EVOLUTION IN THE CYLINDRICAL GEAR SECTOR: TWO TECHNOLOGIES – ONE MACHINE

Gear cutting and conventional end milling in one single clamping – the new HF-M Series from Klingelnberg combines both technologies in one machine. As a result, herringbone gearing can be produced in a reliable and reproducible manner. This involves adding an extra "End milling" function to the tried-and-tested HF gear cutting machine. Alternatively, an even more straightforward second option is available: The "Facer" function integrates deburring and chamfering into the gear cutting machine, eliminating the need for manual work. These latest members of the Klingelnberg "family" are creating the "next generation" of HF Series machines for the cylindrical gear sector.

Herringbone gearing and deburring – two different functions, which used to call for several different types of machine, and demanded a high level of technical complexity, or else had to be performed manually. The associated setting-up processes wasted time and risked jeopardizing component quality. Even with manual machining, the same kinds of problems occurred. As a result, Klingelnberg decided to expand the application range of its cylindrical gear cutting machines: The cutting machines in the HF Series now enable you to perform the deburring, chamfering, and herringbone gearing processes in one single clamping, thanks to the addition of the "Facer" function and the launch of the new HF-M Series.

To see the kinds of benefits offered by the HF-M Series herringbone gearing feature, you need only look at the statistics from two real-life reference projects: A reduction from 45 hours to 6.5 hours and from 60 hours to 9.5 hours – these figures sum up the results in a nutshell. The first pair of values relates to the machining time for a customer component with 99 teeth and a module of 8.8 mm (d_a=1023 mm), and the second pair of values to a shaft with 22 teeth, a module of 8.8, and an outer diameter of 271 mm. Here, the levels of quality achieved met (or exceeded) the requirements of DIN 7 in the case of the profile and DIN 6 in the case of the lead. The time benefits that can be achieved depend on the component and the quality requirements involved. When a high level of component quality is the main concern, the results can be improved by two to three quality grades. The time benefit becomes more significant when the component has a large number of teeth.

Fig. 1: HF base machine

Overview of HF Series

HF	650	1000	1250	1600	2000
Max. workpiece Ø (mm)	650 (900*)	1,000	1,250	1,600	2,000
Axial slide distance top table (mm)	1,000	1,000 (1,760*)			
Max. cutter diameter (mm)	290	385			
Optional internal cutter head	–	F3**	F2**/F3**		
Min. tooth root Ø [0° helix] (mm)		500	500/800		

HF	2400	3000	4000	6000	8000
Max. workpiece Ø (mm)	2,400	3,000	4,000	6,000	8,000
Axial slide distance top table (mm)	1,760			1,500 (2,000*)	
Max. cutter diameter (mm)	385	500		500	
Optional internal cutter head	F3**/F2**			F1**	
Min. tooth root Ø [0° helix] (mm)	500/800			800	

(Specifications subject to change without notice)

* Optionally available ** Profile form cutter

HF SERIES

Machine design
- Single- or multi-bed versions available
- Double V guide (ideal damping features)
- Vertical axis concept (optimum chip flow)

Torque drive in machine table
- High control rigidity
- No mechanical contact (in contrast to worm wheel drive)
- Free of play, wear-free, temperature-stable
- Large table hole

Capto® tool interface
- High levels of basic stability and accuracy
- Transmission of high torques
- High flexural rigidity
- Self-centering

Counter support
- V guides
- High repetition accuracy
- Adjustable clamping force
- Hydraulic or numerical control (NC)
- Retractable center
- Various steady rests available
- Automatic clamping via four hydraulic cylinders

Figs. 2 and 3: Deburring with the "Facer" function

Keep What Works . . .

Klingelnberg has now launched a brand new generation of its tried-and-tested HF Series by introducing additional "Facer" and "End milling" functions. It was important not to alter the base machine. Instead, the priority was to build on this solid basis by including additional functions. This is because the HF gear cutting machines are based on a technological concept that set new standards in dry processing with indexable insert tools when it was developed back in 2003. Even now – more than ten years later – it is still classed as a cutting-edge technology for toothed cylindrical gear production.

