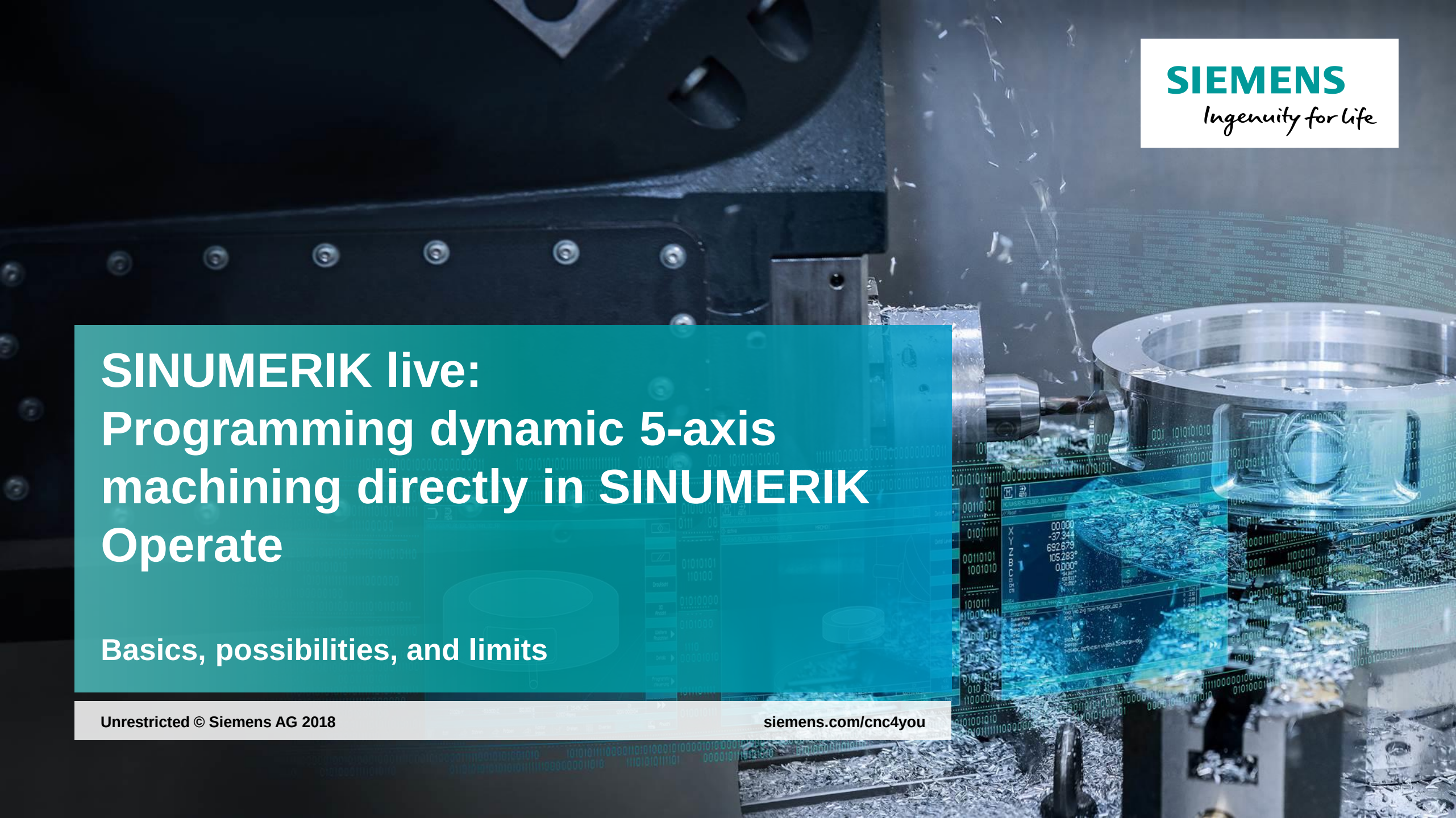

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SINUMERIK live: Programming dynamic 5-axis machining directly in SINUMERIK Operate

Basics, possibilities, and limits

Programming dynamic 5-axis machining directly in SINUMERIK Operate – Basics, possibilities, and limits

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1. Repetition of basics
2. 5-axis transformation
3. Tool orientation
4. 3D cutter radius compensation
5. Example workpiece live on the machine
6. Summary

