



Technical Information

Dynamic Efficiency – Working Efficiently and with Process Reliability

Considerable potential lies in the efficient heavy machining—roughing at high cutting speed—but also in the machining of hard-to-cut materials like titanium alloys, nickel-based materials or stainless steel, which are standard materials in the aviation and aerospace industry. Heavy machining is primarily about removing as much material as possible in the shortest time. This is where many components of the machining process are pushed to their limits. So for this type of high-performance cutting, comprehensive process management is an indispensable prerequisite for quality and economy. The forces that result from the cutting process place an extreme load on the machine and tool. The goal must therefore be to optimize metal removal rates, maximize tool service life and minimize the machine load.

With the concept of **Dynamic Efficiency**, HEIDENHAIN offers innovative TNC functions that help the user to increase process reliability in heavy machining and roughing in order to improve efficiency. Dynamic Efficiency comprises these three TNC functions:

- Active Chatter Control (ACC): This option reduces chatter tendencies and permits greater infeeds
- Adaptive Feed Control (AFC): This option controls the feed rate depending on the machining situation
- Trochoidal milling: Cycle for the roughing of slots and pockets in a way that eases the load on the tool and the machine



Each function in itself provides advantages in the machining process. However, they can also be ideally combined to achieve decisive improvements.

- Reduced machining time thanks to higher material removal rates (ACC, AFC, trochoidal milling)
- Tool monitoring (AFC)
- Longer tool service life (ACC, trochoidal milling)

With Dynamic Efficiency, your manufacturing process becomes faster, easier on the machine and tool, and as a result, more efficient and economical.

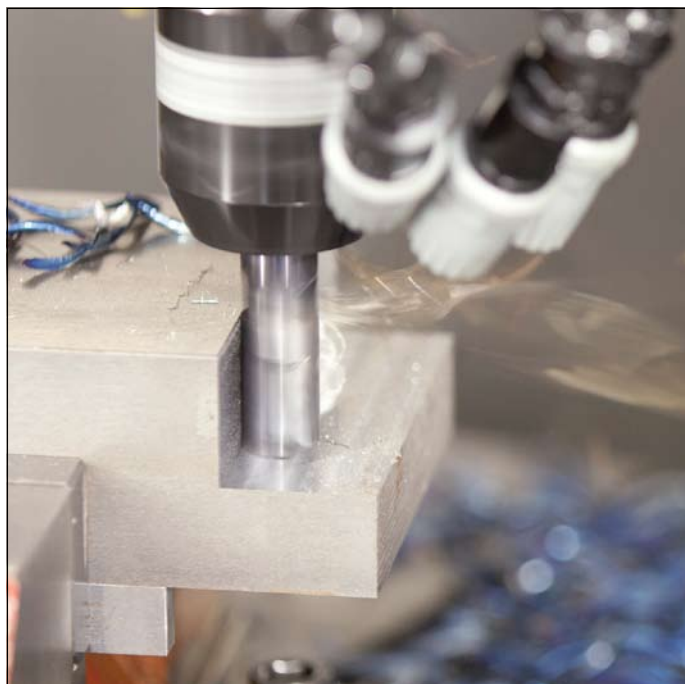
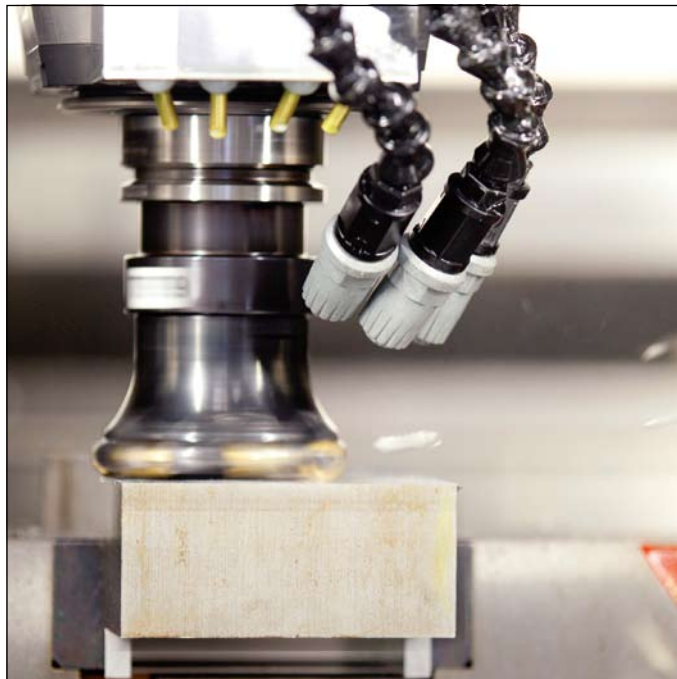
dynamic + efficiency

