With the Gratomat procedure, milling cutters are used to cut the chamfers on the contour of the teeth. The hard metal tools are pre-loaded and pressed onto the faces of the workpiece at a defined angle. The procedure is flexible with respect to workpiece geometry as the milling cutters are usually suitable for different components. Furthermore, it is rather insensitive with respect to component strength. With a sufficiently long cycle time for gearing, chamfering can be performed simultaneously. This is true in particular for spur gearing as here the top and bottom are chamfered at the same time. At helical angles > 10°, the faces are machined sequentially, which lengthens the time needed for chamfering.

The kinematics of the procedure generate a characteristic, uniform chamfer form (see Fig. 2). Here, the chamfers are largest on the head of the tooth and around the root of the tooth, and smallest in the area of the root form circle. In contrast to the contour line, the width of the chamfer toward to the flank can be regulated with the circumferential speed and contact pressure of the tool. The Gratomat procedure produces rather flat chamfers relative to the face, i.e. rather large chamfer angles with respect to the helical angle.

Integrating the procedure in the gear cutting machine allows Liebherr to offer a chamfering unit which is attached, for example, to the control side of the machine without requiring additional space. The workpieces are handled by a 4-station ring loader.

The special tools needed make pressure deburring less flexible with respect to workpiece geometry, but this is made up for with extremely short chamfering times. For this reason, it is primarily employed simultaneously. So-called roll pressing tools are used for chamfering by way of pressure deburring (see Fig. 3). These roll off under pressure with the workpiece. The process consists of cold forming the sharp face edges. Displaced material is sheared off at the faces by deburring or filing discs. The pressing tool is a complex system of several gear wheels configured for a specific workpiece. Besides high component strength, the low level of flexibility restricts economy and use is limited primarily to large-scale production. The chamfering result is illustrated in Figure 4 by way of example. The chamfers in the area of the tooth flanks can be clearly seen. Furthermore, the sheared off deformations on the face can also be seen. The tooth root can also be chamfered if the tool is configured accordingly, but this will lead to a shorter service life (less favourable rolling conditions). If the fine-machining procedure (shaving or hobbing) permits, it may be possible to skip the Chamfering of gearing smoothing of the flanks. This will double the service life of the tool, reducing the price and improving versatility. Furthermore, if the Liebherr deburring gear is chamfered on both sides, it can be turned at the end of its service life. That also has a cost-reducing effect.

The main benefits of the procedure are:
- Extremely versatile
- Ideal for gear makers but also for large-scale production
- Different workpieces can be chamfered with standard milling cutters
- No workpiece deformation
- Root of tooth can be chamfered
- Less sensitive to interference contours (e.g. slight deviate to the root circle of the gearing)
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Chamfering of gearing

Different procedures can be selected for chamfering pre-ground spur wheels on gear cutting machines: Gratomat, pressure deburring and ChamferCut. Know the benefits and limitations of the different procedures and you will quickly find the optimum solution for your specific application.

There are several different procedures for chamfering the gear wheels, which offer their suitability according to batch size, the required chamfer form, subsequent machining and component geometry. Chamfering can be performed in separate machines, or ideally directly in the gear cutting machine. This article will discuss the procedures which can be integrated into the machine: Gratomat, pressure deburring and ChamferCut (see Fig. 1) and will present the resulting chamfer geometries on the basis of typical machining examples.

ChamferCut

The ChamferCut procedure, in which the chamfer is produced with special chamfering tools, is on the rise. ChamferCut cutters classically enable the workpieces to be deburred and chamfered in the same clamping position directly after gearing. The tool, a workpiece-specific form cutter, works in the continuous process. The chamfers are machined to create a very high chamfer quality and excellent reproducibility. However, the sequential machining lengthens the cycle time. The main advantage of this procedure is the uniform, parallel chamfering of the faces of the gearing along the whole contour of the tooth, including the curvature of the root of the tooth which can be also chamfered without problem (see Fig. 2). The selection of the tool is its highly asymmetrical profile, which distinguishes it significantly from classic hobbing profiles. However, apart from that, the ChamferCut cutter is similar to a hobbing machine and can likewise be repeatedly reconditioned by recutting the tool face at the end of the service life. Decision for practical use of the procedure are the functionality and user-friendliness of the related machine software. To this end, Liebherr has developed a software package that takes into account the geometries from the setting data of the tooling file and implements the necessary axial movements and corrections needed due to the specific tooth profile of the machine. This is optimised by the CNC axis on the basis of the width and symmetry of the tooth and in the root of the tooth, the chamfering can be performed in a single-cut strategy. Not only does this save time; it also has a positive effect on the load life of the hobbing machine. The chamfering result is illustrated for the face of the component. Besides the precise, parallel chamfers along the flank of the tooth and in the root of the tooth, the undamaged, deformation-free face can be clearly seen, which is especially beneficial if the component features an oblique face. The chamfer face can be set completely all via the NC axes. The chamfer angle is in the range of about 15 to 25°. Conclusions: One of the main advantages of the ChamferCut procedure is the extremely precise chamfering face with no additional machining required. Chamfering times are shortened, the separate clamping of the workpiece when hobbing and chamfering is no longer needed and the workpiece can be fully loaded in an extremely short machining cycle time. Until now this was often an exclusion criterion. The advantage of the ChamferCut procedure is the tool costs. The key drawback of the ChamferCut procedure is the tool costs. The key drawback of the ChamferCut procedure is the tool costs. The key drawback of the ChamferCut procedure is the tool costs. 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