SINUMERIK live:
Multi-face machining milling (3+2 axes)

Principles, handling and use cases with SINUMERIK Operate

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Application engineering made easy
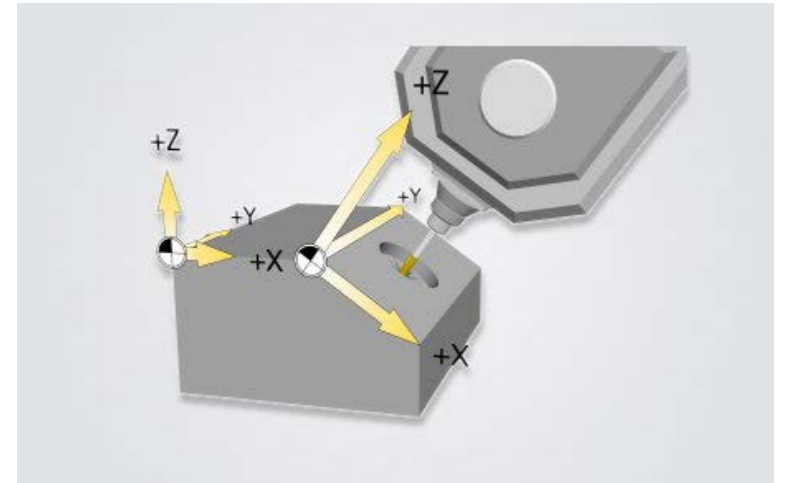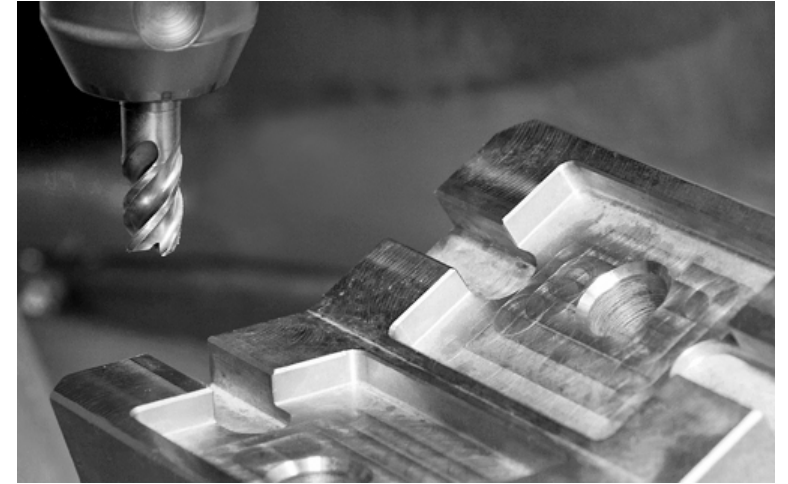
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Video series with the goal of presenting individual topics on the use of SINUMERIK at a practical level in minimal time!

Consisting of short slide presentations and **practical application**!

Multi-face machining milling (3+2 axes)

Principles, handling and use cases with SINUMERIK Operate

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Definition of milling:

Milling is a metal cutting process. In this process, the material is removed by the milling tool, which is rotating at high speed about its own axis, while either the tool moves along the programmed contour or the workpiece is moved accordingly.

Axes:

- Rotation of the tool about its own axis (Z axis)

- Movement in the direction X, Y or Z

- Rotation about rotary axes A, B or C via tool head or table

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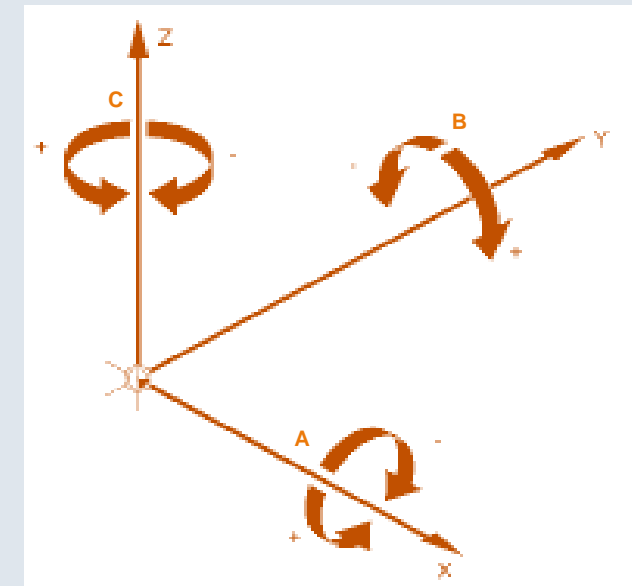
Milling tools:

- Have one or more cutting edges
- The material is removed by the rotating motion of the tools
- No rotation in the center point of the tool

Distinguishing milling tools by…

- … type of tool clamping (end mill or shell-type milling cutter)
- … cutting material (solid carbide or HSS)
- … shape of the cutting edges (for roughing or finishing)
- … milling strategy (groove milling, face milling, right-angle cutting, …)

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3-axis machining

3+2 axis machining

Dynamic 5-axis machining
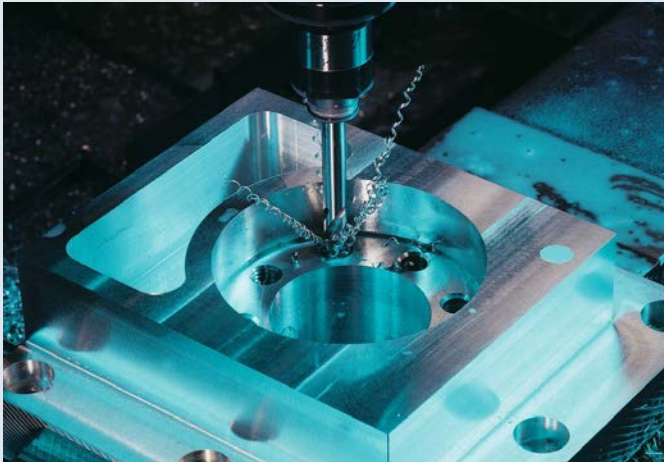
For 3-axis machining, the machining is done via programming the three linear axes. The contour is milled in a synchronized way by the movement of the three linear axes. The tool is positioned vertical to the workpiece.

With three linear axes and two rotary axes, any point in space can theoretically be reached with any tool orientation. Thus, the tool can be statically aligned to the machining surface.
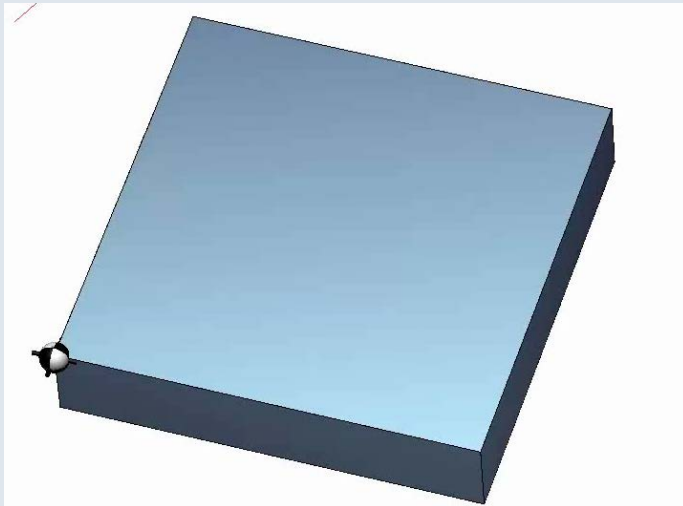
The three linear axes (X, Y and Z) and two of the rotary axes (A, B or C) are also used for orientating the tool. The axes are positioned dynamically and simultaneously.