Dynamic Efficiency

More efficiency in heavy machining and roughing

Dynamic Efficiency focuses on all processes with high cutting forces and high metal removal rates. These include roughing processes in general, but also the machining of hard-to-cut materials such as titanium, corrosion-resistant nickel-based alloys (such as Inconel) and many other materials that are used in the tool and die making business, the aviation and aerospace industry, and in medical and energy technology. The forces that result from machining place an extreme load on the machine and tool. This high load is often observed as process-induced vibrations that occur during machining. The goal of improvement must therefore be to increase metal removal rates while at the same time extending tool service life and reducing the machine load.

Dynamic Efficiency from HEIDENHAIN addresses exactly these points.



With the concept of **Dynamic Efficiency**, HEIDENHAIN combines innovative TNC functions that help the user to make heavy machining and roughing more efficient while also enhancing its process reliability. Because these are software functions, they require no intervention in the mechanics of the machine. **Dynamic Efficiency** helps to increase the metal removal rate and reduce machining time.

Dynamic Efficiency comprises three functions:

- Active Chatter Control – The ACC option reduces chatter tendencies and permits greater infeeds
- Adaptive Feed Control – The AFC option controls the feed rate depending on the machining situation
- Trochoidal milling – A function for the roughing of slots and pockets that eases the load on the tool and the machine

Each solution in itself offers decisive advantages in the machining process. But the combination of these TNC features, in particular, exploits the potential of the machine and tool and at the same time reduces the mechanical load. Changing machining conditions, such as interrupted cuts, various material dipping treatments or simple clear-out also show that these features pay for themselves. In practice, removal rate increases of 20 to 25 percent are possible.

Dynamic Efficiency permits higher removal rates and therefore increases productivity without making the user resort to special tools. The avoidance of tool overload and premature tool wear as well as the additional gain in process reliability contribute considerably to improved economy.

