Chamfering Can Make the Difference—The Choice Is Yours

Match the ideal solution to the workpiece

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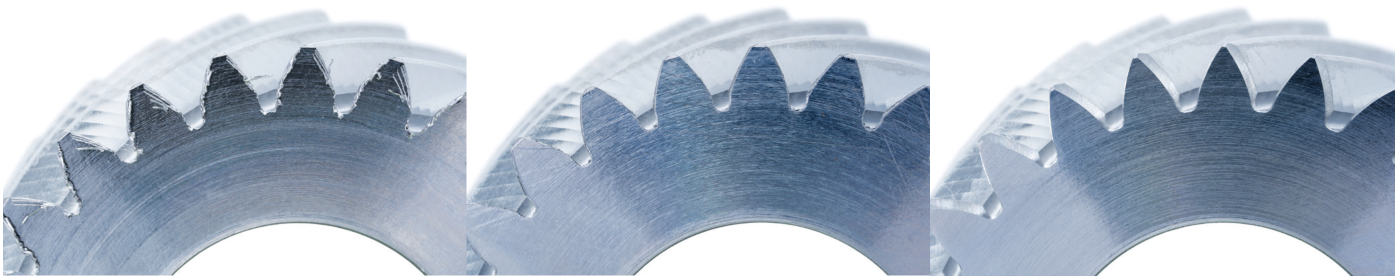


Gear hobbed with remaining hob burr (left). Gear hobbed and rough deburred during hobbing (middle). Gear after hobbing, rough deburring and then chamfer hobbing in parallel with hobbing (right).

They say necessity is the mother of invention. The arrival of a new generation of cylindrical gear chamfering solutions in recent years isn't by accident. Gear manufacturers who might have turned a deaf ear to a new chamfering technology just a few years ago now welcome it with open arms. After all, the benefits of quality chamfering are now well-known, and their application is near-mandatory. Inadequate and uneven chamfers cause extraordinary costs when applying expensive hard-finishing tools down the value stream. Gears that aren't properly chamfered and deburred can lead to overloaded edges and unanticipated and undesirable noise. This is particularly true in EV applications where torque transmission, unlike combustion engine vehicles, goes from zero to a much higher maximum almost instantly. As a result, EV gears require hard finishing (honing and threaded wheel grinding), and chamfering/deburring becomes critical. In the case of honing, a burr as small as just a few microns left on the hardened flank of a gear can cause excessive and costly wear on the honing ring, increasing tool cost and reducing productivity.

Nonetheless, gear manufacturers are wary of introducing anything to their processes that will appreciably increase cost-per-piece. Chamfering solutions must be both effective and extremely economical. Ideally, they should be ingeniously paired with preceding soft-cutting machines so that the long-term total cost of ownership becomes virtually unnoticeable—at most just a penny or two per piece. No single chamfering solution fits all. Each offers advantages and disadvantages that can rule them out, given the needs of a particular application, or make them the perfect fit.

For comparison purposes, let's look at several common and most recent chamfering technologies and their likely range of applications from small workpieces produced in high volumes to larger workpieces produced in lots as small as one.

Chamfer Rolling for High-Volume Production

Chamfer rolling with secondary deburring discs. A very fast process that can, however, form a secondary burr that must be removed downstream.

Sometimes referred to as press chamfering or rotary chamfering/deburring, this very fast forming process has been around for years, and it is used effectively for high-volume production of planetary gears or shafts with interfering contours. Using gear-shaped tools that mesh with the workpiece creates chamfers along the tooth edges. Excess material flows mainly to the face side of the gear, where it's cut away with single blades, deburring discs, or file discs, depending on gear shape and/or machine configuration. However, the forming process can result in a minute deformation of the workpiece and material flowing into the gear tooth flank itself, thus forming a secondary burr that must be removed in yet another operation before hard finishing downstream. Additionally, with dry machining now predominant, the forming process isn't as efficient as when performed wet, reducing tool life. For EV applications in particular, these factors can combine to raise costs to prohibitive levels.