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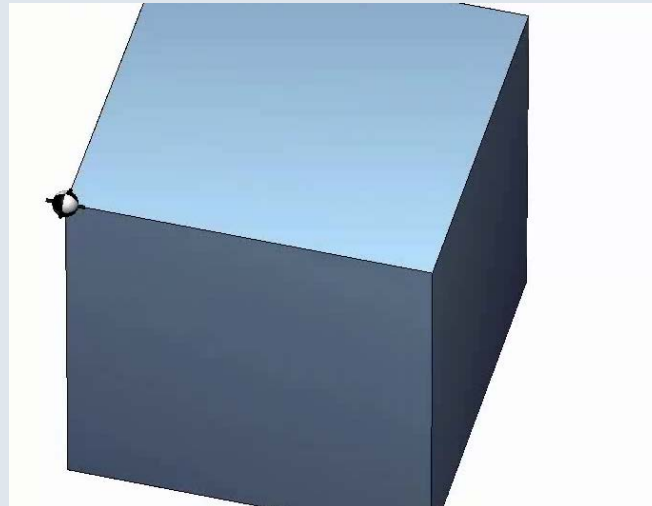*Ingenuity for life*

3-axis machining

The milling machining is limited to the XY plane and can thus follow 2-dimensional contours.
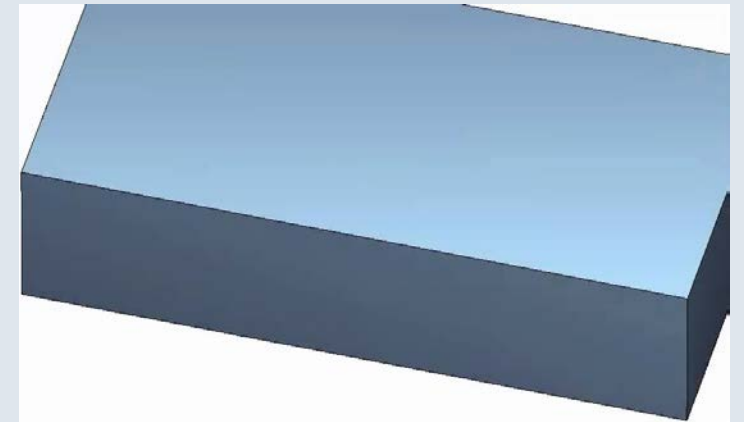

2D machining

3+2 axis machining

The machining itself is limited to 2-dimensional contours. The third dimension is achieved by tilting and securing the machining plane.

2½D machining

Dynamic 5-axis machining

To machine the free-form surfaces, the 5 axes move dynamically and simultaneously.
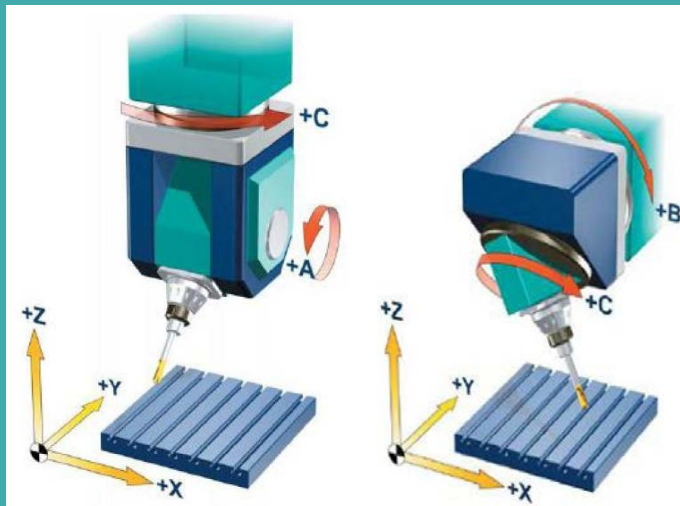

