Functional description

TF5290 | TC3 CNC

Cutting Plus

Version 1.0
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BECKHOFF

Notes on the documentation

This description is only intended for the use of trained specialists in control and automation engineering who are familiar with the applicable national standards.
It is essential that the documentation and the following notes and explanations are followed when installing and commissioning the components.
It is the duty of the technical personnel to use the documentation published at the respective time of each installation and commissioning.

The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, including all the relevant laws, regulations, guidelines and standards.

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Icons in explanatory text

➢ Indicates an action.

⇨ Indicates an action statement.

⚠ DANGER
Acute danger to life!
If you fail to comply with the safety instruction next to this icon, there is immediate danger to human life and health.

⚠ CAUTION
Personal injury and damage to machines!
If you fail to comply with the safety instruction next to this icon, it may result in personal injury or damage to machines.

NOTICE
Restriction or error
This icon describes restrictions or warns of errors.

Tips and other notes

This icon indicates information to assist in general understanding or to provide additional information.

General example

Example that clarifies the text.

NC programming example

Programming example (complete NC program or program sequence) of the described function or NC command.

Specific version information

Optional or restricted function. The availability of this function depends on the configuration and the scope of the version.

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1 Lift functionality

1.1 Overview

Task

When positioning operations are executed in the XY plane, the Z axis is lifted as far above the workpiece as possible to avoid collision with cut-out parts between cutting operations (G01/G02/G03, M04 laser on, M05 laser off). This is called Smart Collision Guard. The CNC automatically calculates motion of the Z axis between contour elements.

Characteristics

The user can specify a maximum lifting distance to lift the Z axis. Lifting/lowering is executed automatically and across blocks so that the path feed rate in the XY plane is reduced as little as possible and the Z axis reaches the specified target height at the start of the next machining contour.

The path motion is normally not affected by the lifting/lowering motion, i.e. the Z axis can be attached and detached without feed stop (on the path). The Z axis moves with jerk limiting.

The Smart Collision Guard is available in 2 methods.

- Advanced Lifting
- Lifting

> **i** This document uses the terms lift axis and Z axis synonymously.

Parametrisation

Neither of the two methods is activated in the basic setting.

In order to use the recommended Advanced Lifting, the Chapter Parametrisation [▸ 12] describes the start-up parameters P-STUP-00060 and P-STUP-00070 in which the value **FCT_LIFT_UP_TIME** is assigned. In addition, the channel parameter P-CHAN-00345 “enable_time_based_lift“ must be set to 1.

The P-STUP-00060 is also assigned the value **FCT_LIFT_UP** for lifting. Do not set the channel parameter P-CHAN-00345 "enable_time_based_lift".

Programming

The lift range is defined by the two commands Z[LIFT_START...] and Z[LIFT_END]. The lift axis is automatically moved by the lift function in the intermediate motion blocks.

Links to other documents

For the sake of clarity, links to other documents and parameters are abbreviated, e.g. [PROG] for the Programming Manual or P-AXIS-00001 for an axis parameter.

For technical reasons, these links only function in the Online Help (HMTL5, CHM) but not in pdf files since pdfs do not support cross-linking.

1.2 Description

> **i** **This functionality has been available since CNC Build V2.11.2800.**

Lifting minimises the risk of tool collisions, e.g. during laser cutting, with workpiece parts that are already cut out.