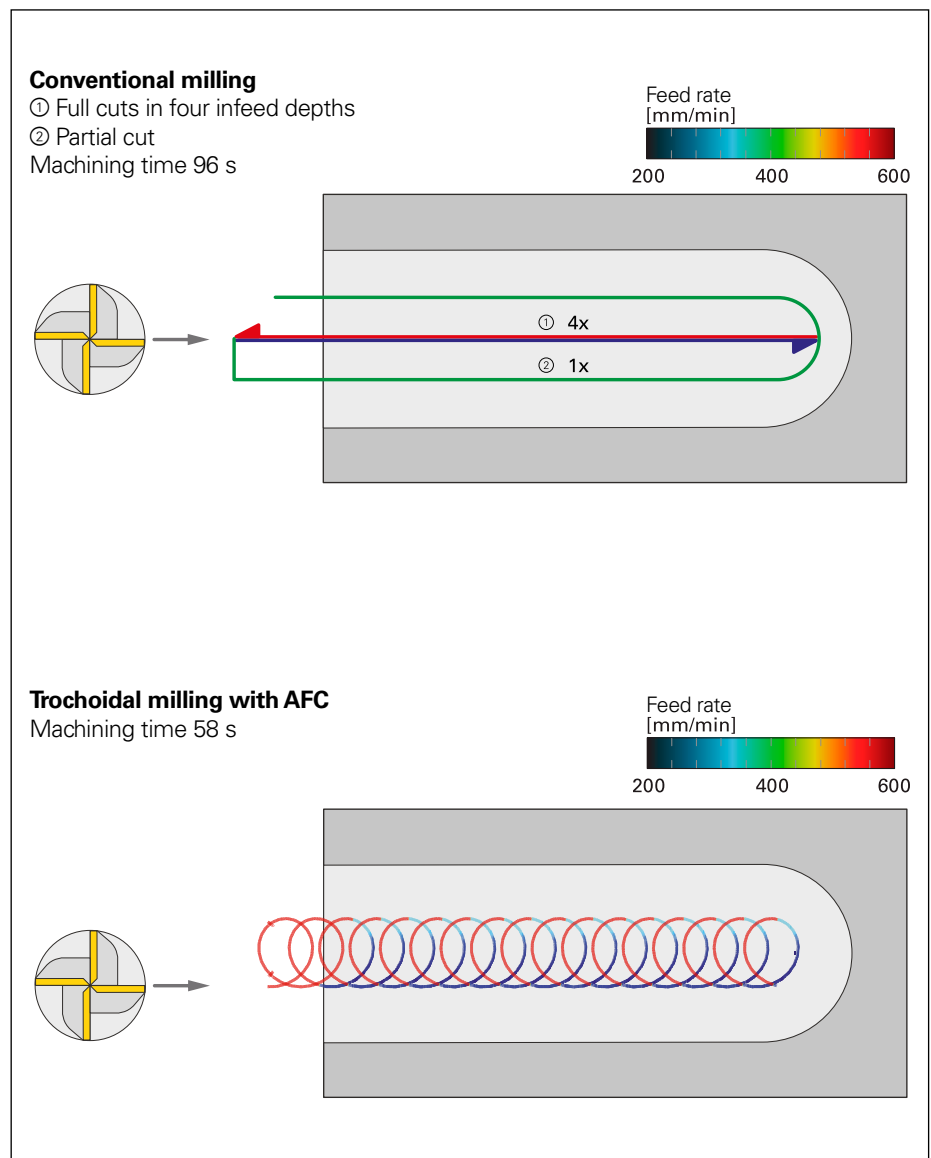
A significant gain in efficiency can be expected if trochoidal milling is combined with adaptive feed rate control. Because the tool moves into the material on a circular path, the load tool and machine is considerably reduced. However, a part of this movement is in the air. In this situation, AFC moves the tool at a much higher feed rate. These features add up during machining with the HEIDENHAIN cycle to enormous time savings.

Machining example

This application example clearly illustrates the benefits of **Dynamic Efficiency**. This slot is machined first with the conventional method and then with trochoidal milling combined with AFC.

In **conventional machining** slot machining begins by plunging into the middle of the slot. Because of technological characteristics (of the material or cutter) each cut can remove only a fourth of the required depth. Once the desired depth is reached, the slot is expanded in a working step to the desired width (green line). The line colors indicate the feed rate achieved.

In comparison, the same slot is machined with **trochoidal milling** together with **adaptive feed rate control AFC**. Trochoidal milling is considered a particularly protective technology for the tool and machine, but alone provides little advantage in speed. This is where AFC can be especially effective. During the air cuts of the circular milling process, AFC significantly increases the feed rate and reduces it as soon as the cutter meets the material. In this way, **Dynamic Efficiency** achieves dramatic time savings in this machining example.



In this machining example, compared with conventional machining methods, **Dynamic Efficiency** increases productivity by 40 %.

ACC

Active chatter control (option)

Strong milling forces come into play during roughing (power milling). Depending on the tool spindle speed, the resonances in the machine tool and the chip volume (cutting power during milling), the tool can sometimes begin to "chatter." Because chattering places an extreme load on both the tool and the machine, it is considered one of the factors that limit the metal removal rate.