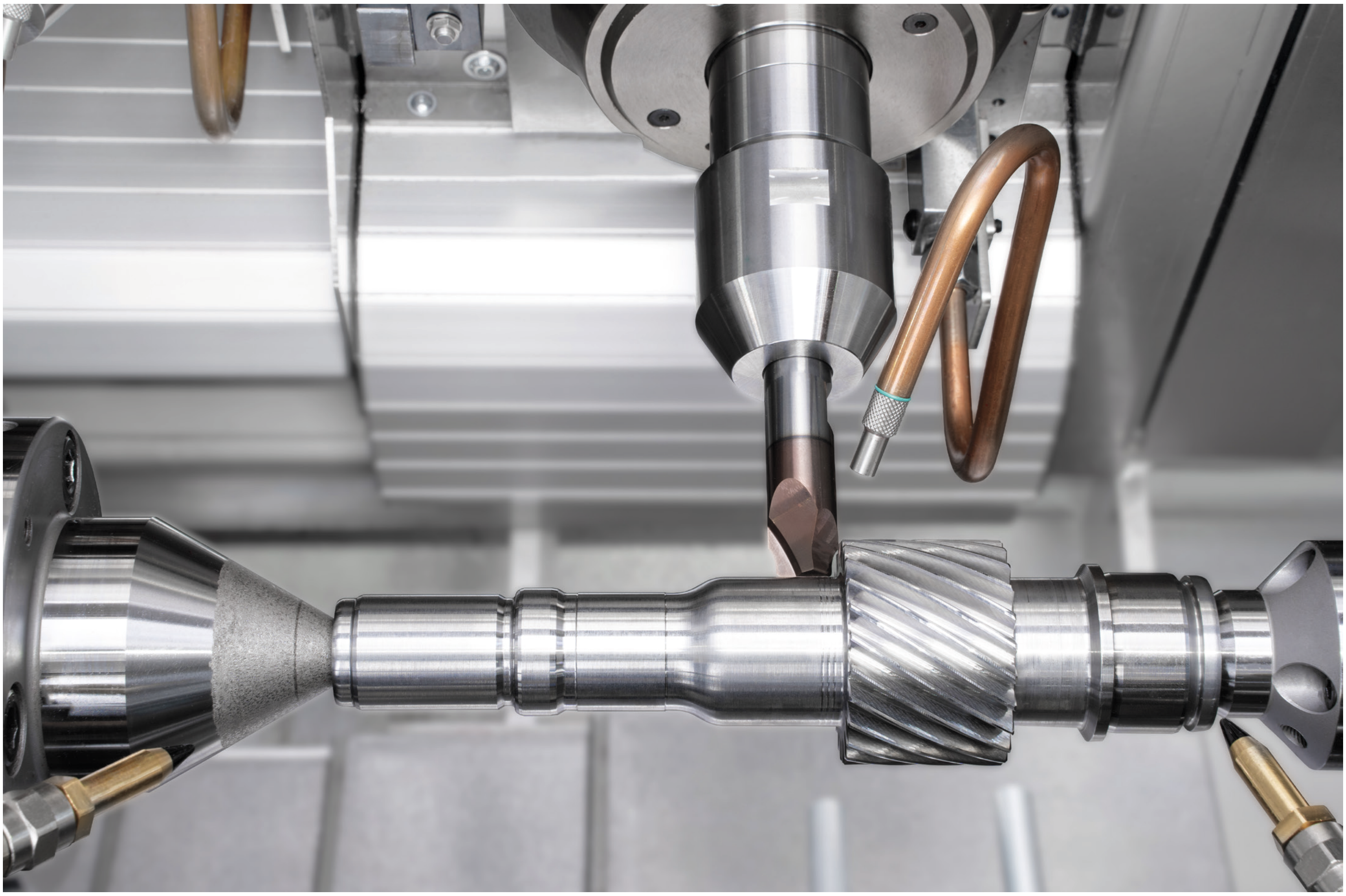
Radial Chamfering for Small to High Volume Production

Chamfer rolling is a poor choice for EV transmission gears, pinions, and shafts; new chamfering processes are needed. One of these is radial chamfering. It can now be applied in parallel with gear hobbing for the first time. Rather than forming the chamfer through rolling, it is produced with a cutting process using either one or two resharpenable milling cutters, thus eliminating a subsequent operation to remove the excess material that can result from chamfer rolling. With cycle times and tool cost per piece of paramount importance, replacing chamfer rolling with radial chamfering makes perfect sense—particularly for shaft-type parts. These shafts, often with the root diameter of the chamfered gear and the shaft diameter in close proximity, are inherently more difficult to chamfer and deburr due to the clearance requirement. Radial chamfering is the right chamfer process for gears with adjacent contours that need to be shaped or power skived as well. Even with just a few millimeters gap common to cluster gears, double pinions or rotor shafts, radial chamfering with the proper tool design offers the ideal solution.

