Chamfering and Deburring – the Underrated Process

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Chamfering and deburring of cylindrical gears does not get much love from manufacturers. The process is seen as a necessary evil since it is adding cost without adding "value." However, there are good reasons for not underrating this important auxiliary process. Chamfering and deburring takes care of several issues which may come up during the manufacture of quality gears.

First of all, chamfers prevent damages in gearboxes if acute edges or remaining burrs from the hobbing or shaping process become brittle during super-carburization in the heat treatment process. Under load these extensions can break off and hardened particles can reduce transmission life causing major damages with premature transmission failure.

From a gear manufacturer's view, burrs have a negative impact on the cost-per-piece produced, respectively tool life in subsequent finishing processes like honing. A hardened burr will eat away finishing tools, typically at the same spot wasting precious tool life and resulting in more dressings required, adding even more cost. When gear faces are used for clamping or locating purposes burrs are not allowed either. In part handling, chamfers prevent damages like nicks when parts are handled on automation systems where workpieces can touch. And finally, when handling workpieces manually sharp burrs can injure operators. These issues can be avoided by choosing the proper chamfering and deburring technique.

Over the years several processes have been developed to remove burrs effectively and to chamfer gears with an undefined or defined chamfer.

The following article will focus on efficient processes which can create consistent and defined chamfers. For this reason we will not elaborate on electrochemical deburring or chamfer grinding.

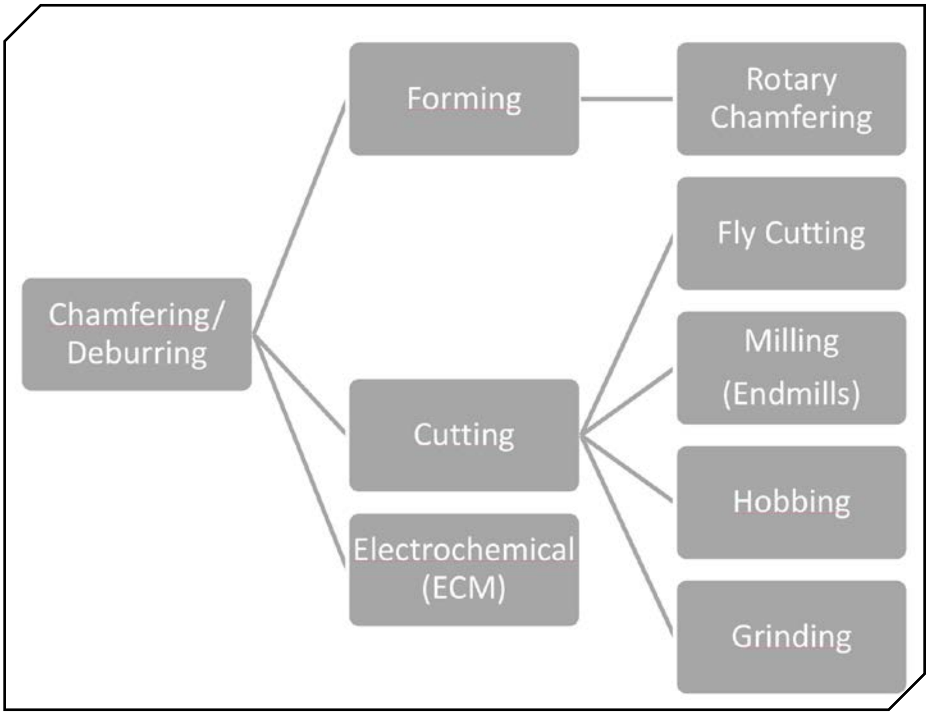
Forming Chamfering

The process most frequently applied for smaller cylindrical gears up to module 5 mm is rotary chamfering. It covers most gear geometries and is an extremely fast process which makes it applicable for even the smallest applications like planetary pinions which feature cycle times below 10 seconds.

