Deburring – The Underestimated Task

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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.

Figure 1 Deburring tools.

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.

How complex the task of deburring is depends significantly on the outer contour of the component, as well as on the area to be deburred, in accordance with the user's specifications. The outer contour can be straight in the area of the edge to be deburred, but it can also comprise a number of contour elements. A straight chamfer can usually be processed easily in just one cut using a deburring tool. Complex deburring edges typically do not allow this. In these cases, several deburring tool positions and cuts must instead be considered.

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.

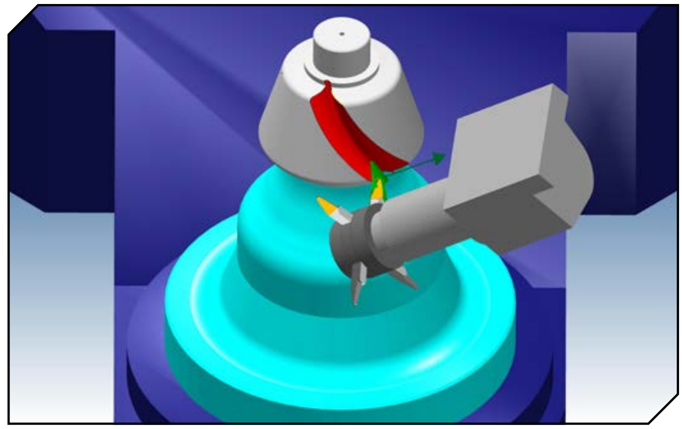

Figure 2 3D view of all components involved in the deburring task.

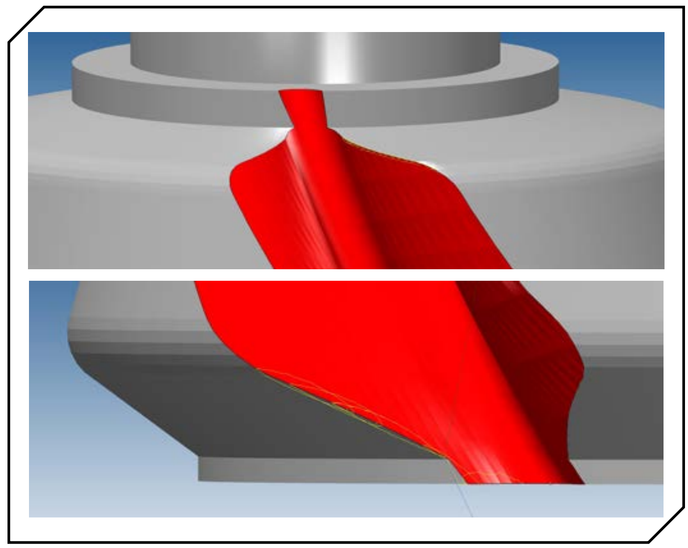

Figure 3 Edges to be deburred, resulting from the cutting area between the component envelope and the component gap.

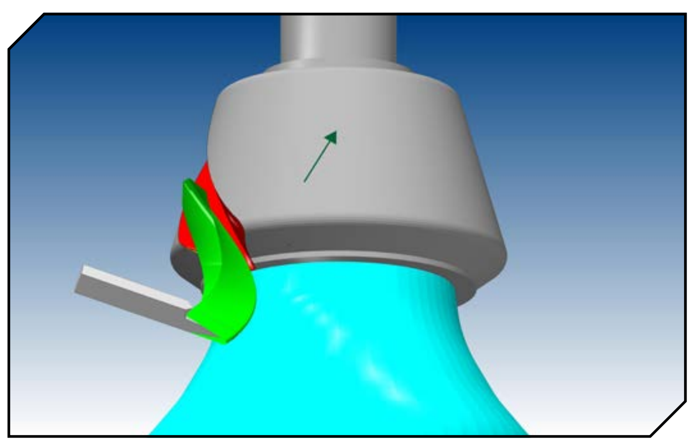

Figure 4 Component clamped in device, deburring tool trajectory in green.

