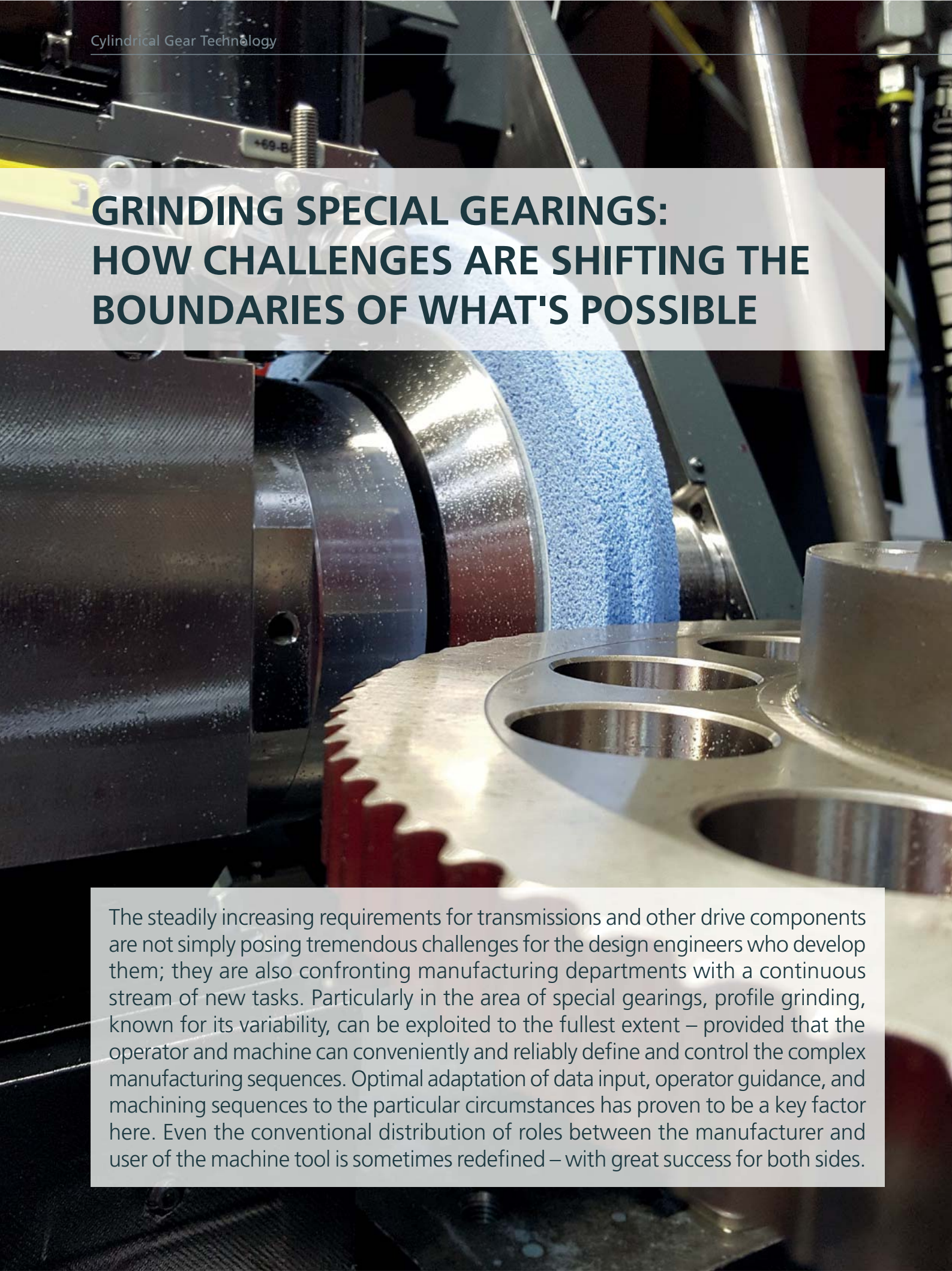
GRINDING SPECIAL GEARINGS: HOW CHALLENGES ARE SHIFTING THE BOUNDARIES OF WHAT'S POSSIBLE



The steadily increasing requirements for transmissions and other drive components are not simply posing tremendous challenges for the design engineers who develop them; they are also confronting manufacturing departments with a continuous stream of new tasks. Particularly in the area of special gearings, profile grinding, known for its variability, can be exploited to the fullest extent – provided that the operator and machine can conveniently and reliably define and control the complex manufacturing sequences. Optimal adaptation of data input, operator guidance, and machining sequences to the particular circumstances has proven to be a key factor here. Even the conventional distribution of roles between the manufacturer and user of the machine tool is sometimes redefined – with great success for both sides.