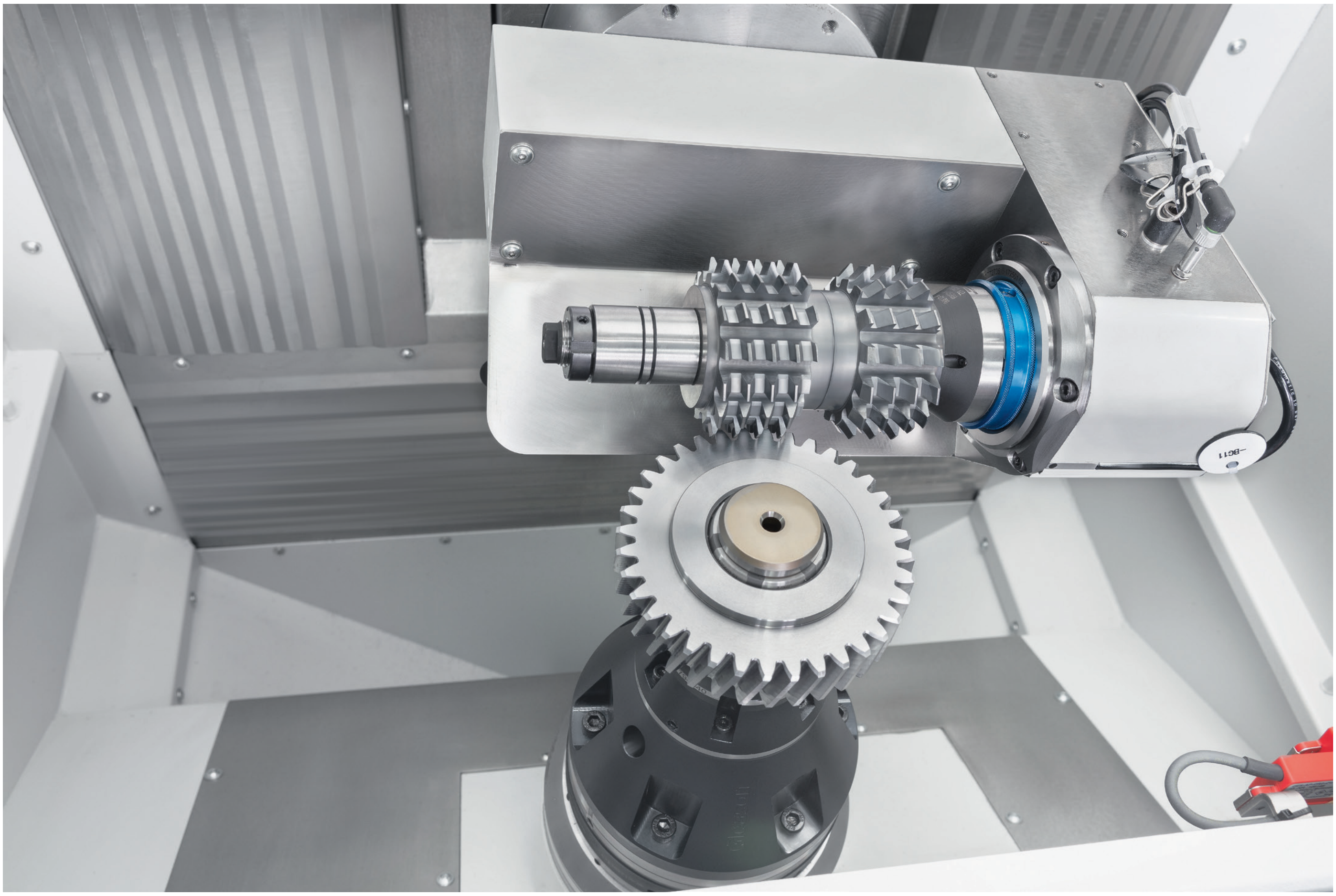
A single radial chamfering tool can be designed for chamfering the gear flanks, with or without root chamfering. A two-tool option adds more flexibility to adjust the chamfer angle with tools specifically designed for the obtuse and acute edges to meet a customer's specific design requirements before the subsequent hard-finishing operations. This is particularly advantageous in the case of gears with high helix angles where obtuse and acute angles can be quite different. Using Gleason simulation software, chamfer form, angle, width and even the expected inspection graph will be defined in advance.