1 Repetition of basics
Comparison of 3+2 and 5-axis milling

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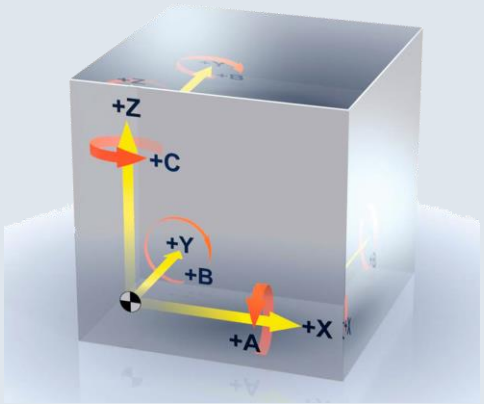


Common aspects:

3 linear axes (X, Y, and Z)

and

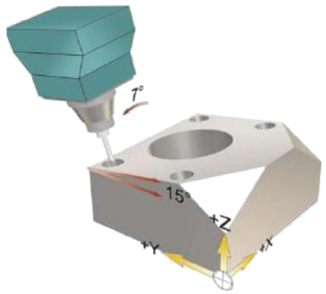
2 rotary axes (A, B, or C)

Difference:

3+2-axis:	static orientation of the tool
5-axis simultaneous:	dynamic orientation of the tool

When is which used?

3+2-axis:



roughing/preliminary finishing of 3D contours

Consideration of economic efficiency (for most components on the market, 3+2 machining is sufficient)

Tool and fixture making

5-axis simultaneous: final machining and finishing

Workpieces with deep cavities or frequent changes in curvature

High surface quality

Free-form surfaces (mold making)

Turbine and aircraft engine components

Structural parts (aviation industry)

1 Repetition of basics
Mechanical design of milling machines

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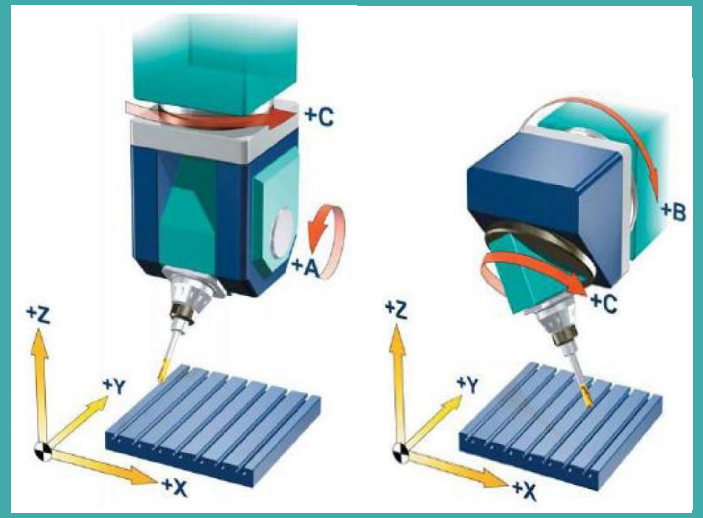
Both for 3+2 axis and for 5-axis simultaneous machining,
two rotary axes (A, B, or C) in addition to the three linear axes (X, Y, and Z) are required for orientation of the tool.

Depending on the kinematics of the machine, these 2 axes can be set by **a swivel head and/or a swivel table**.