3D machining

For both the 3+2-axis machining and the 5-axis simultaneous machining, you need two rotary axes (A, B or C) for **orientating the tool in addition to the three linear axes (X, Y and Z)**.
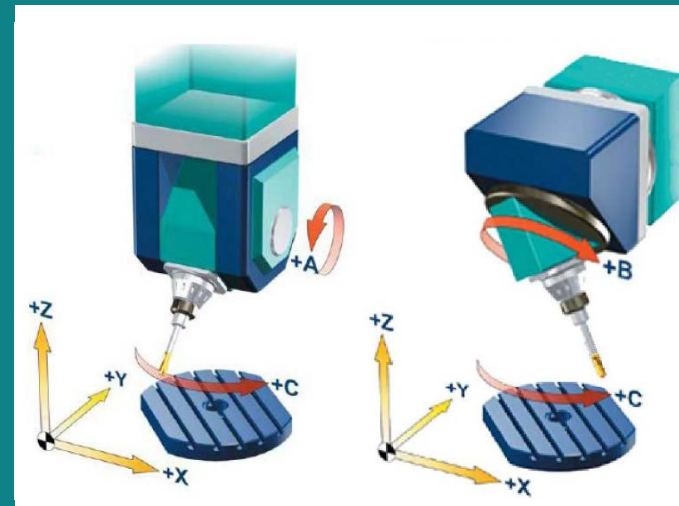
Depending on the kinematic characteristics of the machine, these 2 axes can be set using **a tiltable head and/or a tiltable table**.
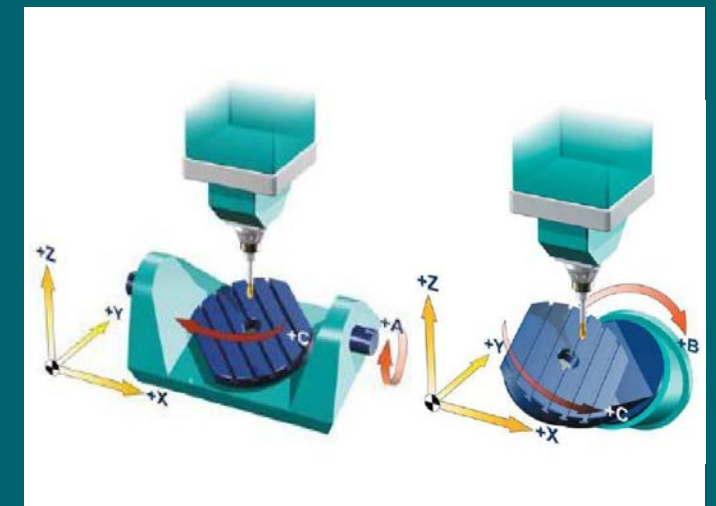
Head kinematics

Tiltable head

Mixed kinematics

Tiltable head
and tiltable rotary table

Table kinematics

Swivel rotary table

Comparison 3+2 and 5-axis simultaneous

Tool orientation

3+2-axis	5-axis simultaneous
• Static	• Dynamic

Programming

3+2-axis	5-axis simultaneous
• "manually"	• CAD/CAM

Use in the SINUMERIK

3+2-axis	5-axis simultaneous
• Swivel cycle Cycle800	• 5-axis transformation • TRAORI

Workpieces

3+2-axis	5-axis simultaneous
• Tool and equipment manufacture	• Free-form surfaces and mold making

Advantages

| 3+2-axis	5-axis simultaneous
"Manually" programmable, nevertheless with great flexibility	• Maximum flexibility • Noncuts are avoided • Optimum positioning of the tool
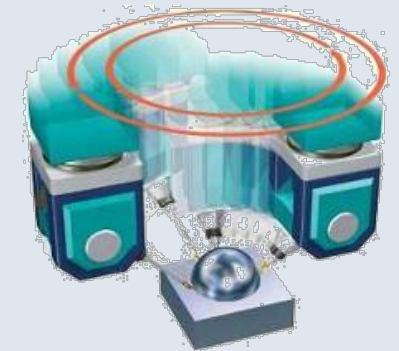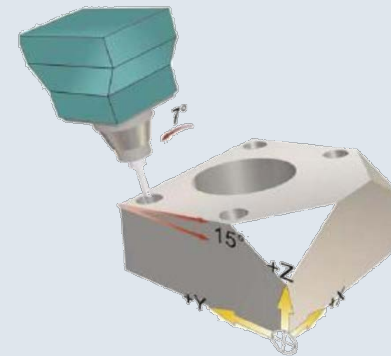
2D milling technologies in a tilted plane