To create the new generation of these machines, the design had to be completely rethought – both in terms of the principle behind it and its practical application – and pioneering solutions had to be opened up within the gear industry. Know-how was consistently carried across from the profile grinding machine sector and applied to gear cutting. This knowledge was then incorporated into a brand new machine while drawing on a high level of software expertise. It was out of this knowledge transfer that the HF Series was born. The series really stands out thanks to the extremely stable basic machine design with its high level of rigidity and optimum damping features, which are due to the double V guide. As a result, the machine bed is the most hard-wearing of its kind. On top of that, the series uses a torque motor as a table drive and relies on a principle that was completely revolutionary within the industry at the time: dry processing with a vertical machine design. Although the HF Series is optimized for dry cutting, it is also ideal for use for wet cutting.

In order to meet the requirements of high-performance machining, Klingelnberg worked together closely with Sandvik Coromant® to develop a tool interface with extremely high torsional rigidity and a Capto® holder so that the torque could be transferred from the drive motor to the cutting tool reliably. This is another good example of a brand new approach. Thanks to the long shift travel path and large free

Dry cutting is still the absolute state of the art.

spaces, either standard or large special tools can be used. It is also possible, for example, to mount form cutters and hobs on the cutter arbor at the same time. The optionally available internal cutter heads (available in various sizes) make the potential range of applications even wider. Depending on the performance required and the size of the workpiece, these can be used on the vertical axis instead of the external cutter head.

. . . and Allow Scope for New Ideas

Dry cutting may still be the absolute state of the art, but that does not mean that there is no scope for new ideas. When it set about enhancing the HF Series, Klingelnberg decided to combine various established technologies in an innovative way. This resulted in two variants, which allow users to select practical extension options that really add value: the "small solution" incorporates deburring by the "Facer" function, while the "large solution" combines form cutting with end milling in a single machine, thereby providing an efficient solution for gears with a collision contour (e.g. herringbone and double helical gearing).

Additional Option: "Facer"

During cylindrical gear production, burrs are removed from components and defined chamfers are made in two ways. Firstly, special machines are used. Secondly, in particular for single-item and limited-lot production, the classic approach is to manually process each gear tooth individually. Not only does this limit productivity, but it also restricts reproducibility and quality. That is why the additional "Facer" function on the HF Series will be of particular interest to anyone who has to produce individual parts and small batches of components: it enables the deburring and chamfering processes to take place directly on the cylindrical gear cutting machine. The major benefits of this built-in solution are that it saves the extra time that would normally be required and prevents the reduction in quality that would result from changing over.

In mid-2013, Klingelnberg started offering this additional function on HF machines for small sizes of up to 1,250 mm. The "Facer" function is a cost-effective solution

"FACER"

- Chamfering integrated in machine via chamfering unit in counter support
- The machine software calculates and controls contour motion and processes
- For creating freely definable, high-quality chamfers
- Low investment and tool costs reduce the per-component costs
- Can chamfer and debur any kind of straight, helical, or herringbone gearing
- Minimal tooling and adjustment work
- Ideal for single-item production

Fig. 4: Maximum productivity benefits thanks to pre-machining with form milling tools

Fig. 5: Roughing and tooth root machining

Fig. 6: End milling – tooth flank finishing

Example component, gear (m8.8; d_a=1023 mm)

- 1 or 2 cuts per tooth flank
- Confirmed main time of 6.5 h (currently takes customer: 45 h)
- Profile acc. to DIN 7/8 or AGMA 10/11, reference tooth trace acc. to DIN 6/7 or AGMA 11/12

Example component, shaft (m8.8; d_a=271 mm)

- 6 cuts per tooth flank
- Confirmed main time of 9.5 h (currently takes customer 60 h)

"END MILLING"