Head-head kinematics

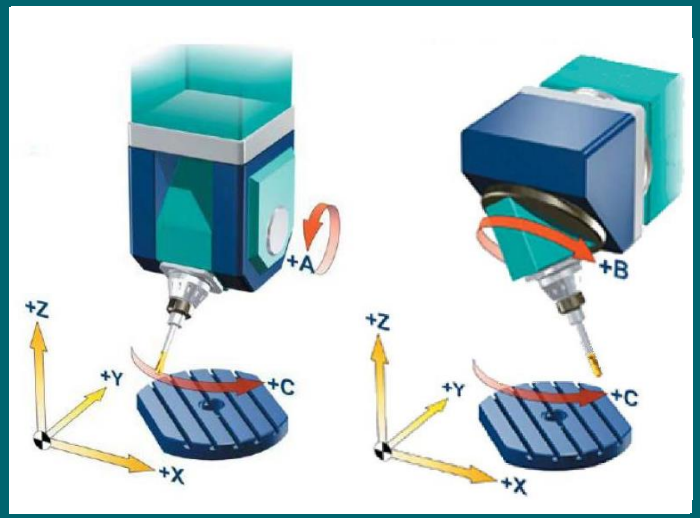


Swivel head

Table-table kinematics

Swivel rotary table

Mixed kinematics



Swivel head
and swivel rotary table

1 Repetition of basics
Mechanical design of milling machines – example

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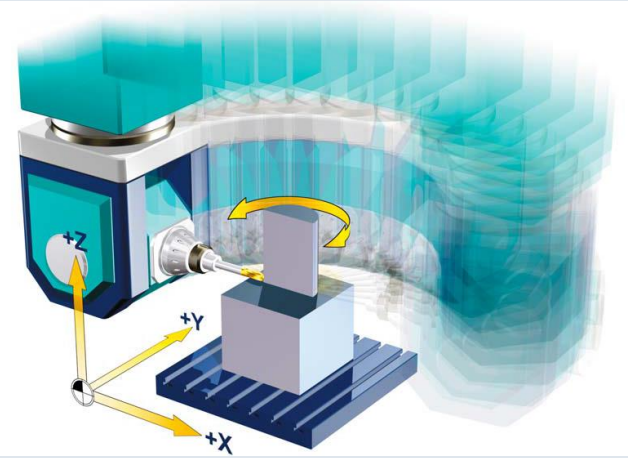
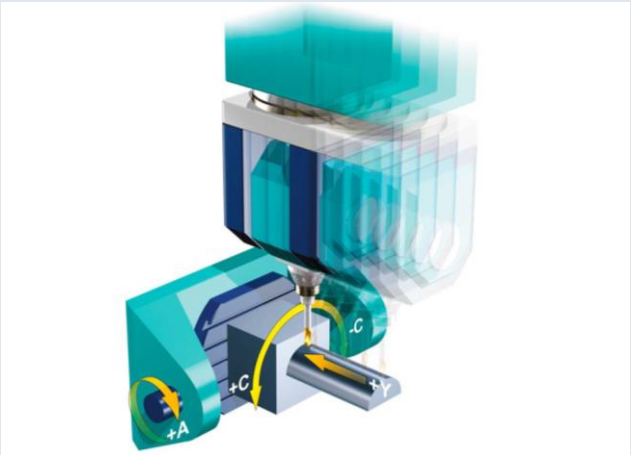


Motion sequence for head/head kinematics

- Machine kinematics with rotary axes A and C in the head
- Semicircle in plane X/Y with linear axes X and Y
- Tool always perpendicular to the workpiece surface due to rotation of the tool through 180° about the Z-axis → C-axis
- Description of a semicircle (a circumference) with axes X, Y, and C

Motion sequence for table/table kinematics

- Machine kinematics with rotary axes A and C in the table
- Tool perpendicular to the workpiece surface → Rotation of the A-axis through 90°
- Semicircle by rotation of the C-axis through +90° in each case to -90°
- Description of a semicircle (a circumference) only with the C-axis



1 Repetition of basics
Mechanical design of milling machines – example

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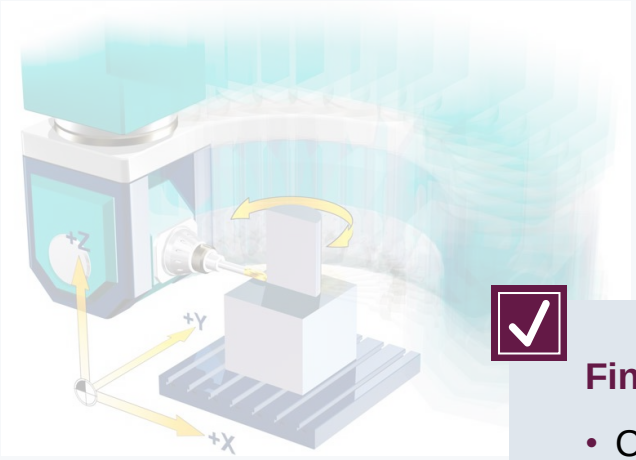


Motion sequence for head/head kinematics

- Machine kinematics with rotary axes A and C in the head
- Semicircle in plane X/Y with linear axes X and Y
- Tool always perpendicular to the workpiece surface due to rotation of the tool through 180° about the Z-axis → C-axis

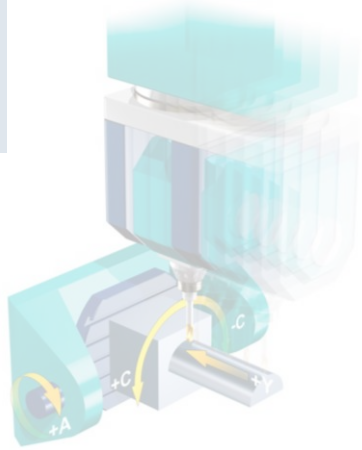
, Y, and C

Findings:

- Completely different machine movements produce the same result
- Movement of the tool tip and tool orientation relative to the surface are identical