Standard geometries

The SINUMERIK provides a large selection of machining cycles for the drilling and milling of standard geometries.
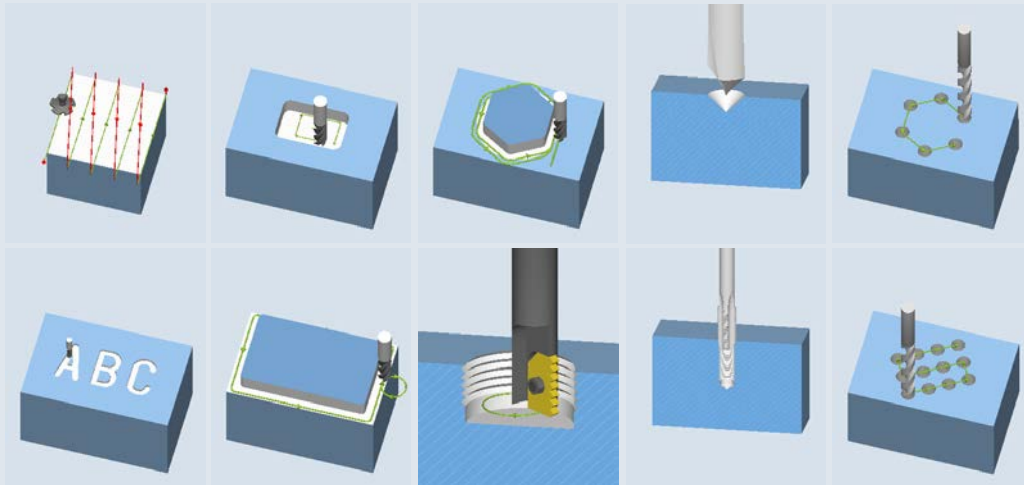
Contour milling

- Machining of contour pockets and pins
- Automatic detection of residual material
- Free contour generation with contour computer/DXF reader
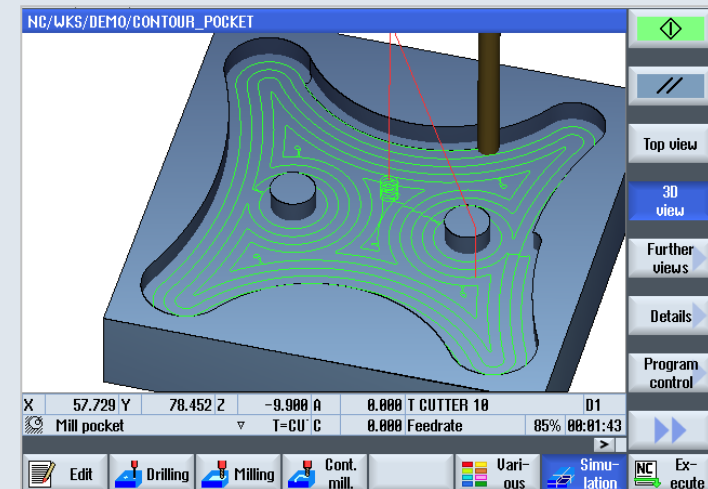
The **full range of SINUMERIK technology cycles** is also available **in tilted planes** – from simple drilling all the way to contour machining with residual material detection.