Limits of the metal removal rates

Three main factors limit the metal removable rates attainable in a milling machine for a given material: the thermal and mechanical stability of the tool, the available spindle power and the occurrence of chatter. In itself, the occurrence of chattering is not a sign of machine defects. When tool stability and spindle power are sufficient, it cannot be avoided as the limit of cutting performance.

Causes of chatter

Chatter is the term or a dynamic instability of the cutting process due to vibrations during cutting. High cutting forces come into play during roughing and particularly here during machining of hard-to-cut

materials. The periodically occurring forces result in vibration between the tool and workpiece. If feedback develops between the vibration and the cutting process, more energy is put into the process as friction than can be converted to heat. The vibration is amplified and chatter ensues. Whether feedback develops depends on various factors, which include dynamic compliance of the machine at the tool center point (TCP), the tool and the cutting parameters.

Because chatter is a self-generated oscillation, chatter frequencies are always near to the natural frequency of the machine.

Conventional measures

Chatter puts excessive stress on the tool and the machine. It is therefore usually avoided. The occurrence of chatter vibrations depend among other things on the selection of the cutting qualities (chip thickness, chip width, cutting velocity, etc.). To prevent it in practice, the cutting data (cutting depth, spindle speed and feed rate) have to be reduced, which however results in lower productivity.

Benefits of ACC

With its TNC option Active Chatter Control (ACC), HEIDENHAIN now offers an effective control function to reduce a machine's inclination to chatter. ACC uses damping to increase the cutting rate at which chatter arises.

The effect of ACC is particularly positive during heavy cutting:

- Significantly better cutting power
- Higher metal removal rates (up to 25% and more)
- Low forces on the tool thereby increasing service life
- Smaller load on the machine.
- Higher process reliability

Operating principle of ACC

Because active chatter control (ACC) is entirely a software solution, it requires no changes in the machine. Additional systems (such as sensors or actuators) that increase the complexity and therefore the probability of total system failure are unnecessary. ACC detects chatter through the measuring signals of the drives and uses the machine's own feed drives to withdraw energy from the vibration.



Part milled without ACC: Chatter marks are clearly visible.



Part milled with ACC: At the same feed rate and cutting depths the surface shows no chatter marks. The machining process took place with reduced loads on the tool and machine.

However, this also places limits on the chatter phenomena that can be countered with ACC. The feed drives can only remove enough energy in a frequency range up to 100 Hz of the chatter vibration. Higher-frequency vibrations are not sufficiently damped. In individual cases, some chatter vibration below 100 Hz also cannot be damped, for example because it is limited to the tool while the drive affects the table.

Impact in practice

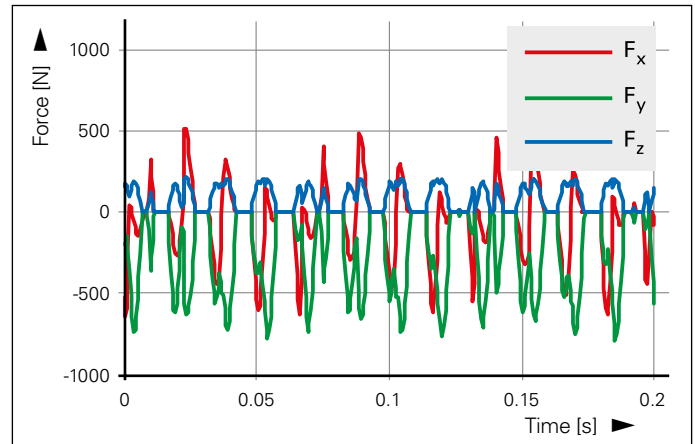
In milling experiments on a large number of various materials with differing cutters, it proved possible to significantly increase the metal removal rate (by up to 25 % and more) in cases in which chatter was a process-limiting factor. In addition, the prevention of chatter greatly reduces the forces affecting the tool and the machine. This increases tool service life and positively affects the life cycle of machine components (main spindle, guideways, ball screws and bearings).