Motion sequence for table/tal

- Machine kinematics with rota
- Tool perpendicular to the workpiece surface → Rotation of the A-axis through 90°
- Semicircle by rotation of the C-axis through +90° in each case to -90°
- Description of a semicircle (a circumference) only with the C-axis



2 5-axis transformation
Simultaneous movement of the linear and rotary axes

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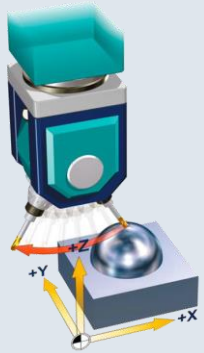
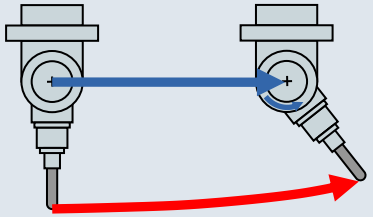
Tool orientation:



Movement of the rotary axis for orientation of the tool

➔ Tool tip moves along a circular path

Synchronous motion:



Linear interpolation of the rotary and linear axis

➔ Curved line

How can this effect be avoided in simultaneous 5-axis machining?

→ Complicated calculation of the axis movement would be necessary to prevent this unwanted movement.

2 5-axis transformation
Solution: TRAORI

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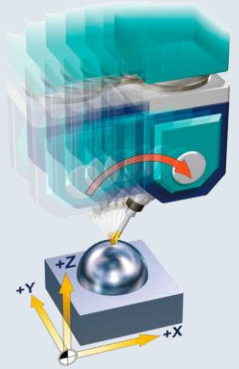
Tool orientation:

Movement of the rotary axis for orientation of the tool

➔ Tool tip moves along a circular path

TRAORI



Tool orientation:

Movement of the rotary axis and compensating movements of the linear axes for orientation of the tool

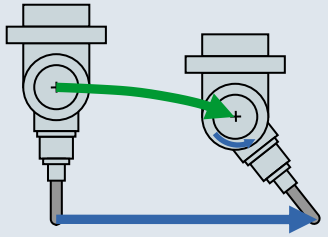
➔ Tool tip remains immobile in space

Synchronous motion:

Linear interpolation of the rotary and linear axis

➔ Curved line

TRAORI



Synchronous motion:

Additional compensating movements in the Z-direction

➔ Straight line

2 5-axis transformation
Tasks of the 5-axis transformation

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```
SIEMENS
NC/
N10 G17 G71 G90 G54 G64¶
N20 T="SF_D16_3SN_VHM_SL"¶
N30 M6¶
N40 S12000 M3¶
G0 Z55¶
N50 TRAORI¶
N60¶
```

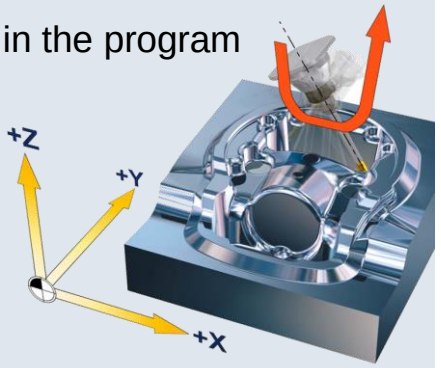
The TRAORI command activates the 5-axis transformation.

Position data now always refer to the tip of the tool.

→ NC programs only describe the relative motion between the tool and workpiece.

What does TRAORI do?

- Transformation of the relative motion between the tool and workpiece into machine axis movements.
- Automatic calculation of the compensating movements in X, Y, and Z on a change in tool orientation
- All axes are interpolated simultaneously
- Changes to the tool length and zero offset
  are considered in the program sequence.



→ **Kinematics and tool-dependent NC programs.**