Precision is our mission. Top quality is our aim. Enthusiasm is our driving force." That's how Zörkler – a typical high-end gear manufacturer based in Jois, Austria – headlines its web presence. And with good reason: This innovative firm's product range includes a number of complex special applications from the aviation, railway, automotive, and industrial sectors – a spectrum requiring a production line that delivers flexibility and high precision in equal measure.

To meet these demands, Zörkler acquired a new multi-function machine for small and medium-sized workpieces. What makes this machine so special? Because the control software is adapted specifically for each machining task, it is suitable not "just" for standard tasks, but also for a variety of special tasks, making it extremely economical. Moritz Wurm, Head of Gear Grinding at Zörkler: "We rely on the Höfler brand's many years of experience and development. Its list of options covers just about everything that can be manufactured using the profile grinding method – starting with countless variants of involute and non-involute cylindrical gearings; to cylindrical worms, clutch gearings and splines; to side faces and circular faces."

Support from the Control Software Makes the Difference

In most production plants, grinding of commonplace Hirth gearings is done on a CNC machine suitable for this purpose, but generally without specific software support. The time required for manual DIN programming and the "finesse" needed for setup are always an obstacle to achieving shorter machining times and higher quality. What's more, when users create machining programs entirely on their own, they are unable to benefit from advances made by the machine tool manufacturer. And dependency on specialist knowledge, typically of a single employee, is a significant risk in terms of staffing.

What a modern machine tool has to offer for convenient, precise machining of complex special gearings, in contrast, is demonstrated by a uniform, intuitive operating concept harmoniously combined with application-specific adaptations for data input, operator guidance, and machining sequences. This feature played a key role in Zörkler's purchasing decision: "For us, a simple user interface, particularly for the module used to grind Hirth gearings, was an important reason behind our decision in favor of the new RAPID 800 K," explains Moritz Wurm.

For years in fact, all (further) development of Klingelnberg's GearPro software has centered on this user-friendly interface and the intuitive operating concept. GearPro is also used in the RAPID 800 K cylindrical gear grinding machine, which combines the familiar user interface for standard gearings with a range of functionalities that has grown over the years: from visualized, three-dimensional gearing and machine models; to calculating and generating appropriate tool profiles; to determining the precise position of surfaces to be ground as well as sophisticated grinding and dressing strategies. For Hirth gearings in particular, due to their sometimes large number of teeth, optimized indexing methods such as the sector indexing method established in gear cutting are indispensable to achieve high-quality indexing.

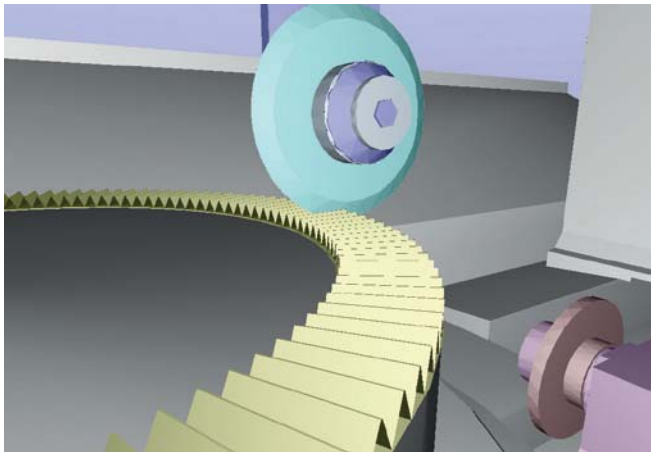


Fig. 1: Hirth gearing modeling with Klingelnberg software

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How to Shorten Machining Times

Compared with manufacturing on standard CNC machines, Hirth gearings can now also be manufactured with shorter machining times on the RAPID.