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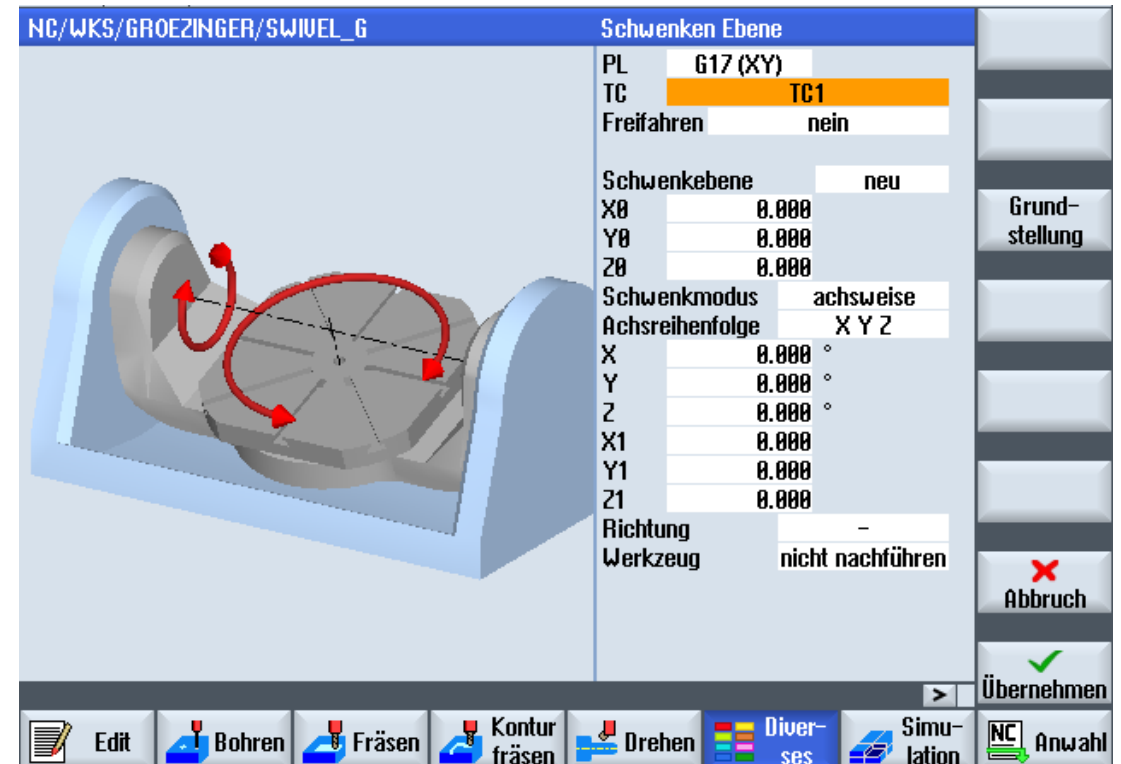
The center for programming the 3+2-axis machining is the **Cycle800 swivel cycle**. Thanks to the **graphically interactive input screen**, all of the swivel tasks can be quickly and conveniently programmed directly on the CNC controller.

Swivel cycle Cycle800:

- Graphical input screen in ShopMill

- Selection of the swivel data set

- Control of the swivel sequence (retract, swivel direction)

- Definition of the swivel mode (by axis/projection angle/direct)
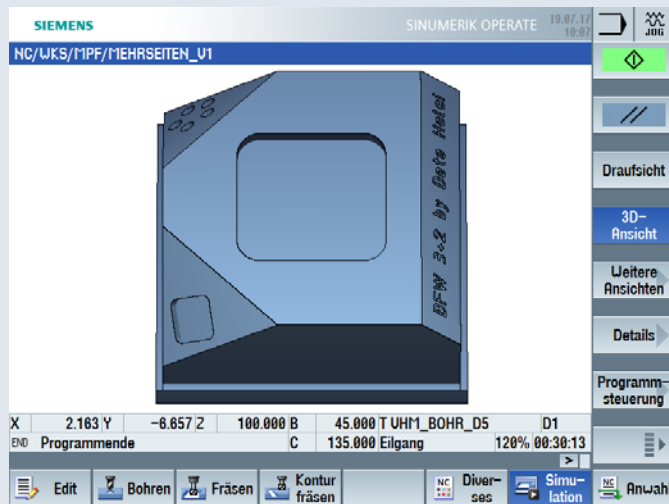
- Entry of the swivel parameters

The swivel axes are always turned in so that the machining plane is vertical to the tool axis for the subsequent machining.

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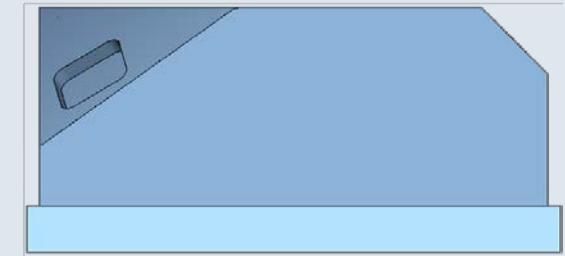**Example workpiece for multi-face machining 3+2 milling:**

① Preparation of blank:
face milling of the 5 cube faces

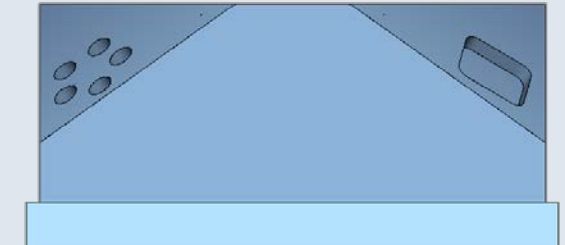**②** Pocket milling on untilted G17 plane