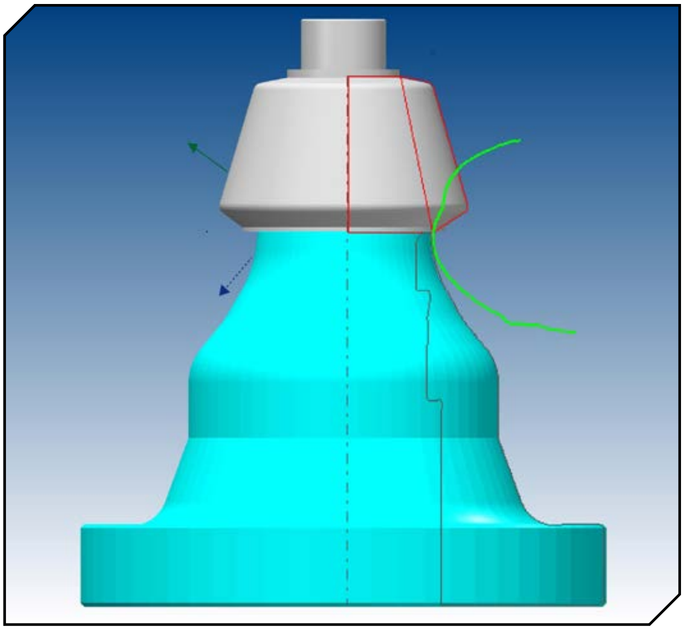

Figure 5 Envelope contour of a clamping device and component (red); collision range of all deburring positions (green).

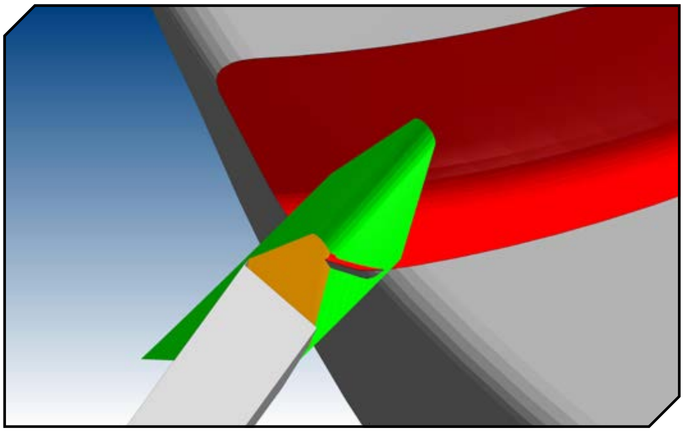

Figure 6 Action of the deburring blade cutting edge at the tooth root and final shape of the deburring edge after a single cut.

Figure 7 Contour generated with five different positions of the deburring tool.

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

Figure 8 Contour generated with many different positions of the deburring tool.

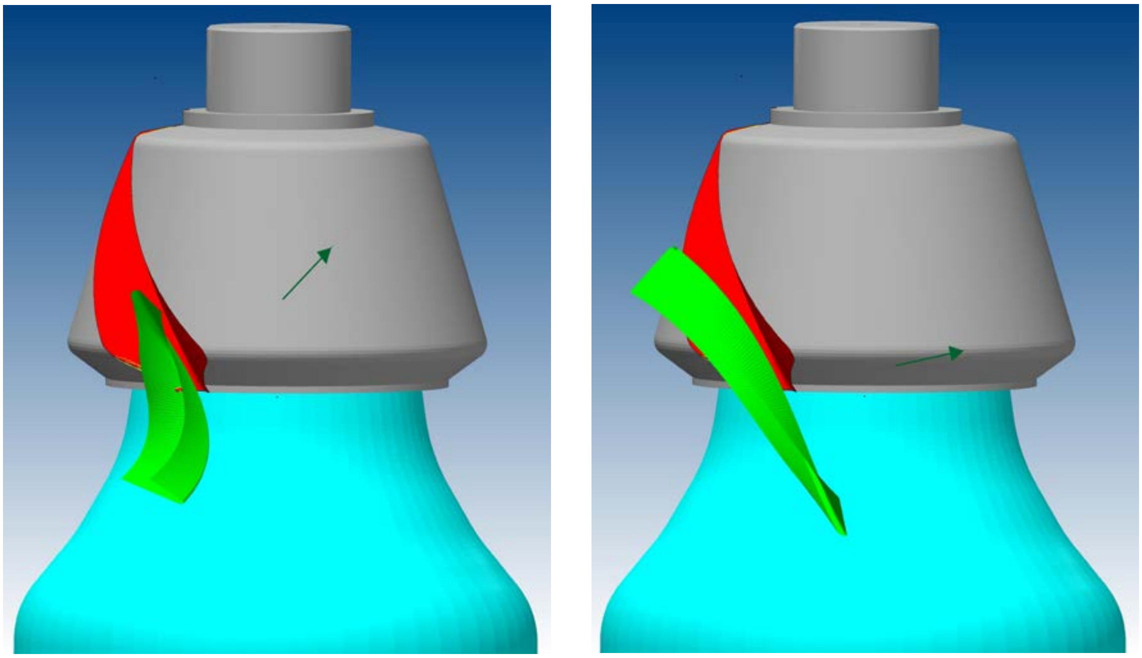

Figure 9 Comparison of the two possible coupling situations for the same deburring task.

to use six simultaneously controlled NC axes. Here a contiguous 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 deburring 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 spatial expansion relative to the trajectory of the deburring blade. In a number of deburring tasks, however, this spatial expansion 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 trajectory 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 collision. 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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