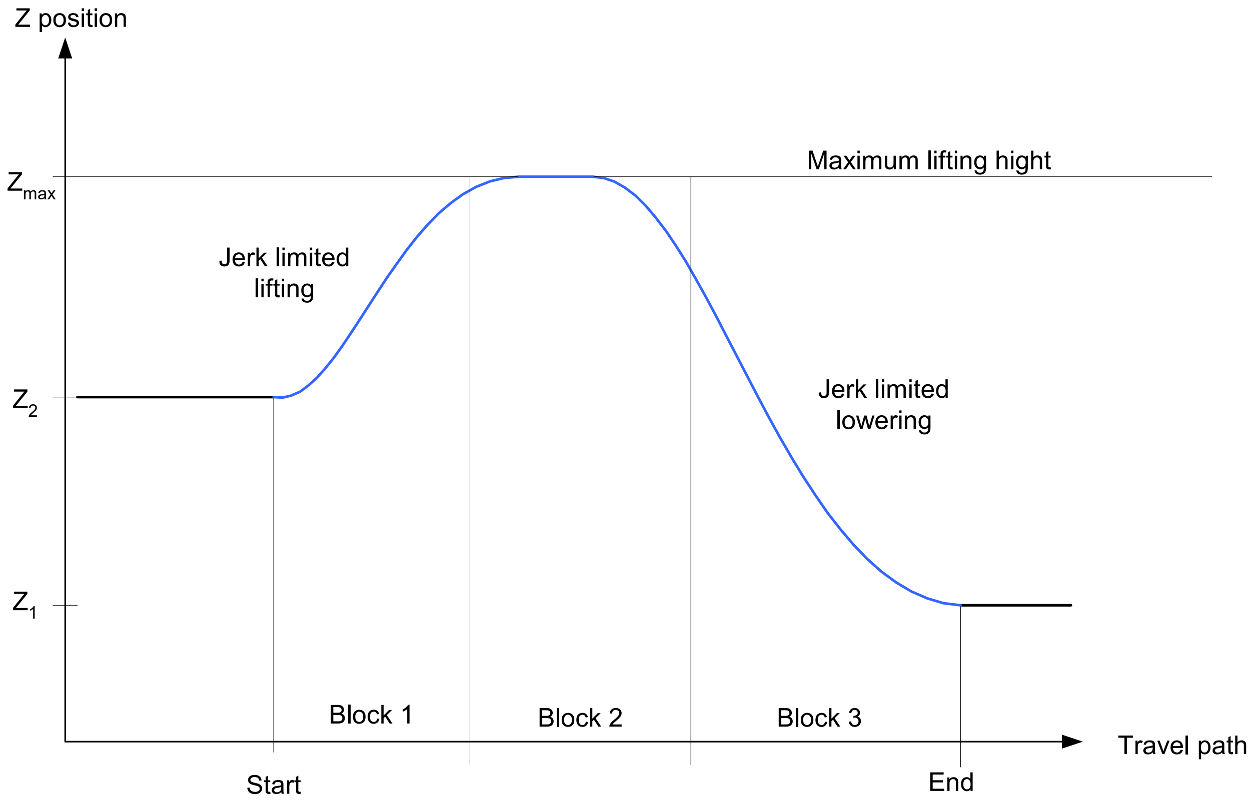


Fig. 1: Description of lifting in 3 NC blocks

A comparison table of the two methods is contained in the section Differences between Advanced Lifting and Lifting. [▶ 22]

1.2.1 Advanced Lifting

This method is recommended.

Reason:

- Advanced Lifting permits a greater lifting height to be reached.
- It increases collision protection.
- Advanced Lifting has no negative impact on lifting height caused by changes in feed rate or path override.
- Conventional lifting may result in Z axis overload.

Exception: A Type 3 slope is used or less computing time is required for technical reasons.

1.2.1.1 Advanced Lifting properties

The target position and position limiting are specified at the start of the lifting motion.

If the start or target position of the lift axis is outside the programmed maximum lifting height, the maximum height is increased, e.g. for lifting to the maximum of the start and target positions. Therefore, any Max/Min limiting of the position has no effect.

If a height difference [POS] was programmed for the lifting motion and the lift axis dynamics are not sufficient to reach the required height in the time defined by the path feed rate, the path feed rate is reduced automatically. In extreme cases (e.g. if the motion path = 0), the path axes stop and the lift axis is linearly positioned at the target position.

Waiting conditions (M functions with synchronisation, G04, M00, etc.) are possible during lifting/lowering. With Advanced Lifting the lift axis moves on to target height.

The Advanced Lifting function requires slope type 'TRAPEZ', [#SLOPE [TYPE=TRAPEZ], (or TYPE=STEP) (or TYPE = SIN²).

HSC (Type 3 slope) is not supported with Advanced Lifting.

Minimum path length

The channel parameter P-CHAN-00244 defines the minimum path length. If the path motion between lift start and lift end is shorter than the minimum path length, the lifting motion is suppressed. The programmed target position of the Z axis is approached directly.

When P-CHAN-00244 = 0 is in the default setting, the lifting motion is always executed irrespective of the real path distance.

1.2.1.2 Parameterisation

The channel parameter P-CHAN-00345 is switched when it is enabled to Advanced Lifting. These calculations must be carried out in the GEO real-time task of the controller.

To enable this function, the function must also be activated in the controller start-up list in the parameters P-STUP-00060 and P-STUP-00070 by the keyword **FCT_LIFT_UP_TIME**.

Automatic lifting/lowering is currently not included in the basic scope of functions (FCT_DEFAULT) and must therefore always be activated.

Further information on the start-up list parameter P-STUP-00060

The parameter P-STUP-00060 in the start-up list defines the individual functions in the contour planning. As a result, individual functions can be selected for testing, deselected for performance reasons (by not setting them) or activated as a specific function.