Chamfer Hobbing for Medium to High Volume Production

While chamfering with hobs has been known for decades, chamfer hobbing takes the process to a new level. Chamfering is performed using a Gleason chamfer hob. The cutting tool has characteristics very similar to a gear hob. It is made with high-speed steel and features AlCroNite Pro coating for exceptional tool life in dry-cutting conditions. With Gleason chamfer hobbing, one chamfer hob is



Radial chamfering for shafts and gears with collision issues and shortest cycle time requirements.



Chamfer hobbing with low tool cost.

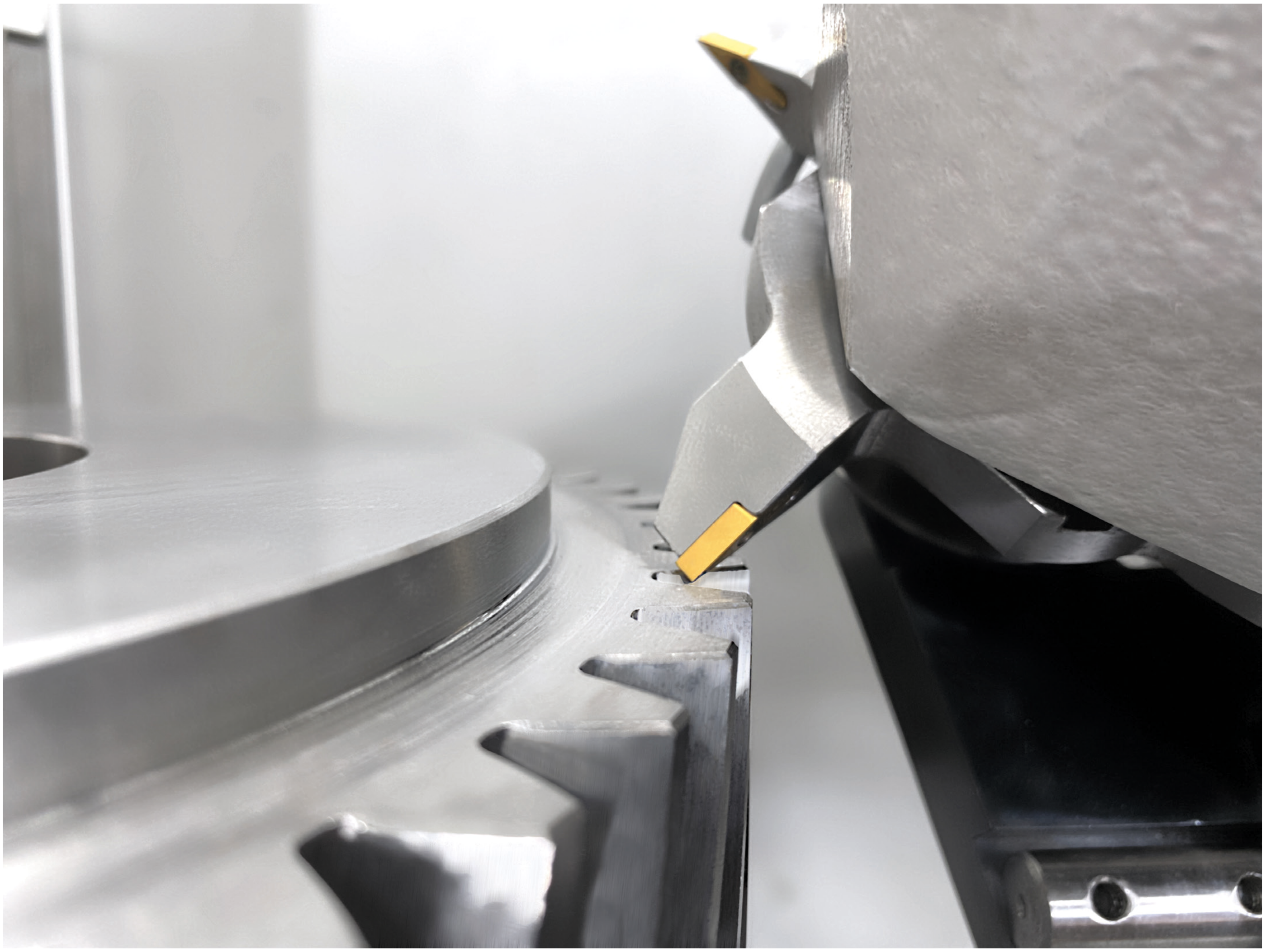
used for each tooth flank, with a tooth profile specifically designed for the chamfer form that's required. The chamfer hob looks like a standard gear hob but with asymmetric teeth. One flank is designed for cutting the chamfer, the other flank is designed not to touch the counter flank. This process delivers great flexibility regarding required chamfer angles. Typically, parallel-chamfer forms are cut along the tooth edge only or including the root area. Chamfer angles like those commonly produced in the chamfer rolling process are targeted (15–30 degrees on the obtuse edge, 25–35 degrees on the acute edge). In the chamfer hob design process, Gleason technology software is used to simulate the required chamfer and identify and avoid all potential collisions of the tools with the counter flank and interfering contours above and below the actual gearing. By cutting into the gap, burrs are avoided on the face side of the gears. With typical chamfer angles, there are no measurable burrs on the flank that require removal downstream. These factors, plus tool shifting to more evenly distribute wear and extend tool life, result in the absolute lowest tool-cost-per-piece: just one cent or less on average for a typical EV intermediate gear.