```
SIEMENS
NC/
N200 X20 Y20 A3=0.35 B3=-0.35 C3=1¶
N210 G40 X0 Y0 Z2 A3=0 B3=0 C3=1¶
N220 TRAFOOF¶
N230 M30¶
```

The TRAFOOF command deactivates the 5-axis transformation.

3 Tool orientation
Linear interpolation ORIAXES

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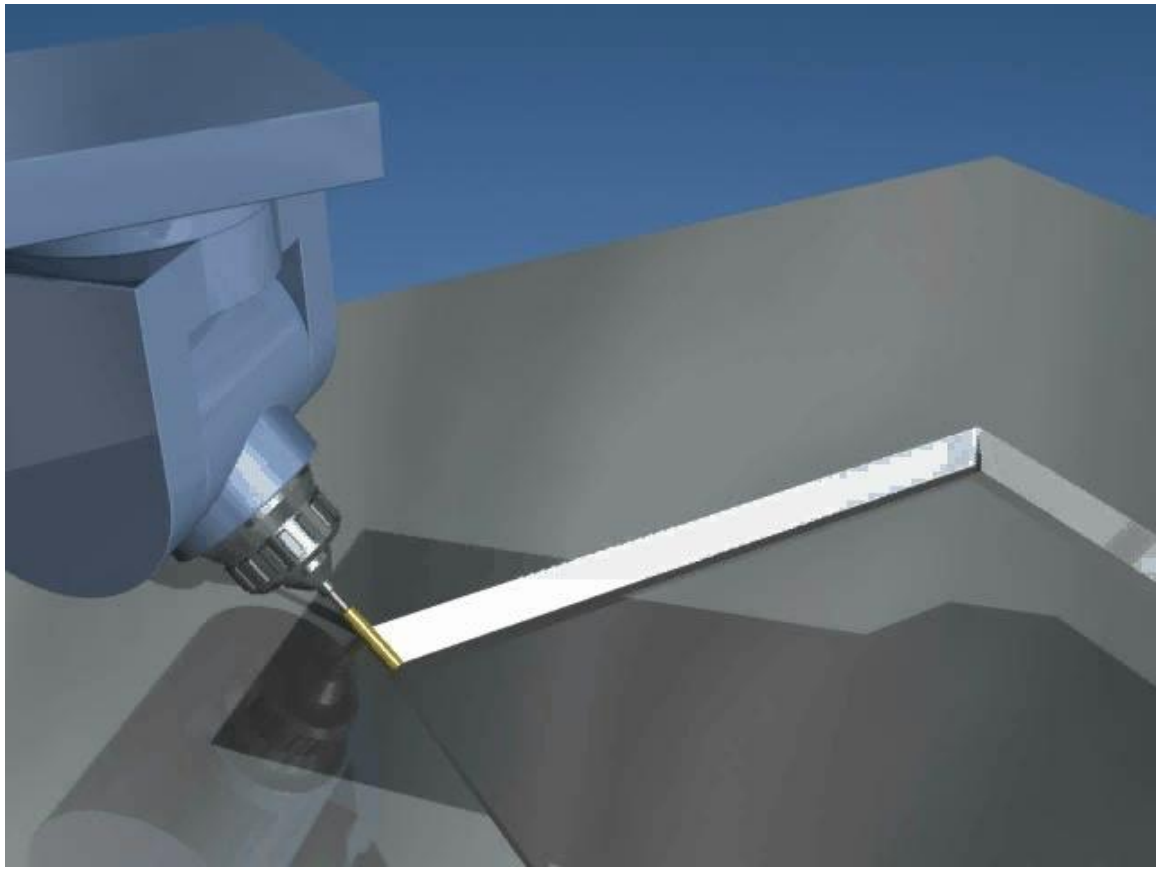
ORIAXES

- Command for linear interpolation = standard interpolation type
- Linear interpolation of the rotary axes synchronously with the movement of the tool tip
- Progress of orientation depending on the machine kinematics
- Can be used if tool is not required to move along a precisely defined surface in the WCS (e.g.: face milling with a ball cutter)



3 Tool orientation
Vector interpolation ORIVECT

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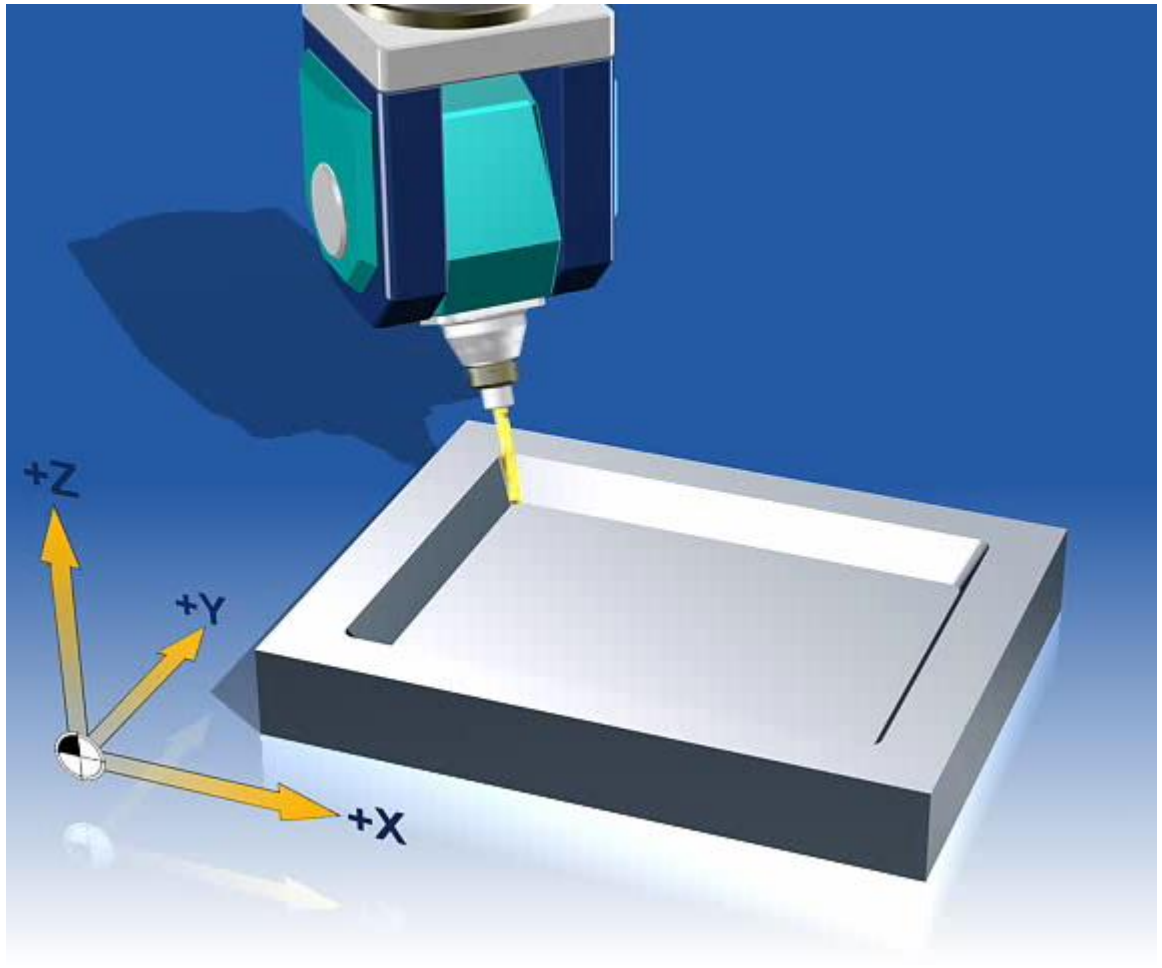
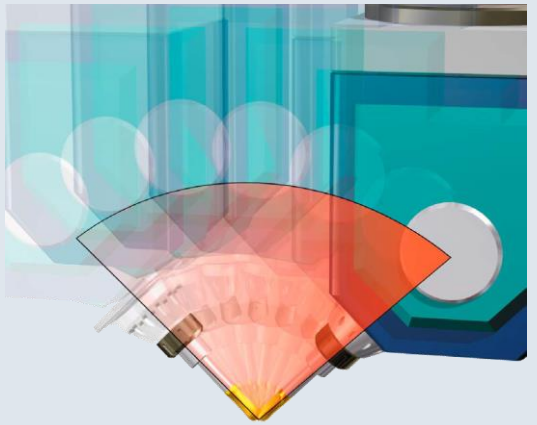