For Advanced Lifting the identifier **FCT_LIFT_UP_TIME** must be set.

Advanced Lifting P-STUP-00060

```
configuration.channel[0].path_preparation.function FCT_DEFAULT | FCT_LIFT_UP_TIME
```

Further information on the start-up list parameter P-STUP-00070

In the start-up list the parameter P-STUP-00070 defines the individual functions of the path interpolator. As a result, individual functions can be selected for testing, deselected for performance reasons (by not setting them) or activated as a specific function.

To activate Advanced Lifting the identifier **FCT_LIFT_UP_TIME** must be set.

Advanced Lifting P-STUP-00070

```
configuration.channel[0].interpolator.function FCT_DEFAULT | FCT_LIFT_UP_TIME
```

1.2.1.3 Special cases

Special case 1: POS greater than POS_LIMIT

If the specified lift axis target position is outside the limit, the limit has no effect. This means that the axis is positioned at the target position at the start of the lifting motion and not at the end. This also applies if the start position > limit.

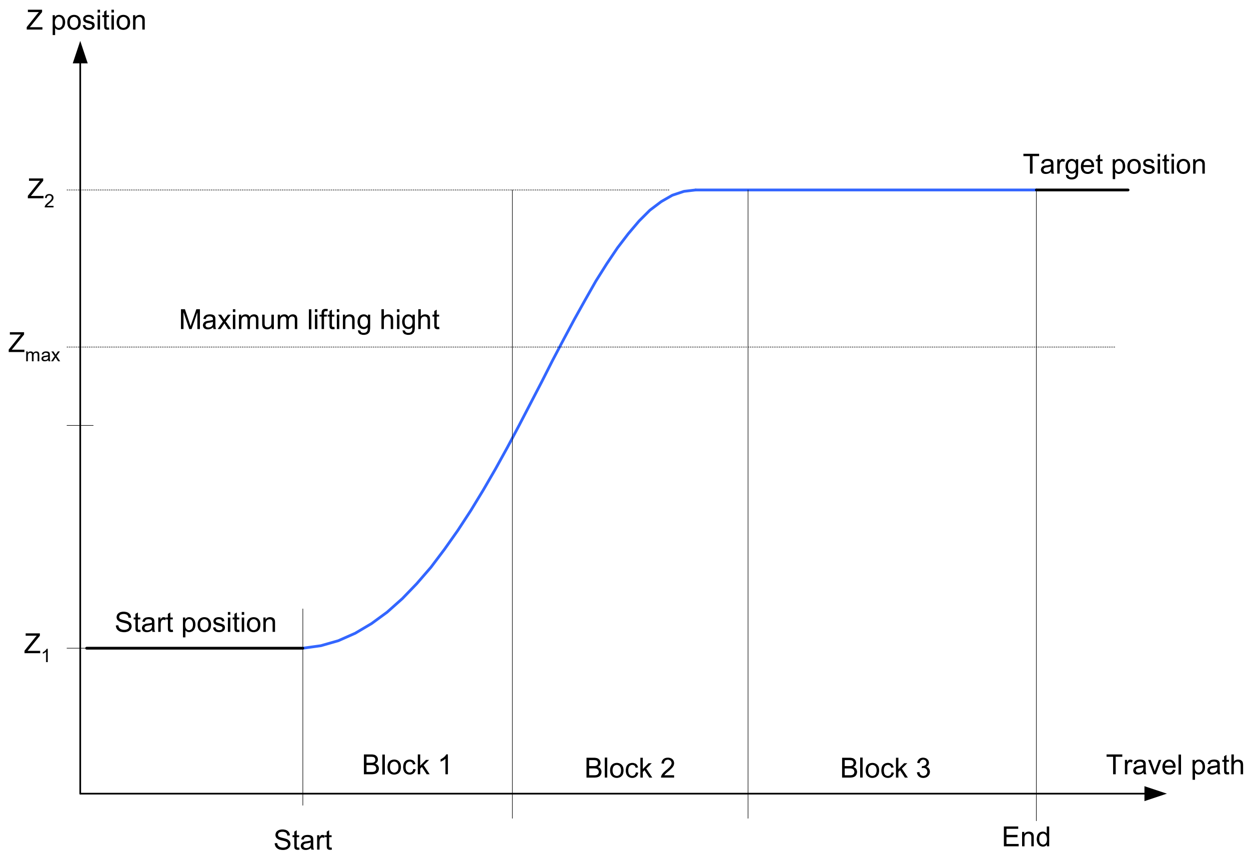


Fig. 2: Target position > limit

POS greater than POS_LIMIT

```
N10 Z10
N20 Z[LIFT_START POS=40 POS_LIMIT=30]
N30 X10
N40 X20
N50 X35
N60 Z[LIFT_END]
```

Special case 2: Syntax error within the lift range

Programming error within START – END

In the event of a syntax error in the NC program, the path motion is always executed up to the last correctly decoded point in the NC program. If the error location lies within a LIFT_START – LIFT_END range, the lift axis is positioned at the maximum lift height at the error location.