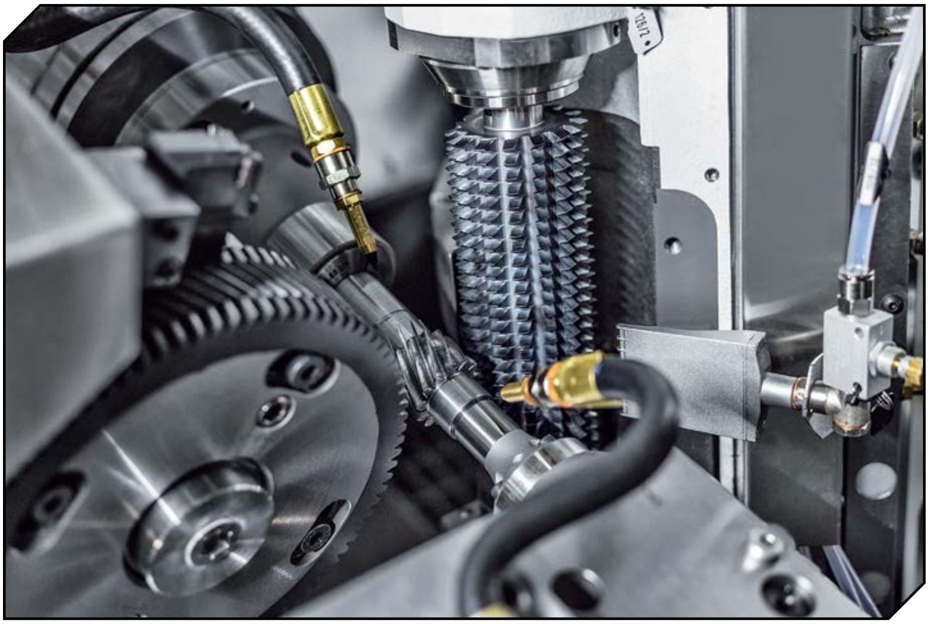
Rotary chamfering is a forming process which creates chamfers along the tooth edges by gear shaped tools which are meshed with the workpiece. Material flows mainly to the face side of the gear where it is cut away by single blades, deburring discs or file discs, depending on the gear shape and/or the machine configuration. Unfortunately some material can "flow" into the gear tooth flank, the so-called "secondary burr." While shaving or threaded wheel grinding can easily cope with this small bulging of material, a subsequent honing process requires a better quality input, in order to not jeopardize the comparably expensive tool life. Two strategies are used to get bulging free flanks: Either edge zone burnishing or a two-cut hobbing process.

For edge zone burnishing special rotary chamfering tools feature a 180 degrees chamfering section and another 180 degrees section with burnishing functionality. Secondary burrs on gear flanks generated by rotary chamfering discs are rolled down into the flank surface leaving only the required stock for the subsequent finishing process and keeping nevertheless the required scallop depths.

The two-cut hob process regularly features a pre-cut and a final pass with the rotary chamfering process in between both cuts. Secondary burrs in the flank are removed by the second hobbing pass. As the second pass is determining quality and remaining stock for the following honing process, cutting parameters are chosen to keep the total hobbing time close to a one-cut process. Unless a double spindle machine is used the sequential chamfering usually amounts only to an additional 4–5 seconds. This process



Typical processes used for chamfering and deburring of gears.



Rotary chamfering/deburring on an integrated station for subsequent chamfering/deburring of geared shafts, Gleason P90iC.

strategy also works well for finish hobbing applications which require chamfers.

Rotary chamfering produces chamfers with angles in the range of 20–30 degrees and — depending on the application — even beyond this range. The process provides constant results with comma-type or parallel chamfers, root chamfers, acute or the obtuse chamfers. Due to short machining times and long tool life it is the process of choice for medium and high volume production of cylindrical gears.