Application of ACC

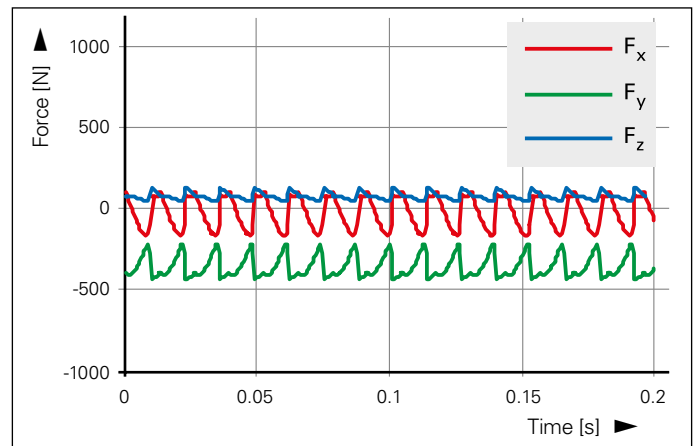
ACC operates in a certain frequency range below the tool's tooth engagement frequency. The user defines whether ACC become active by simply selecting the tool. Because the respective tool geometry has effects on the cutting forces and therefore influences the characteristics of any ensuing chatter vibrations, a separate parameter set can be configured for each tool. The tools are changed, the control automatically switches the tool-specific parameter sets.

Because of differing machine geometries, the machine tool builder can also separately configure the ACC parameters specifically for all feed axes. In certain cases, this additional parameter assignment can improve the effect of the ACC algorithm.

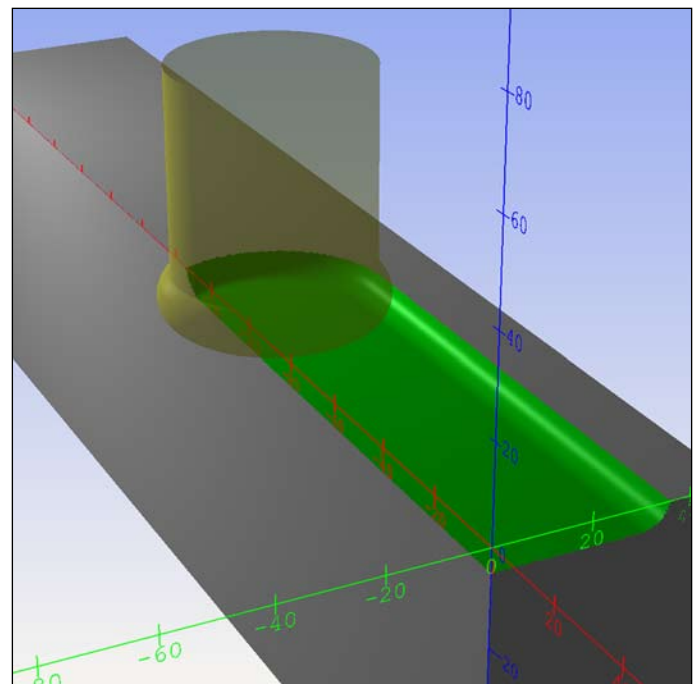
Cutting forces during chatter



Cutting forces with ACC



Simulated machining



AFC

Adaptive feed rate control (option)

The feed rate during milling operations is usually chosen depending on the material to be machined, the cutting tool and the cutting depth. It is specified for the respective milling operation. If the cutting conditions change during the operation, for example due to fluctuations in cutting depths, tool wear or in material hardness, this has no influence on the feed rate. On the one hand, for example if the material thickness decreases, this can mean that the feed rate that is at times lower than necessary. The machining time is therefore higher than it need be. On the other hand, a high programmed feed rate—particularly if the chip volume increases—can result in spindle and tool overload.