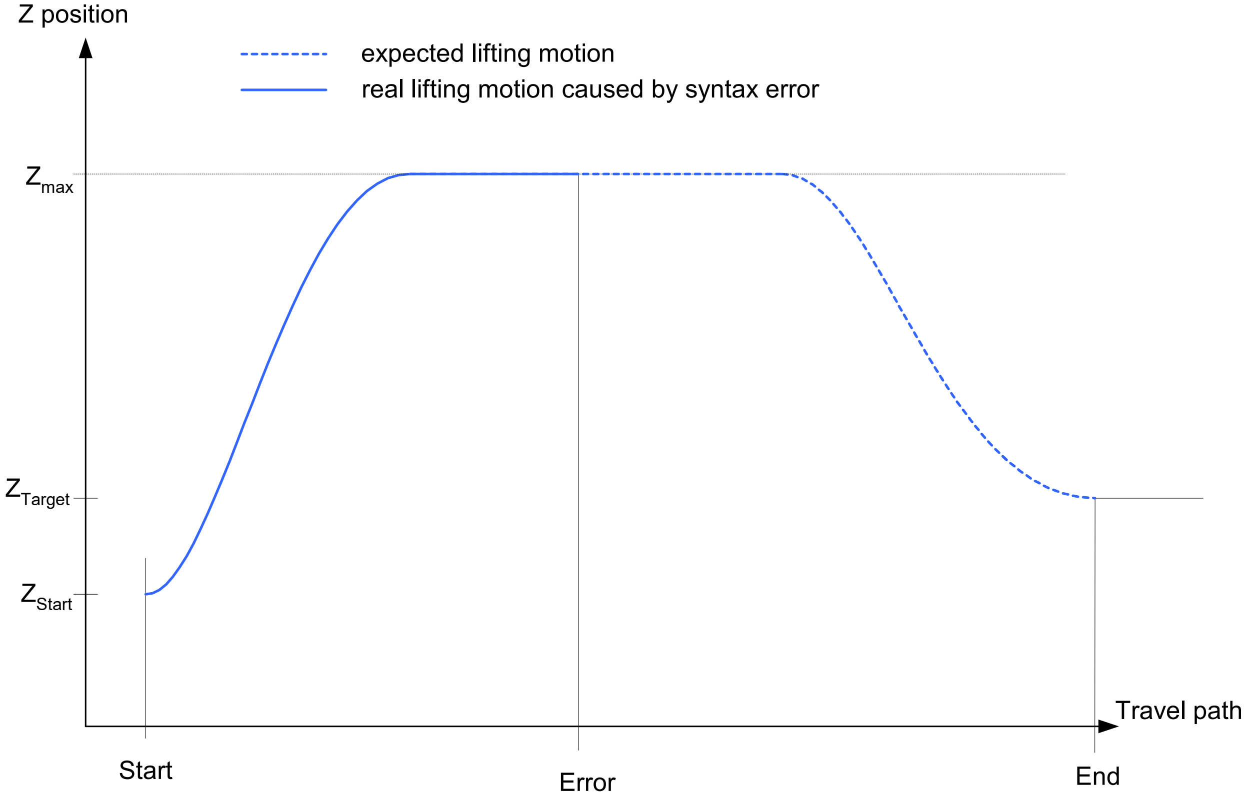


Fig. 3: Premature termination of lifting due to a syntax error

Syntax error within the lift range

```
N10 Z10
N20 Z[LIFT_START POS_LIMIT=30]
N30 X10
N40 X20
N50 X35
...
N100 syntax error
...
N560 X50
N570 X60
N580 X100
N600 Z[LIFT_END]
```

Special case 3: #FLUSH, #FLUSH WAIT

Flushing the channel (#FLUSH, #FLUSH WAIT) may mean that the path must be stopped if the lift axis is unable to reach the lift position in time. Otherwise, #FLUSH WAIT has no effect on the lifting profile.