HIGHLIGHTS IN BRIEF

- The application range for profile grinding encompasses a wide variety of face gears
- Grinding and measuring special gearings with GearPro combines a high degree of variability with proven user-friendliness
- Customer-specific adaptations to special geometries can be handled entirely or in part by Klingelnberg, or optionally programmed by customers themselves
- The interface between GearPro and the Klingelnberg measuring software is of fundamental importance for a closed quality loop and will be further developed

Special Gearings Thanks to the Free Profile Option

An additional application field is opened up by the "free profile" option, which enables the transverse profile of cylindrical gearings to be defined by any number of straight line and circular arc sections. Here the usually data-intensive representation of the profile can be generated externally and then imported, or it can be calculated from just a few input values if a parameterized description is provided.

Cycloid Speed Reducers

The cycloid speed reducers frequently used in robotics are currently one of the most important applications of such special gearings. This a special type of cycloidal drive, in which one or more cam disks with a cycloidal outer contour roll over cylindrical pins. The cams are supported in appropriately shaped concave slots of a surrounding ring housing.

On the housing side, the profiles to be ground consist of simple circular arc sections and can therefore be described in the definition table with just a few parameters specifying their position and radius. The cycloidal profiles of the cam disks, by contrast, follow a more complex mathematical relationship; however, they can also be described with just a few parameters. This makes it possible, with the help of wizard functions programmed for this purpose, to present the inherent complexity and associated design know-how only to the extent necessary to machine the workpiece. When programming the machining cycles, a range of variants and options are therefore available for centering, grinding, measuring, and correcting. Among these is a data interface for the Klingelnberg P-series measuring machines, which spares

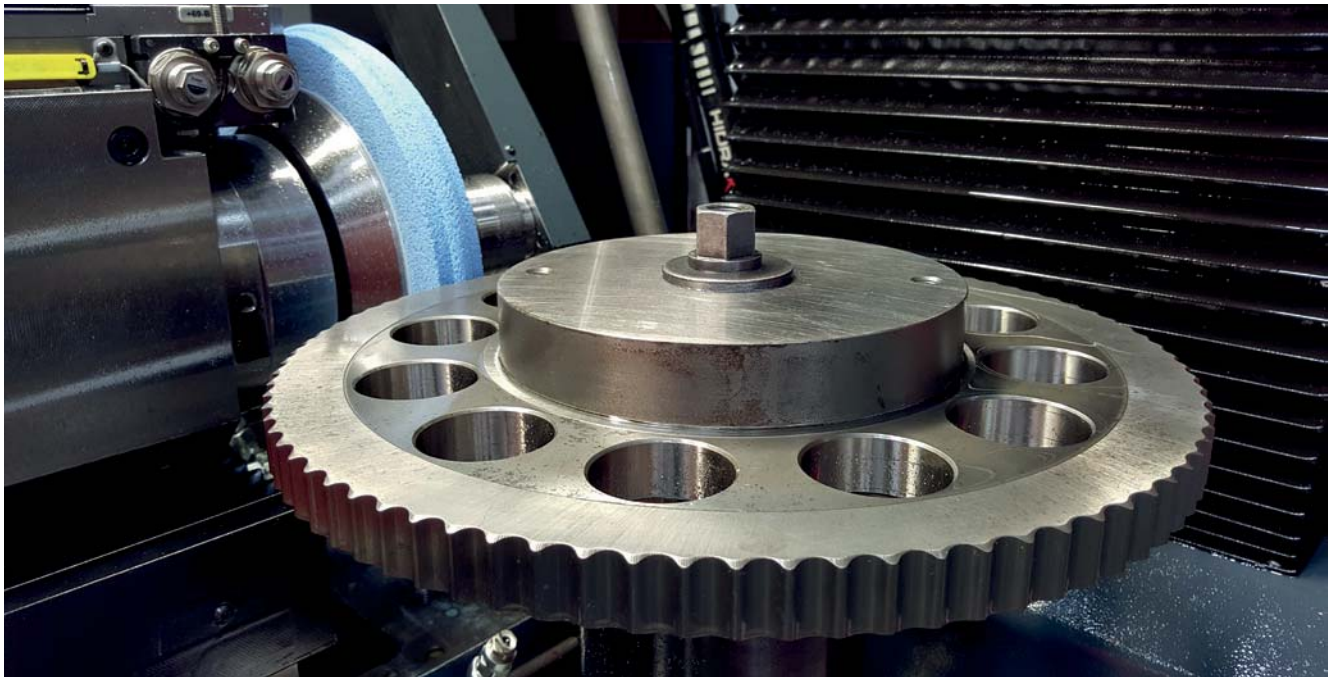

Fig. 2: Cam disk of a cycloid speed reducer

users the need to generate appropriate measured data – a process that is time-consuming and prone to errors.