③ Swiveling about Y and engraving of the tilted plane
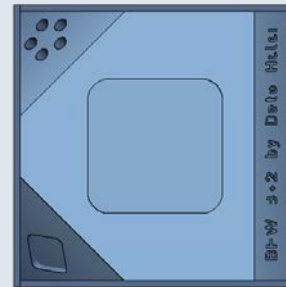
④ Swiveling about Y and Z and milling a rhombus-shaped pocket
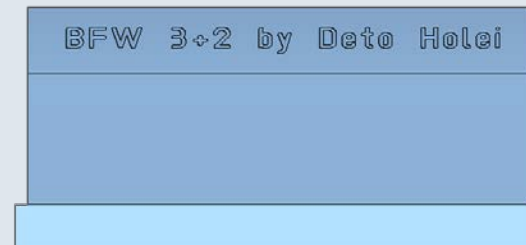
⑤ Re-swiveling about Y and Z and inclined drilling according to a drilling pattern

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Example: **Programming of the engraving on a tilted plane**

1) Swivel cycle Cycle800
2) Face milling cycle Cycle61
3) Engraving cycle Cycle60

1) Swivel cycle Cycle800

During parameterizing or programming of swiveling, the controller provides support in the form of the **graphical overview display** - "Animated Elements".

All of the **swivel axes can be programmed directly on the machine**. The rotation of the workpiece coordinate system in the program is then automatically converted to rotations of the respective swivel axes of the machine when the workpiece is machined.

Example workpiece with ShopMill
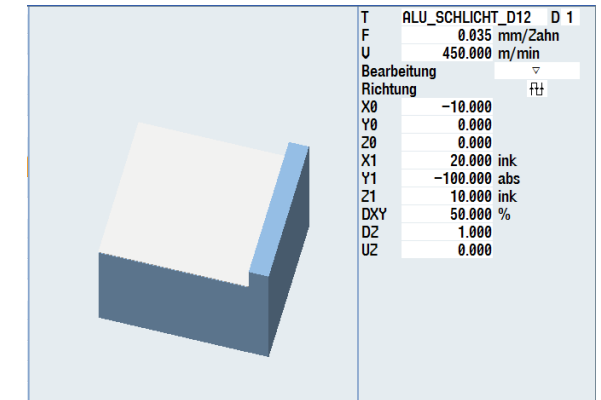

2) Face milling cycle

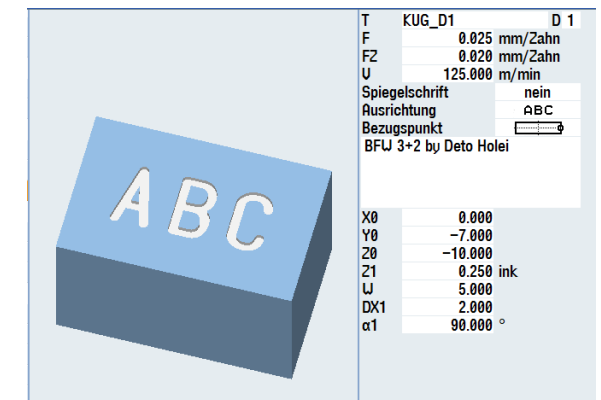If the plane is tilted, the inclined plane can be milled with the aid of the face milling cycle.

It must be observed that you must imagine the milling plane as rectangular, even if the intersection of the milling plane and the swiveled workpiece result in a triangular face.

T	ALU_SCHLICHT_D12	D 1
F	0.035	mm/Zahn
U	450.000	m/min
Bearbeitung		▽
Richtung		⇅
X0	−10.000	
Y0	0.000	
Z0	0.000	
X1	20.000	ink
Y1	−100.000	abs
Z1	10.000	ink
DXY	50.000	%
DZ	1.000	
UZ	0.000	

3) Engraving cycle

On the prepared inclined plane, all of the standard geometries, such as engraving, can then be applied as usual.

The input screen of ShopMill provides support for entering the parameters.