1.2.2 Lifting

This method is only recommended if Advanced Lifting is not possible for technical reasons.

Normally, the lift axis motion is planned as an independent motion in path preparation and is then coupled to the motion of the main axes.

1.2.2.1 Lifting properties

The lifting motion is coupled to the path motion in this method. i.e. if the velocity of the path is changed, the LIFT motion changes to the same extent. Therefore, the same position of the path axes is identical to the position of the lift axis, regardless of the current velocity. This means that if the path motion is stopped (feed hold) or decelerated (override), the motion of the lift axis stops accordingly.

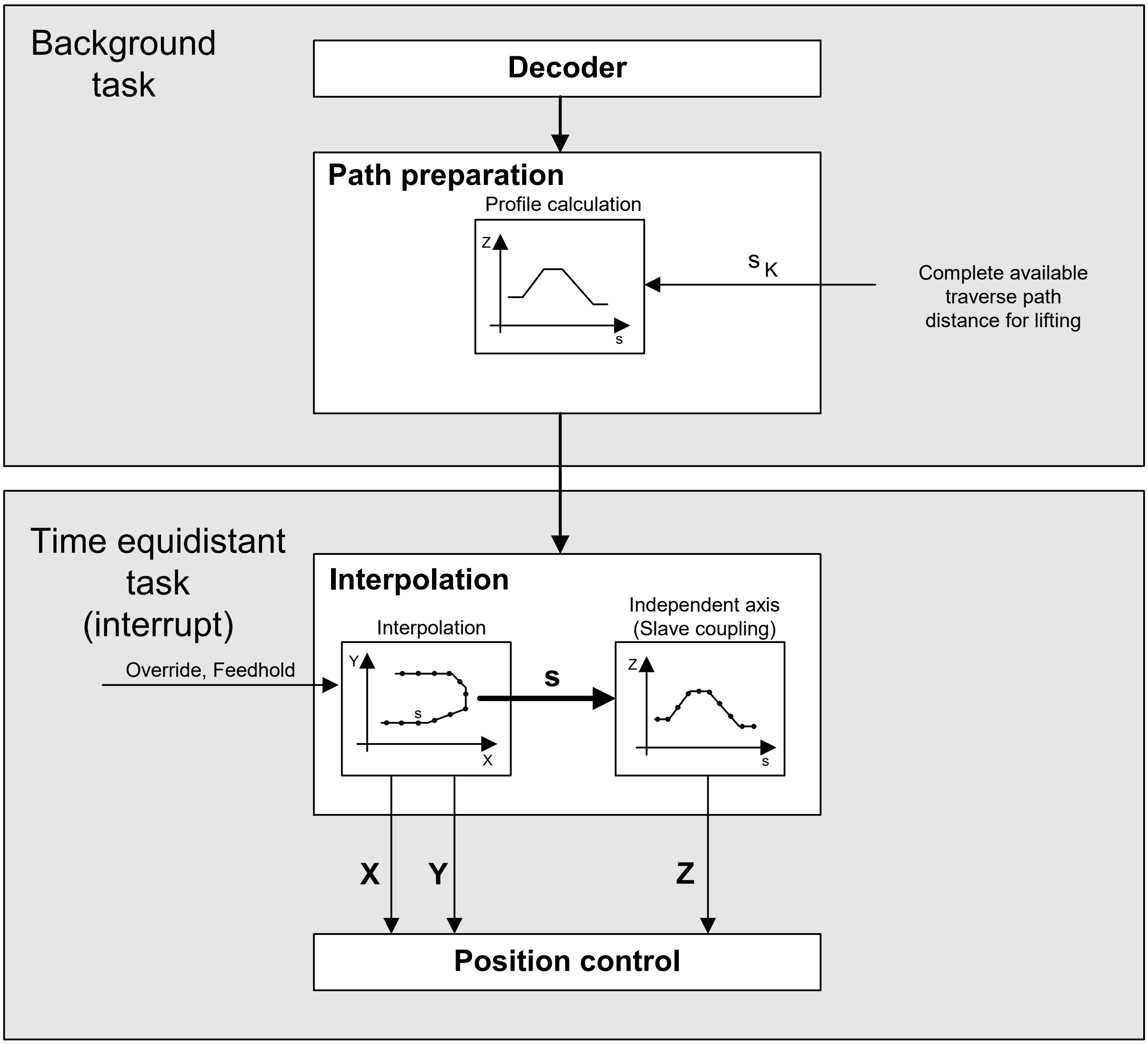


Fig. 4: Structure of planning and executing the LIFT motion

Within the LIFT range, the permitted acceleration on the path is defined so that the maximum permitted acceleration of the lift axis is not exceeded.