Wildhaber-Novikov Gearings

In response to a special customer request for grinding Wildhaber-Novikov gearings, Klingelnberg went a step further: here, parameters are specified not for the transverse profile itself, but rather for the circular arc profile of the basic rack tooth profile to be generated. A customer-specific solution was developed in this case as well – a solution that uses a removal simulation to reproduce the special geometry of the transverse section and, with this as a special case of the free profile option, makes accessible the proven features of the standard grinding processes.

Tooth trace modifications are now possible here, too. The necessary profiles are checked for grindability and dressability and the real allowances – which in the case of special gearings are often only imprecisely known in advance – are determined in several tooth spaces where necessary.

The Most Flexible Variant: Free Programming

The ultimate in terms of integrating application-specific machining sequences into the user-friendliness of the GearPro interface, however, are the freely programmable processes – unmatched in the industry. With these, customers themselves can program and manage any machining sequences and combine them with functions provided by the machine manufacturer. Even reusable subfunctions and diameter-dependent tool paths can be simulated using this flexible concept.

In this way, the design know-how remains entirely in the customer's hands, whereas the control software continues to handle,

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GearPro – the All-in-One Solution

Flexible functions such as "free profile" and freely programmable processes ensure a variety of possible applications and cover a broad range of special gearings, such as cycloid speed reducers and Wildhaber-Novikov gearings.

SPECIAL GEARINGS – OTHER EXAMPLES

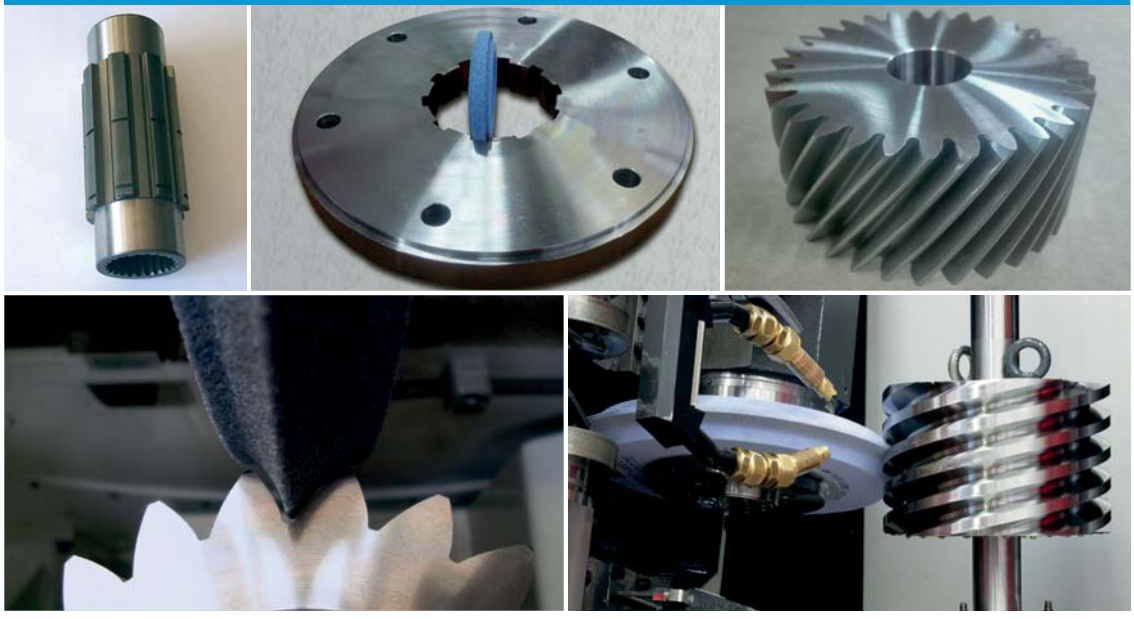

Fig. 3: Spline shaft, splined hub, free profiles, asymmetric involutes, and cylindrical worm (top left to bottom right)

