that the green broach be designed to leave enough stock to ensure full cleanup at the after–heat treatment hard-broaching process. A specially designed broach tool is then used to broach the hardened parts, removing approximately .100 mm (.004 inch) of stock per flank. The results can be compared to a ground component at a much lower per-piece cost.

Other advantages of hard broaching include better process capability compared to the capability that can be achieved with parts that are only green broached and then heat treated. The critical characteristics, such as dimension between pins and circularity, are greatly improved because the part is broached to the desired condition, which removes the distortion caused by heat treatment. Care must be taken to produce the part in the green condition with sufficient stock to be removed by the hard-broaching process if full cleanup is required.

Hard broaching is applicable for components that require precise concentricity, for example, internal splines.
This process also improves the spline bearing area, thus improving and strengthening the interface between shaft and gear. Where automatic assembly operations take place, the improvement in process capability and reduction of variation is a considerable benefit.

MAINTENANCE AND SHARPENING
Broach tool maintenance consists primarily of sharpening the cutting edges by grinding. This is similar to the original manufacturing process and needs to be accurate. To ensure accurate and repeatable results, the use of CNC broach grinding machines is a practical necessity. With proper grinding, broach tool maintenance also requires stripping and recoating the coating, whether it is TiN or the aforementioned Nanodynamic advanced coating.

MACHINE ADVANCES
A major advancement is the development of electromechanical broaching machines. This allows the elimination of large and inefficient hydraulic systems. The use of these machines for production of helical internal gears for automotive use has almost completely replaced gear shaping.

This technology has been developed and implemented in electromechanical rising table broach machines, electromechanical pot broaching machines, and electromechanical horizontal surface broaching machines.

Electromechanical rising table broach machines can exert up to 60 tons of force to produce helical or spur internal ring gears. Close attention is paid to the design and construction of the machines to eliminate any deflection or movement of the machine during the powerful cutting stroke.

Although the standard machines need an overhead clearance of 7 meters (23 feet), a costly pit of reinforced concrete is no longer needed. A compact version, BH50-17, needs only 5 meters (16.4 feet) of ceiling clearance. For high production, two broach tools and part fixtures are used to make two parts with each cycle of the machine. With a typical cycle time of approximately 22 seconds, two parts are produced for a floor-to-floor time of 11 seconds. It would take a large fleet of gear shapers to match this productivity. Many new planetary transmissions have been specifically designed to allow for broaching the internal ring gear rather than shaping.

**Advantages of an Electromechanical System over the Previously Used Hydraulic Machines**

First, control and flexibility are greatly improved. By using the CNC control to monitor and adjust the broaching cycle, optimum cutting speeds can be achieved for each individual part, material, and situation.

In traditional hydraulic systems for helical broaching, the broach machine requires a specific helical guide (lead bar) to rotate the tool during the machining stroke. In some cases, the part and fixture are rotated in concert with the cutting stroke. The guides are highly precise, add typically long (and costly) lead items, and can be used only for one specific helix, therefore, changing the guides is a lengthy procedure and prohibits flexibility.

The advent of electromechanical broach machines allows helical broaching without the need for the specific mechanical guides. A

CONCLUSION
Although the broaching process dates back several generations, it is still a viable method for high-volume production. With the advancements in machine technology, such as the electromechanical systems, this metal removal process can produce quality internal forms such as gears and splines faster and more economically.

With the advent of Nanodynamic coating, broaching efficiency is further enhanced. The per-piece cost of consumable tooling can be cut by half and perhaps even two-thirds. Utilizing a constant-force tool design improves tool life and can result in a shorter tool. Combining the advancements in broach tools with fast and rigid electromechanical machines, broaching is still advantageous to the industry.

**ABOUT THE AUTHOR:** Dwight Smith at Federal Broach and Machine Company has more than 25 years of experience in the gear manufacturing industry, including metrology, analysis, and project management. Smith serves as a committee chairman for AGMA, and he is an instructor for the AGMA Basic Gear School.