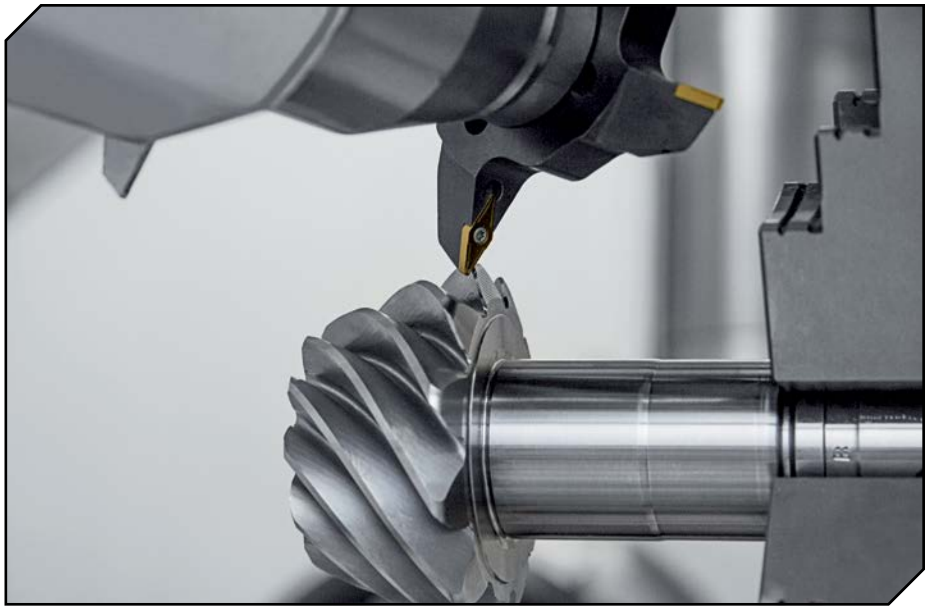
Cutting of Chamfers

An alternative to rotary chamfering is cutting the chamfer. Several methods are available: Let's start with **chamfer hobbing**. Chamfer hobs can be either mounted on the main hob spindle itself or by means of some kind of station attached to or integrated into the machine. The benefit of an additional, separate station is the time-parallel processing of the auxiliary task which allows the chamfering process to be executed in completely masked time. Another benefit of a separate station versus mounting chamfer hobs on the main spindle is the less complicated, "fiddly" setup procedure and the independent tool change when required. Cutting chamfering provides a defined chamfer with minimum secondary burrs which again is ideal for subsequent hard finishing processes like the honing process. Compared to the rotary chamfering process collisions have to be avoided when machining e. g. cluster gears. On the other hand modules larger than 5 mm, which would be the limit for rotary chamfering, would not be a problem to chamfer. Since the tool is workpiece-dependent this process is preferably used for medium and high volume production like automotive.

Chamfering by Fly Cutting is a continuous cutting process with a timed relationship between the tool and workpiece rotation, employing a contouring strategy to follow curved tooth edge geometries with a generic cutting tool and would be the choice for cutting chamfer when looking for small batches and flexible lot production. The coordinated motions of the chamfer unit axes allow the cutting tool to generate a chamfer along the workpiece edge contour. The chamfer tool has a star shaped body, with two to four replaceable, indexable standard inserts. Depending on the cutting strategy secondary burr removal processes with discs or inserts can be considered.

Ideally, one or two tool sizes fit most workpieces, therefore this process can be considered highly flexible. While fly cutting has been long employed on bevel gears, it has been just recently adapted as a viable chamfering process for cylindrical gears, one perfect example is the new Gleason 400HCD Hobbing Machine. Integrated into the machine on a separate station, the fly cutting process can be performed completely time-parallel to the hobbing process. Similar to chamfer-hobbing upper and lower gear edges

Machine Gleason Genesis 400HCD with rotary chamfering/deburring on a separate station allowing for time-parallel hobbing and chamfering/deburring.