Benefits of AFC

Adaptive feed rate control option (AFC) from HEIDENHAIN optimizes the feed rate by taking the spindle power and further process data into consideration. AFC ensures that the maximum possible feed rate and thereby increases efficiency. It offers a number of benefits.

Optimizing the machining time

Fluctuations in dimensions or material (blowholes) often appear particularly on cast parts. By correspondingly adapting the feed rate, the control maintains the previously “learned” maximum spindle power during the entire machining time. The total machining time is shortened by an increased feed rate in the machining zones with less stock removal.

Tool monitoring

The TNC's adaptive feed rate control continuously monitors the spindle power required for the current feed rate. As a tool becomes blunt, the spindle power increases. As a result, the TNC reduces the feed rate. As soon as the feed rate falls below a defined minimum, the TNC reacts by switching off, with an error message, or by changing to a replacement tool. This helps to prevent further damage after a tool breaks or is worn out.

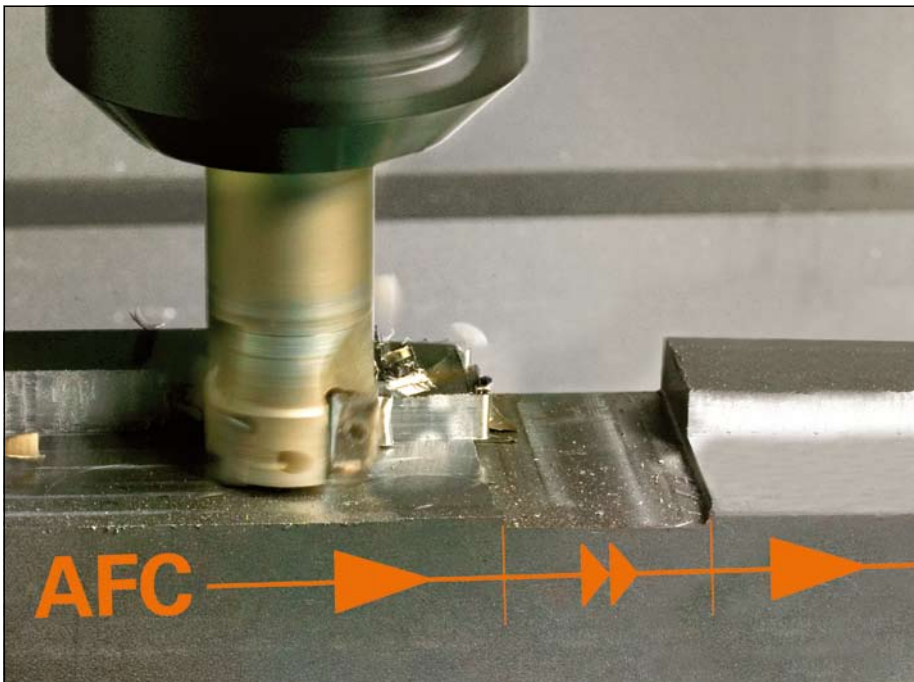
Protection of the machine mechanics

Reducing the feed rate down to the reference value whenever the learned maximum permissible spindle power is exceeded also reduces the strain and wear on the machine. It effectively protects the spindle from overload.