ORIVECT

- Command for vector interpolation
- Interpolation of the vector on the plane formed by the start and end vector
- Changes in orientation due to movement of the rotary axes by the shortest path
- Frequently for milling pockets with usually flat and inclined walls

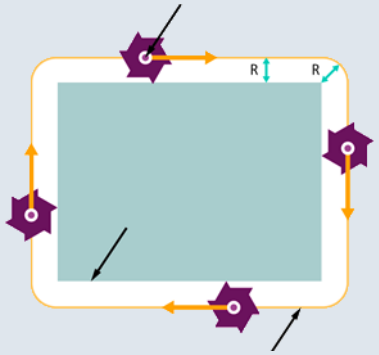


4 3D cutter radius compensation
2D cutter radius compensation to 3D cutter radius compensation

2 ½ D cutter radius compensation = conventional

Contour, center-point path of cutter
→ 2 ½ D (G41/42)

→ Tool orientation always identical



3D cutter radius compensation = extension

Continuous change in the tool orientation

→ Continuous change in the offset direction

→ Definition of the offset direction as a vector in space

3D cutter radius compensation

- Activation of the 5-axis transformation → TRAORI
- Activation of the 3D cutter radius compensation → CUT3DC/DF
- Compensation of cylindrical tool geometries:
  - Shank-type milling cutter with and without corner radius
  - Ball nose end mill
  - Cylindr. die-sinking cutter
  - Tapered die-sinking cutter
  - Beveled milling cutter with and without corner radius

4 3D cutter radius compensation
Difference between circumferential and face milling

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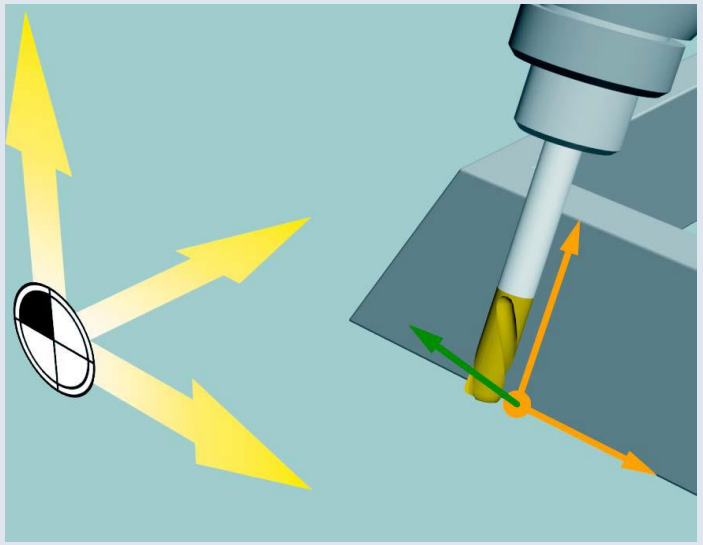
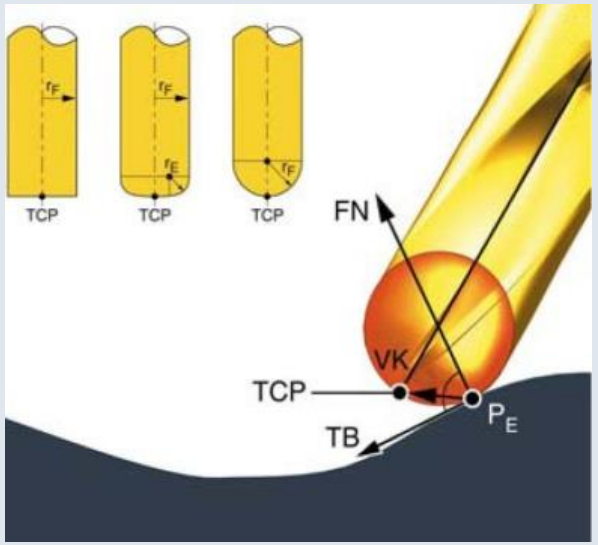
CUT3DC circumferential milling

- The direction of compensation is always perpendicular to the plane on which the cutter is moving



CUT3DF face milling

- Complex → No constant offset
- Compensation value and direction depend on the tool radius and corner radius
- Tool orientation relative to the workpiece surface



6 Summary