TOP-NOTCH QUALITY AND PRODUCTIVITY

"In application engineering, we experience – almost on a daily basis – how versatile and complex the requirements have become in toothed gear machining. In many cases, the geometry and machining strategies are so sophisticated that effective production isn't possible without intuitive, powerful software support. That's why we have channeled all our experience in the last few years and decades into a host of different, application-specific wizards and optimized machining sequences. And it's paying off for our customers: They can deliver an unbeatable range of production capacity on their HÖFLER cylindrical gear machine – while achieving reproducible top-notch quality and productivity."

Dr.-Ing. Christoph Kühlewein, Application Engineering,
KLINGELNBERG GmbH

where necessary, the management, operator guidance, and provision of basic machine functions, as well as control of individual sequences such as dressing.

Latest Applications

The most recent applications of this most flexible of all GearPro operating variants include grinding of clutch gearings with typical, extremely pronounced crown teeth, as well as grinding of freely defined profiles on circular faces.

"Our customers can be sure that we will continue to develop high-end solutions for future tasks based on GearPro's proven, intuitive operating concept."

Dr.-Ing. Markus Brumm, Director Cylindrical Gear Division

Challenge: Asymmetric Profiles

Particular challenges always arise in addition when the profiles to be generated are asymmetric. For involute gearings, too, this property is increasingly used wherever significant outputs are transmitted via a transmission operated preferably or exclusively in one direction only. The advantage of the quite often significantly different pressure angles of the left and right tooth flank in these gearings is that a greater load-bearing capacity is achieved on the load-bearing flank, and the tooth root strength is improved considerably due to the larger possible radii of the root rounding.

As a consequence of two tooth flanks with differing slopes, however, the removal conditions can differ widely, making the standard machining process uneconomical or even impossible. This is reflected not least in the limit values of the performance-related chip parameters, such as the specific stock removal rate Q'_W. If the unequal conditions are not taken into account, this will inevitably result either in a great deal of wasted time or an excessive thermal load on a tooth flank. The difference becomes clear by comparing the geometric conditions when grinding an even surface and a sloped surface (see Figure 5): Although the same radial infeed produces the same cross section (A_Q) and thus the same machined volume (V_W) per unit of time Δt, the swept areas (A_K) differ significantly.

But GearPro's intelligent removal control automatically ensures an optimized grinding strategy here, too. In both single-flank machining and the more economical two-flank machining, the effective chip thicknesses are optimized, while at the same time the specified tooth trace modifications are precisely generated.

Grinding Cylindrical Worms

When grinding cylindrical worms, in contrast, fundamentally different geometric conditions arise due to the extreme helix angle alone: Not infrequently, the transverse profile of one thread encompasses more than 180°, and the axes of the tool and workpiece are nearly parallel to one another. GearPro consequently touch-grinds the two tooth flanks in the axial direction – contrary to the usual practice – and in this way generates significantly clearer signal edges in the solid-borne noise sensor that is "listening in". The respective grinding wheel profile, which can only be dressed in some instances with special dressing rolls, gives rise to additional special requirements for the five supported flank profiles: ZA, ZN, ZI, ZK, and ZC. Due to the axially defined measurands, both the testing and correction of worm-type gearings also differ.

Fig. 4: Every function described can be used on a RAPID 800.

Short and to the Point

Grinding and measuring special gearings with GearPro combines a high degree of variability with proven user-friendliness. Users can expect customized, high-end solutions for future tasks as well. ◆

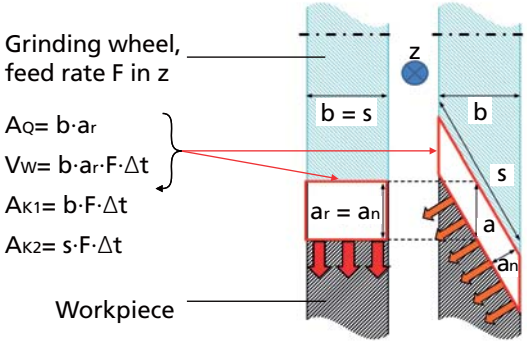

Fig. 5: Heat input as a function of profile slope

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