Autopath chamfering on a Gleason Phoenix 280CX, chamfer-cutting a bevel pinion.

are chamfered sequentially. Due to the required cutting time fly cutting is especially beneficial for medium to large sized gears so chamfering can be done during the hobbing cycle without jeopardizing productivity of the complete system.

A very flexible way of chamfering is offered by **chamfer milling employing endmills** typically made out of carbide. This is a very universal method since workpiece-specific tools are not required and fitting endmills can be ordered as commodity tools. Endmills can either be mounted on a swinging arm and the contact pressure defines the chamfer size or sit on a NC controlled tool carrier which follows the teeth edges. Especially with the milling tools on swinging arms the flexibility is higher prioritized than a tolerated and defined chamfer. Due to the duration of this chamfering/deburring process its strength is more in small or medium batch production and in the manufacture of larger gears. In most cases these technologies are performed on stand-alone machines when supporting dedicated gear cutting machines.

Conclusion

Chamfering/deburring is an interesting example of a necessary but unloved process often proclaimed dead, that has been resurrected. One that is approached with expensive ideas, but is coming back strongly, especially in cases where honing as a finishing process is required. When large quantities of smaller gears have to be manufactured efficiently (minimum cost and within tight tolerances), rotary chamfering combined with one- or two-cut cycles or cutting chamfer is the method of choice. If modules larger than 5.0 mm have to be chamfered and deburred, cutting chamfer has been a viable solution. The "new" fly cutting process, borrowed from its bevel gear relatives, has further enhanced this quite costly process by adding flexibility to the cutting chamfer process while maintaining efficiency with considerably lower tool costs and even easier handling. More flexible methods exist, for example, chamfer grinding or chamfer milling, but they lack the productivity and tolerances of the previously-mentioned processes.

Chamfering/deburring with rotary tools or cutting tools and endmills for larger applications will address most challenges customers face today. We are excited to show our ideas at AMB in Stuttgart, IMTS in Chicago and Jimtof in Japan.

For more information:

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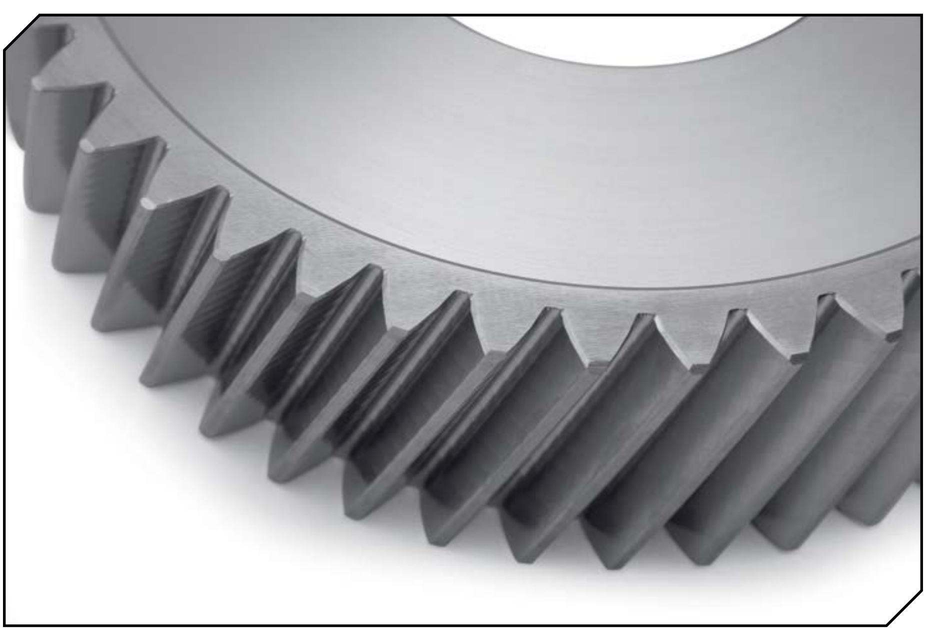

Cylindrical gear with defined chamfer, hobbed and fly-cut.

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