Fly Cutter Chamfering

While fly cutter chamfering has long been used in bevel gear cutting applications, it has just recently been made available for larger (truck-size) cylindrical gear production and those applications where maximum flexibility and frequent part changeover make the use of dedicated tools (e.g., chamfer rolling and chamfer hobbing) prohibitively costly. Instead, this process mills the chamfer with its desired characteristics along the gear edge contour by synchronizing a fly cutter—generally a star-shaped body with four standard, replaceable inserts—with workpiece rotation. Since each edge of the tooth is done separately and the chamfer size and angle depend on machine movements, not tool design, the process is quite universal. With just a relatively few different standard inserted blade sets and base bodies, a single tool can be used for different modules, pressure angles and number of teeth. Size and chamfer angle can easily be programmed.

Chamfering Integration Made Easy

Naturally, all the aforementioned chamfering processes must be made available to gear manufacturers such that their impact on cycle times, tool cost per piece and the price of total ownership is so small as to be virtually inconsequential. Chamfering can be fully integrated with hobbing and power skiving machines and performed in parallel with these primary cutting processes. In cases where hobbing machines already exist and replacement is not desirable, chamfer design requirements can, of course, be met with standalone chamfering machines such as the Gleason 280CD, which currently offers both chamfer hobbing and fly cutter chamfering. In every case, the approach has always been to make chamfering technologies as readily available and as easy to integrate as the cutting processes themselves. For example, for the latest requirements of EV transmission gears, pinions, and shafts, where cycle times and tool cost per piece are critically important, Gleason offers the new horizontal 100HCD



Fly cutter chamfering for the highest flexibility—one tool for many different workpieces.

hobbing machine. It performs radial chamfering in parallel with gear hobbing, thus not impacting chip-to-chip times. The new vertical Genesis 180HCD and 280HCD hobbing machines also feature chamfering in parallel with gear hobbing: chamfer hobbing on the 180HCD and the option for both chamfer hobbing and fly cutter chamfering on the 280HCD for workpieces with diameters up to 280 mm and module 5 mm. Note that these machines feature either an additional gantry loader or a 4-station ring loader to link gear hobbing with chamfer cutting and external automation/storage.

Gleason Genesis 280HCD hobbing machine with integrated chamfer station for chamfer hobbing or fly cutter chamfering.

Finally, when any of these technologies cuts a chamfer, the quality engineer must ensure it's in tolerance according to the part print. Measuring is mandatory. This process can be slow and laborious with conventional mechanical contour measurement machines. Today's gear inspection technologies, like the Gleason GMS series of analytical gear measuring systems, can be equipped with integrated chamfer inspection software to speed and simplify the chamfer inspection process by providing a complete analysis of different chamfer sizes and angles, thus simplifying comparison with the workpiece drawing.

Summary

These latest solutions are available today to apply the right chamfer process to widely disparate applications such as automotive-type gears and shafts, truck-size gears, or job shop applications. Most importantly, the total ownership cost for chamfering has never been lower, nor has the case for chamfering been more compelling.

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