Deburring or chamfering of gear teeth is gaining attention in practical settings. And with a view to make the production sequence as efficient as possible, it is becoming increasingly important to be able to implement the deburring tasks directly on the cutting machine after spiral cutting. Read on to find out how complex this seemingly simple task can turn out to be, and how a new deburring concept provides for enhanced efficiency.

Why are bevel gears deburred or chamfered? The reasons vary greatly. In bevel gears, the edge area between the concave flank (gap) and the component’s outer contour must be deburred in every case. That is where the bevel gear cutting tool normally exits the material and leaves behind a more or less conspicuous burr. This area is extremely sharp-edged and must be chamfered to avoid the risk of injury. As wear on the bevel gear cutting tool increases, a burr can also develop in the cutting area between the convex flank (gap) and the component’s outer contour. This area should therefore also be taken into account and deburred as necessary.

Deburring directly on the cutting machine

Deburring outside the cutting machine (in a second clamping) always entails additional component handling, in which the reference of the position of the deburring edge must again be...
established for the deburring task. Manual deburring, by contrast, involves a risk of component damage, in addition to a significant time factor, and is therefore avoided in most cases.

It is therefore noticeably more efficient when deburring takes place directly on the cutting machine. In this case, component clamping is already quite stable, and the position of the gaps after cutting is known and does not change even in the event of multiple setups.

Accordingly, the gap position does not have to be reassigned for repeat production, which significantly decreases the work involved in setup. If several different deburring positions are defined for an extremely complex component contour, their assignment remains stable and they can be sequentially executed in the familiar clamping. The processing times and thus the competitive capacity can be optimized in this way. Modern bevel gear cutting machines make high-productivity cutting processes feasible – with extremely high, reproducible gear cutting quality. These machines also allow complex deburring tasks to be realized. The chamfer generated here can be accurately represented, and the deburring tools have a long tool life.

**Simulating Highly Complex Requirements**

In bevel gear production, deburring directly on the cutting machine is already being required – and performed – with increasing frequency. The implementation can have varying degrees of complexity and therefore suitably adapted, and varying technological approaches, all of which must satisfy one condition: Avoiding collisions. The risk of collision can occur between the deburring tool and the gap, where the opposite flank can become damaged. However, the collision situation between the deburring tool and the clamping device must also be considered. This collision situation is usually less critical for deburring of ring gears. For deburring of pinions, however, collision analysis is often particularly important.

A simulation of this complex task makes it possible to also analyze the penetration of the component/clamping device with the drive of the deburring tool. Such a simulation includes three different elements. These three elements must be made compatible in advance with the capabilities of the specific cutting machine:

1. The simulation starts with a definition of the deburring tool geometry. The deburring tools consist of carbide stick blades that are clamped in a holder. The stick blades can have a variety of profile shapes, with the technological angles specifically adapted to suit requirements. To minimize setup costs on the machine and reduce tool costs, as many deburring tasks as possible are executed with the same deburring tool.

2. The second element includes definition of the suitable exit angle for the deburring tool cutting edge, from the material to be deburred. An exit angle must be selected that will prevent another (secondary) burr from developing as a result of the deburring task, which itself is also a chip-removing operation. Both the deburring tool geometry and the movement executed by the tool in the space play a role here. To thoroughly analyze the deburring task, testing is necessary to determine how many different cuts are required to completely capture the area to be deburred. The exit angle of the cutting edge must be checked for each of these tool positions.
When the component contour description is as precise as possible, it facilitates targeted optimization of the deburring tool positions. Turned part descriptions are increasingly available in digital format. This component contour can be imported into the simulation as a contour element frequently in the form of a Drawing Interchange file (DXF).

3. The third element is a collision and traversing path test for the specific cutting machine. Collision testing is required with reference both to the opposite flank in the gap and to the clamping device used to hold the component in the cutting machine. For this test, the deburring tool trajectory is represented in an adequate spatial expansion. When the clamping device description is done precisely, it facilitates targeted optimization of a collision-free deburring tool position. This clamping device contour is generated automatically for Klingelnberg clamping devices and can also be imported as a DXF element. Testing of this deburring task and the collision check can be tailored to suit the circumstances, such as, machine concepts and machine sizes of individual machine types.

**Machine Axes Determine Flexibility**

For spiral bevel gear production, there are different machine designs on the market. Various deburring options are available, depending on the design. In terms of deburring versatility, the number of available machine axes always plays an important role. Depending on the component size and clamping device concept, the available traversing paths also influence the deburring task options. Compared with older models, new machine generations have a significantly increased range of functions with regard to deburring. This development is reflected in the fact that in modern concepts, great emphasis is placed on the capability to thoroughly implement deburring tasks.

**A Variety of Methods for Component Deburring**

Deburring facets can be generated in different ways – and combinations are also possible. These include:

- For Klingelnberg’s horizontal cutting machines with only four axes available for the deburring task, the single-cut method is used. The tooth root can also be deburred by turning the component in the final position of deburring.
- The numerable-cut method can be employed on Klingelnberg machines with a vertical machine concept and the capability...
to use six simultaneously controlled NC axes. Here a contigu-
ous edge is deburred through several cuts located one after
the other in the heel area. Figure 7 shows the result of five
selected positions. These are necessary because the tooth
flank has an extremely pronounced curvature in the profile
direction, which is offset by three cuts, and because there is a
peculiar contour change on the back cone of the component.
This requires an additional, extremely steep cut. Lastly, the
gap root is deburred with a tightly-turned final cut. Between
each deburring position, the tool is withdrawn from the gap
and re-situated for the next position with a feed movement.

• The many-cut method can also be employed on Klingelnberg
machines with a vertical machine concept and the capability
to use six simultaneously controlled NC axes. A contiguous
edge is deburred through innumerable cuts located in close
proximity to each other. The special thing about this method
is that the deburring tool does not lift out from one position
to the next – rather, it executes every deburring position along
the edge directly with a rapid feed movement. The cutting is
performed primarily by the tool tip radius.

**New Coupled Movement Optimizes the Collision Curve**

All of the component deburring methods presented are based
on a principle of continuous motion. This has the advantage of
extremely short auxiliary times, and therefore a short deburr-
ing time overall. This continuous operation principle requires
a coupled movement of the rotation of the deburring tool axis
and the component axis.

All familiar coupled movements used so far for deburring are
set up in such a way that the component flank moves toward
the deburring blade. This movement requires a specific spa-
tial expansion relative to the trajectory of the deburring blade.
In a number of deburring tasks, however, this spatial expan-
sion of the trajectory relative to the collision situation is a key
challenge.

Klingelnberg has therefore developed a way to create this
coupled movement so that the component flank moves away
from the deburring blade. The spatial expansion of the traject-
ory for this coupling relationship has a significantly different
form and requires considerably less space. Collision-critical
tasks can therefore be performed with much better results using
this deburring principle.

**Conclusion**

The seemingly simple task of performing deburring tasks
on a cutting machine can turn out to be quite complex. This
is evident in the variety and diversity of ways deburring can
take place on a cutting machine – and also in the difficulty of
reliably determining process parameters such as risk of colli-
sion. Simulation provides valuable support in this respect: The
machine settings determined during the simulation can be
loaded directly on the cutting machine, removing all obstacles
to manufacturing real, burr-free components.

The fact that more versatile solutions are being offered and
demanded with increasing frequency reflects just how important
the capability to implement the deburring tasks directly on the
cutting machine after spiral cutting has become for customers.

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