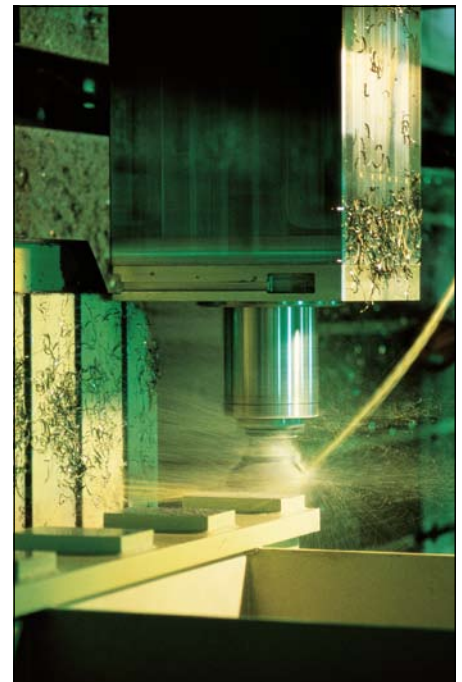
Principle of function

The application is simple: before machining, the maximum and minimum limit values for spindle power can be specified in a table. The values are determined by having the TNC record the maximum spindle power consumed during a teach-in cut. The adaptive feed control then continuously compares the spindle power with the reference power and attempts to maintain the reference power by adapting the feed rate during the entire machining period.

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AFC adapts the feed rate to the various cutting conditions.



Trochoidal milling

Machining any contour slots with trochoidal milling

Tools and machine structures are particularly challenged when they are called upon to mill hard-to-cut, high-strength or hardened materials. Particularly when end mills are full-cutting slots, very strong forces are at play because the tool and workpiece form a contact arc of 180°. This can result in the tool bending and thereby causing geometric errors in the slot. To be able to attain the required component accuracy, the axial cutting depth is often limited to half the tool diameter. Deep slots then have to be roughed in multiple, time-consuming steps.

Advantages of trochoidal milling

The benefit of trochoidal milling is the complete machining of slots of all kinds in a way that reduces load on the tool and machine. The roughing process is a circular motion superimposed on a forward linear motion.

With trochoidal milling, large cutting depths are possible since the prevailing cutting conditions do not increase the wear and tear on the tool. In most cases, this makes it possible to use the entire length of the cutter to achieve higher chip volume per tooth. Circular plunging into the material places less radial force on the tool. This reduces the mechanical load on the machine and prevents vibration. Enormous time savings can be realized by combining this milling method with the integrated adaptive feed control (AFC) option.

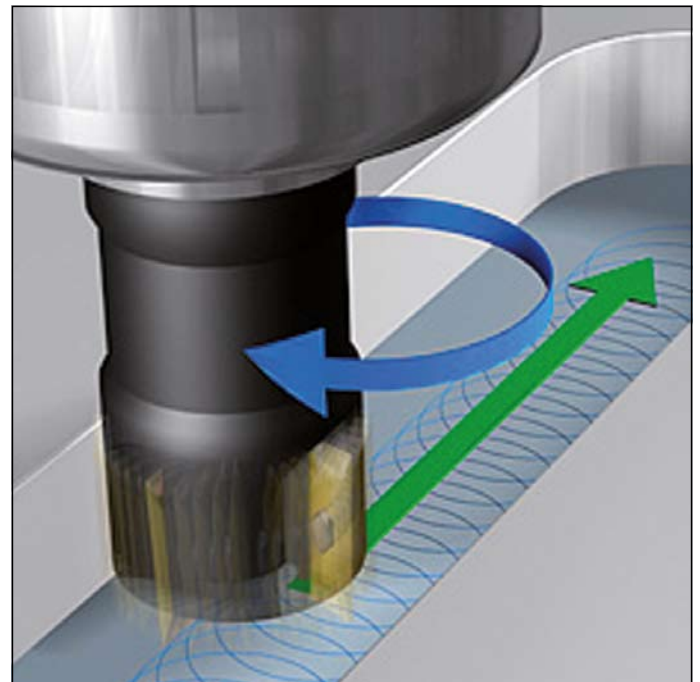
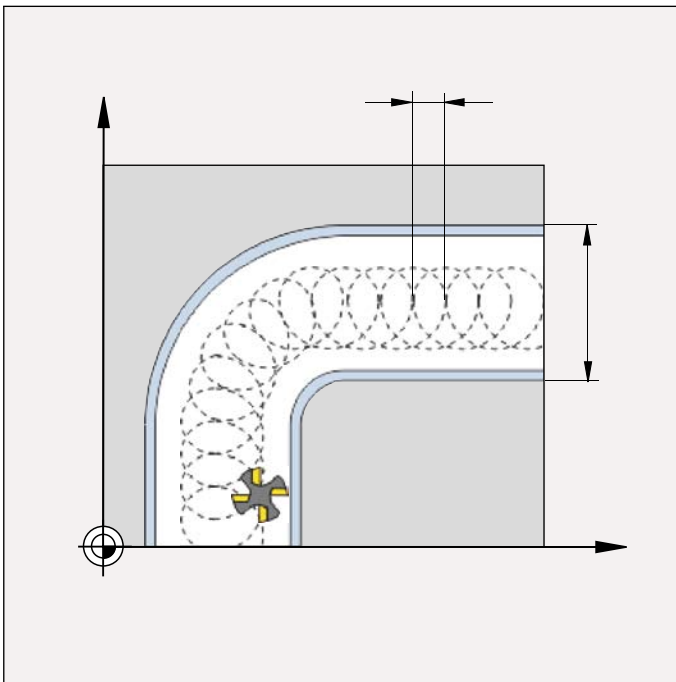
Trochoidal milling as standard function