- HF base machine with additional "End milling" function
- Second column with cutter head for end milling tools (with C3 axis for horizontal swiveling)
- Process: pre-gashing, roughing, tooth root finishing, tooth flank finishing
- Measurement of tools
- Automatic tool changing (optional)
- Software GearPro to support every aspect of process design (e.g. quality specifications → cutting strategy)

that can optionally be integrated into the counter support – without restricting the size of the working area or the counter support functionality. At the same time, the "Facer" function enables you to create freely definable high-quality chamfers: the chamfering unit features three NC axes – one vertical, one radial, and one rotary, for different helix angles. The axis dynamics mean that the "Facer" function can be gradually pivoted in a three-degree grid for flexible machining when processing top and bottom sides and when processing helical gearing. The motion curves required for each contour are calculated fully automatically using the GearPro machine software. Even the tooth space is calculated automatically, meaning that no manual teach-in is required for threading. Operators benefit from an extremely short overall machining time for chamfering (even between roughing and finishing), as they only have to make a few entries during the process. Different cutter heads can be used, depending on requirements. For example, an additional head can be used for collision-free deburring of pinion shafts. In addition to standard universal carbide tools, CoroMill® 316 exchangeable heads can also be used, enabling you to change the cutting edges extremely quickly and cost-effectively. The chippings are disposed of by the machine.

Additional Option: "End Milling"

Since the middle of this year, Klingelnberg has been offering an additional function for the medium size range of 1,000 mm to 2,400 mm. This function is called "End milling", and it is available for the relevant HF gear cutting machines from the new HF-M Series. As a result, herringbone and double-helical gears and gears with limitations in the tool travel, e.g. shaft collar, can be produced in a single clamping operation, in a reliable and reproducible manner. Example uses of herringbone gearing include conveyor technology, the food industry, and marine applications.

There is no other state-of-the-art technology that comes close to matching what the Klingelnberg solution can do, apart from five-axis metal-cutting machines – and even then, there is no real comparison. Because these universal machines originate from outside of the gearing industry, they are

not optimized to suit gearing applications. Consequently, pre-machining takes longer and the machine base cannot be compared with that of the HF Series. Aside from that, some of the technological solutions being used to produce herringbone gearing are 30 to 40 years old – a factor which is detrimental to productivity. Many companies are now replacing these machines because of their high maintenance costs and unwieldy operation.

However, customers do not want a "herringbone gear cutting machine", but a sturdy and precise cutting machine that is capable of machining herringbone gearing. In this context, a universal machine that restricts productivity at the pre-machining stage and calls for elaborate programming is an unsatisfactory compromise. This is the reason why Klingelnberg decided, once again, to focus its development work on its tried-and-tested HF Series. A second column has been added to the base machine, along with a cutter head for end milling tools. The extended option features four additional axes. Together with the table axis, this means it offers all the degrees of freedom required to machine gears with end milling cutters. The pre-machining (form milling or hobbing) and rough machining stages, and the finishing operations for the tooth root and flank, are now all integrated into a single machine. The pre-machining concept involves cutting the gearing so that the results are as close as possible (or as is practical) to the final contour – depending on the component geometry. As a result, the new series is virtually unbeatable from the perspective of productivity. What makes the HF-M really special is the way it brings together two established technologies: on a single machine, gear cutting with a forming tool is successfully combined with end milling for the finishing work. The universal range of applications makes for highly flexible production.

Designing the process and configuring operation is really convenient thanks to the GearPro machine operation software, which is just as user-friendly as the already proven conventional GearPro machine software. To enable fully automated operation, the machine can be equipped with an automatic tool changer for shaft tools.

The two additional functions are not designated to be included on the same machine: The "Facer" function is a "small" and cost-effective option that is purely designed for deburring and chamfering. It can be integrated into the machine without taking up any additional space. In contrast, the "End milling" function is a "large" option that incorporates much more extensive technology – but can still be used for deburring. ◆

"End milling" process

1. GASHING

- Use of form millers (gashers) or hobs
- Pre-machining with maximum productivity

2. ROUGHING

- Use of standard tools (cylindrical, conical, spherical)
- Removal of residual material "ramp"
- Where applicable: removal of residual material if universal gasher in 1. is used.

3. TOOTH ROOT FINISHING

- Use of universal conical/ball end cutters or (where applicable) custom end milling cutters

4. TOOTH FLANK FINISHING

- Use of radius cutters
- Choice of tool/cutting strategy dependent on:
  - quality requirements (max. deviation in form)
  - production quantities
  - availability of tools

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