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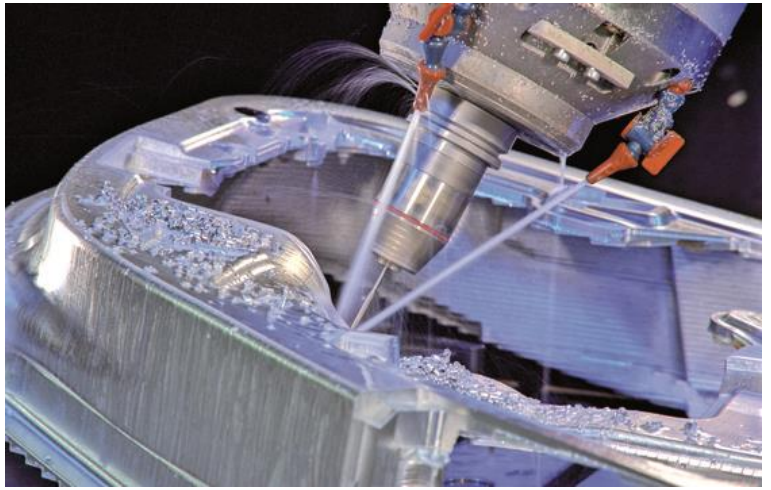
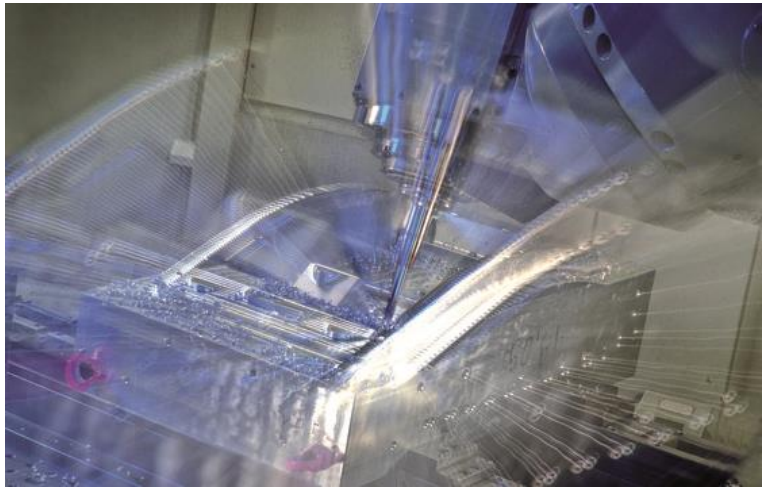
Command for 5-axis transformation (TRAORI / TRAFOOF):
TRAORI enables convenient programming of the tool tip, independently of the kinematics of the machine.

Orientation interpolations (ORIAXES / ORIVECT):
ORIAXES is the command for linear interpolation; ORIVECT, the command for vector interpolation of the tool orientation.

3D cutter radius compensation (CUT3DC / CUT3DF):
The 3D cutter radius compensation takes the changing movement of the tool orientation into account.





Vielen Dank für Ihre Aufmerksamkeit!

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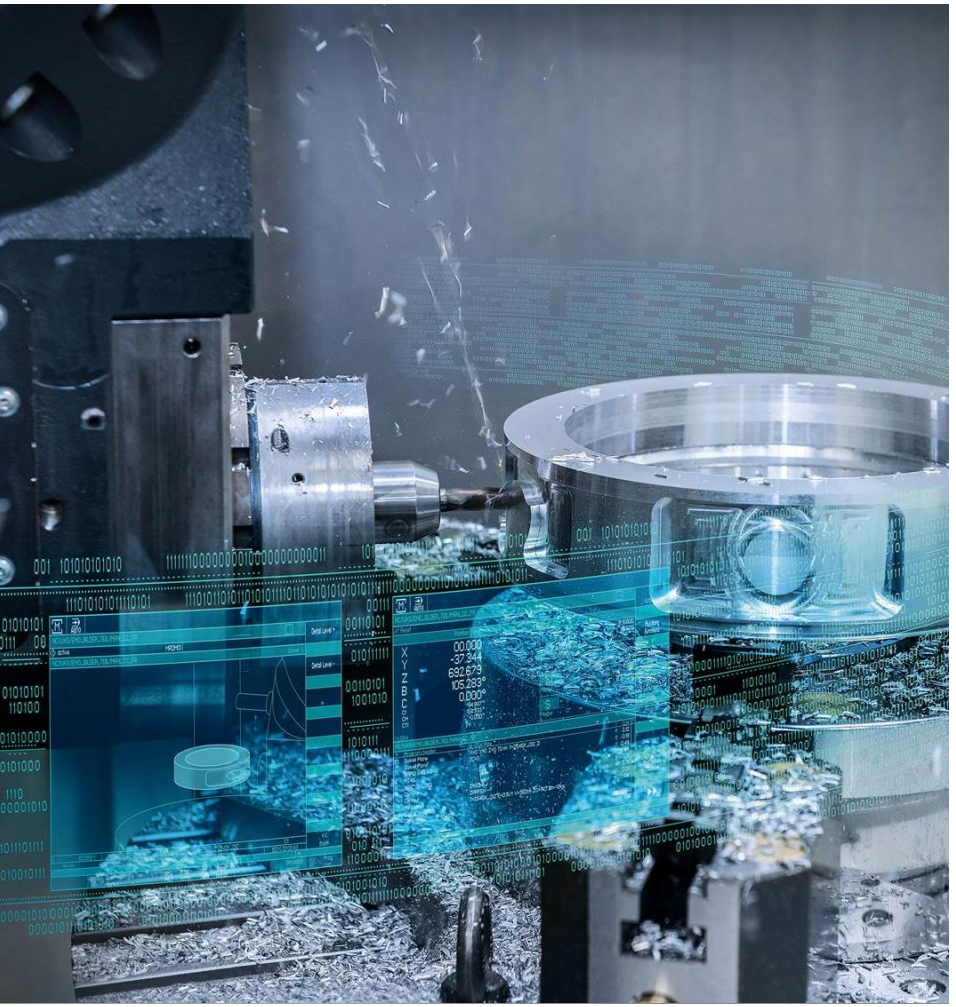

Technologie- und Applikationscenter Erlangen

Link zum Video:
https://www.youtube.com/playlist?list=PL45872A31E6FECBD0

siemens.de/cnc4you