The slot to be machined is described in a contour subprogram as a contour train. You define the dimensions of the slot and the cutting data in a separate cycle. Any residual material remaining can then easily be removed with a subsequent finishing cut.

The benefits include:

- Engagement of the entire cutter length
- Higher metal removal rate (in combination with AFC)
- Relief from mechanical load on the machine
- Less vibration
- Integrated finishing of the side wall

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Trochoidal milling: ultraefficient machining of all kinds of slots

HEIDENHAIN controls

Contouring controls for milling, milling/turning, drilling, boring machines and machining centers

The TNC controls from HEIDENHAIN cover the whole range of applications: From the simple, compact TNC 128 three-axis straight cut control to the TNC 530 (up to 18 axes plus spindle)—there's a TNC control for nearly every application. The TNC 640 is a control for milling machines that are also capable of turning operations.

HEIDENHAIN TNC controls are versatile: They are workshop oriented and feature both shop-floor and offline programming, and are therefore ideal for automated production. They handle simple milling tasks just as reliably as the TNC 640 and iTNC 530, for example, can handle high speed cutting—with especially jerk-reduced path control—or 5-axis machining with swivel head and rotary table.

HEIDENHAIN combines innovative control functions for efficient high-precision machining under the hypernyms **Dynamic Efficiency** and **Dynamic Precision**.

Dynamic Efficiency helps the user to make heavy machining and roughing more efficient while also enhancing its process reliability. **Dynamic Efficiency** is available on the TNC 640 and iTNC 530 controls.

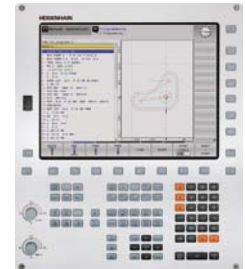
Dynamic Precision makes workpieces more exact, with clean surfaces and high-speed machining, thereby providing high precision and higher productivity. You can use the **Dynamic Precision** software options with the TNC 640, iTNC 530 and TNC 620.



TNC 640



iTNC 530



TNC 620

	TNC 640	iTNC 530	TNC 620
Dynamic Precision	x	x	x
CTC – Compensation of position errors through axis coupling	Option	Option	Option
AVD – Active vibration damping	Option	Option	Option
PAC – Position-dependent adaptation of controller parameters	Option	Option	Option
LAC – Load-dependent adaptation of control parameters	Option	Option	Option
MAC – Motion-dependent adaptation of control parameters	Option	Option	Option
Dynamic Efficiency	x	x	–
ACC – Active suppression of chatter	Option	Option	Option
AFC – Adaptive feed control	Option	Option	–
Trochoidal milling	•	•	•

- x Functions possible
- Standard function

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For more information:

- Catalog: *TNC 640*
- Catalog: *iTNC 530*
- Catalog: *TNC 620*
- Technical Information: *Dynamic Precision*