Waiting conditions (M functions with synchronisation, G04, M00, etc.) are possible during lifting/lowering. During the lifting motion, waiting conditions therefore lead to an interruption of the path and also of the lifting motion.

In the case of strongly bent curves (spline or polynomial contouring) or kinematic transformations, the original blocks can be further subdivided to improve planning the dynamics. This may lead to an increased number of blocks.

If there is an insufficient number of blocks (Look Ahead range)

- due to the large number of motion blocks of the path axes or
- due to the large number of technology functions (M functions),

premature lowering is avoided. Internally, a LIFT_END is added to the programmed height and a LIFT_START is then added.

At present, a maximum number of 20 CNC internal blocks (Look Ahead range) is considered between the lifting motion (START) and the lowering motion (END). A programmed motion block (G0, G1, G2, G3) normally generates an internal CNC block. Smoothing methods generate additional internal blocks.

Planning the dynamics

The lifting motion is planned so that, at constant path velocity, the lift axis is lifted and lowered again with jerk limiting at its maximum acceleration.

If the path feed rate is changed during the lifting motion (feed hold, override, etc.), this leads to additional acceleration of the lift axis. As a result, lift axis acceleration may briefly exceed its maximum limit. However, the overall acceleration due to the feed rate change on the path and the lifting motion itself always remain within the specified overload range. Therefore, the following applies to the axis:

$$|a_{active}| < a_{max} * \text{overloadfactor}$$

where

$$overloadfactor = \frac{dyn\_monitor\_a\_err}{1000} = \frac{P - AXIS - 00442}{1000}$$

Planning lift axis dynamics requires slope type 'TRAPEZ' ([#SLOPE [...]). Slope type STEP may result in Z axis overload.

Path smoothing and lifting

The LIFT function can be programmed if a smoothing method was previously activated (1st case). The LIFT axis has velocity = 0 at the start and end of the lifting motion. Therefore, smoothing is temporarily suppressed at these points.

Exception: With CONTOUR MODE (G61, G261) the lift axis in the block does not move before lifting or directly after lifting (2nd case).

1. case: Lift axis motion before/after lifting

If the lift axis is moved before lift start (block N10) or directly after lift end (block N20), the contouring of all axes at the start or end of lifting is briefly suppressed.