T	KUG_D1	D 1
F	0.025	mm/Zahn
FZ	0.020	mm/Zahn
U	125.000	m/min
Spiegelschrift		nein
Ausrichtung		ABC
Bezugspunkt		
BFW 3+2 by Deto Holei		
X0	0.000	
Y0	−7.000	
Z0	−10.000	
Z1	0.250	ink
U	5.000	
DX1	2.000	
α1	90.000	°

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☑ **Milling in general:**
During milling, the tools rotate about their own axes and run along the contour of the workpiece for chip removal or the workpiece is moved in a corresponding way.

☑ **Milling kinematics:**
3-axis milling is limited to movement of the workpiece and of the tool in 3 axes - X, Y and Z. In 5-axis machining, two of the rotary axes (A, B and C) are also needed to mill 2½D and 3D contours.

☑ **Why is 3+2 not equal to 5?**
The difference between 3+2-axis machining and 5-axis simultaneous milling is in the positioning of the tool or workpiece. This is done statically for 3+2 machining with the Cycle800; dynamically, on the other hand, for the 5-axis simultaneous milling.
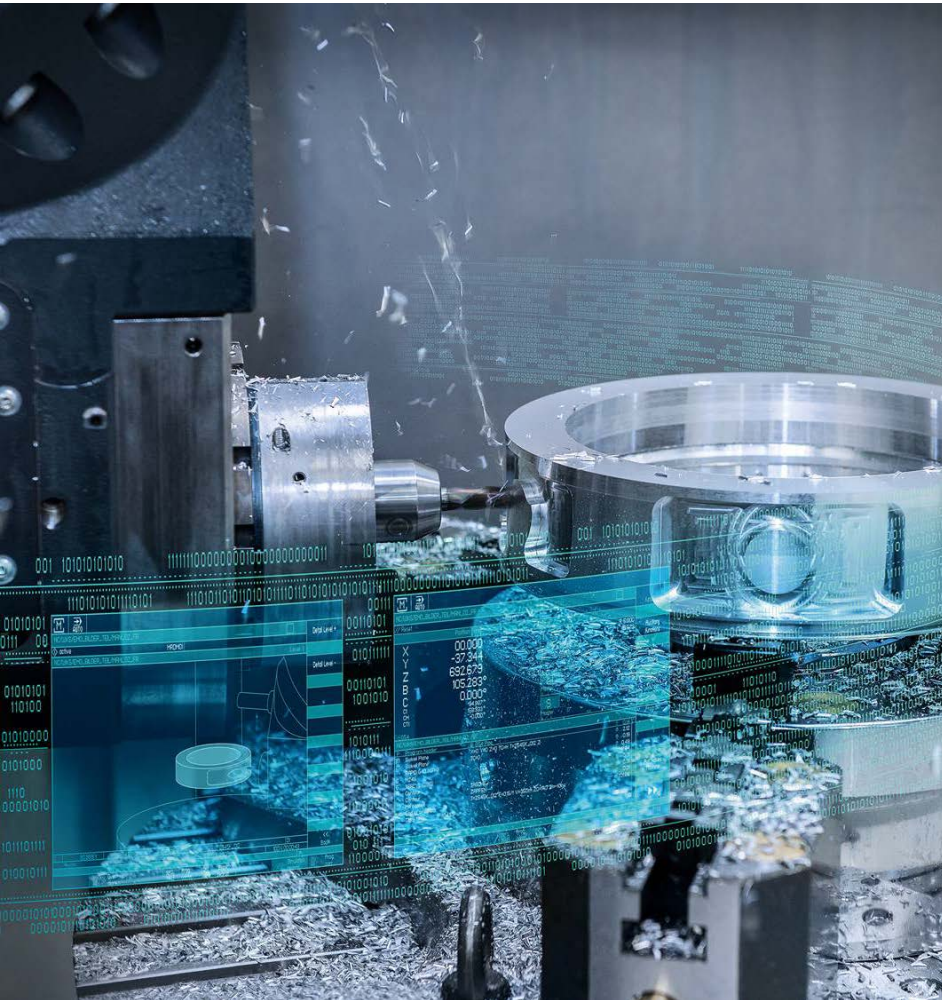
☑ **Swivel cycle Cycle800:**
The swivel cycle can easily be applied in both ShopMill and in the programGUIDE. During this, different parameters, which define the tilting of the plane about the axes, can be entered in the input screen.

Thank you for your attention!

Technology and Application Center Erlangen

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