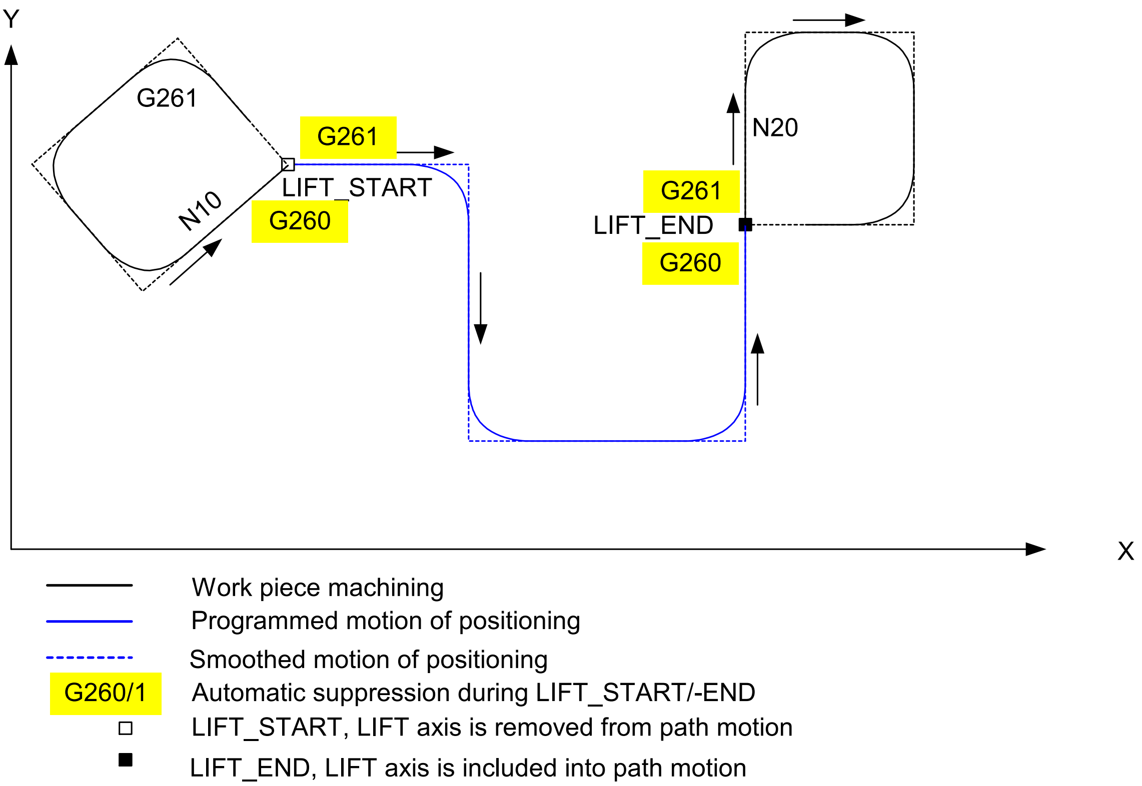


Fig. 5: Contour smoothing with automatic activation/deactivation at LIFT start/end

2. case: No lift axis motion before/after lifting

The other axes can be smoothed if the lift axis is not moved before lift start or directly after lift end (block N20).

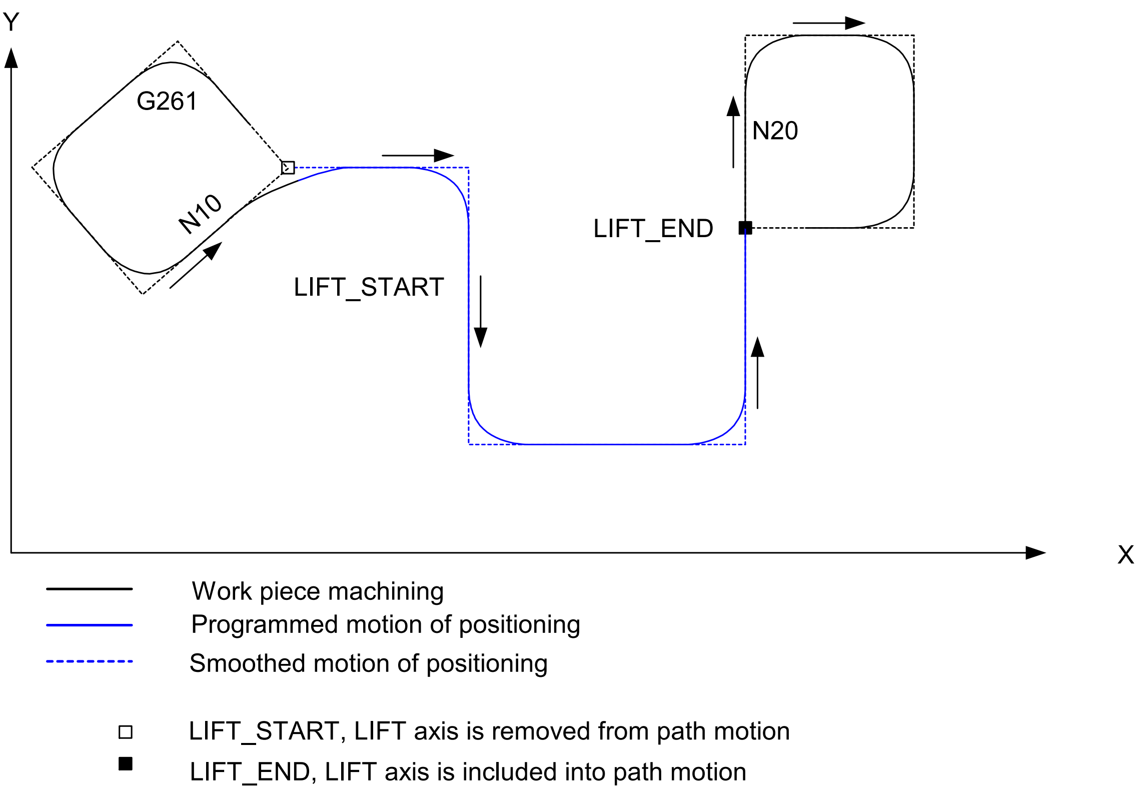


Fig. 6: Contour smoothing without lift axis movement before/after lifting

Smoothing methods may not be additionally selected or deselected between LIFT_START and LIFT_END.

1.2.2.2 Parameterisation

To activate lifting, the parameter P-STUP-00060 must be assigned the value **FCT_LIFT_UP** .

Lifting

```
configuration.channel[0].path_preparation.function FCT_DEFAULT | FCT_LIFT_UP
```

1.2.2.3 Special cases

Special case 1: Look Ahead range overflow

Large number of blocks between START – END

The Look Ahead range comprises a maximum of 20 NC blocks. Lifting is executed prematurely if the range of the motion path (Look Ahead range) considered during lifting is fully occupied due to a large number of blocks. In this case, the axis is first lifted to the specified maximum height and lowered shortly before END (see blue curve in the figure)..

Premature lifting can lead to a situation where less motion path is available for the lifting motion than the user actually assumes. As a result, path velocity may be reduced in order to execute the lifting motion and re-engagement.

Conclusion: A high number of blocks between lift start and end leads to premature lifting of the lift axis and to a possible deceleration of the path motion. For this reason Advanced Lifting is recommended.

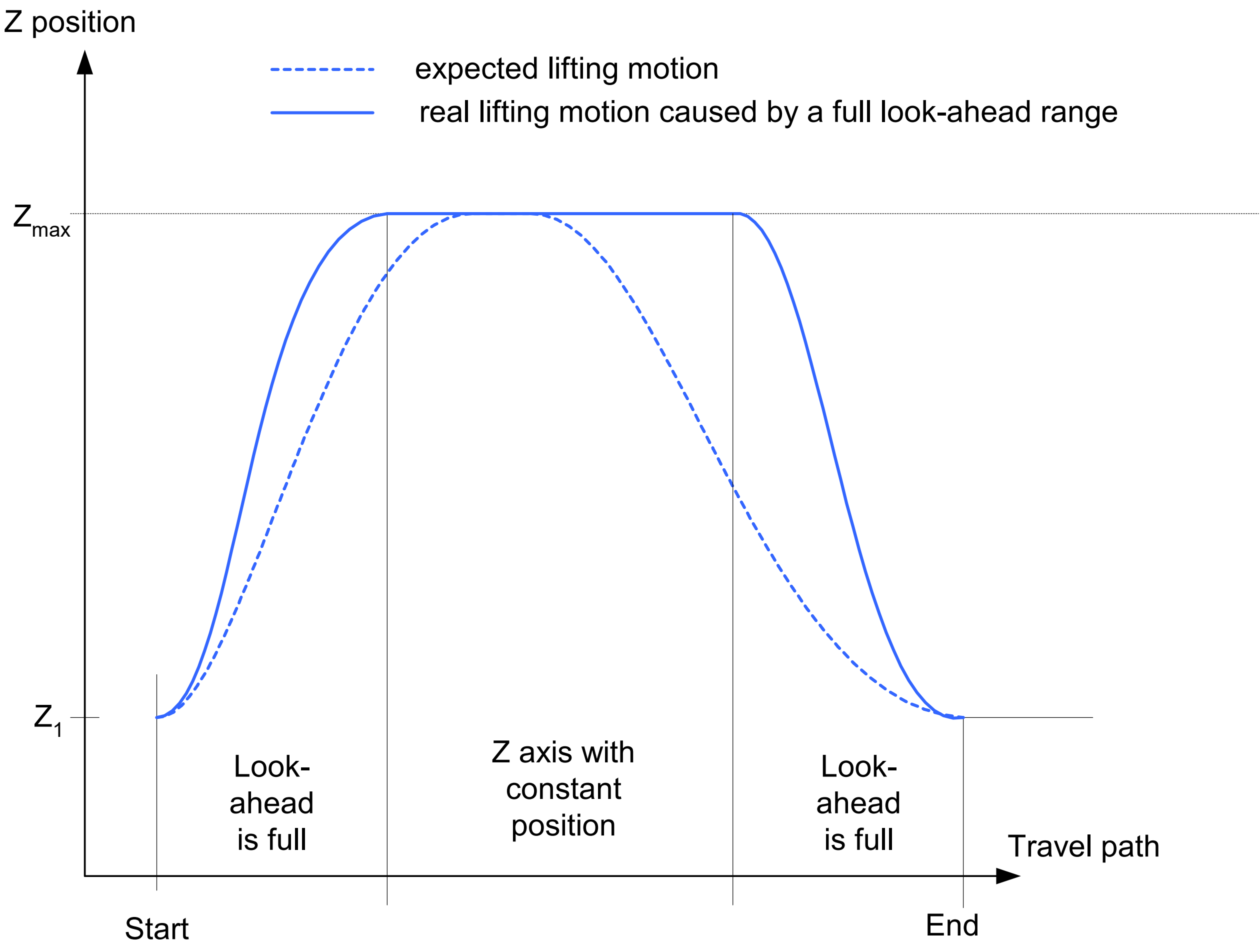


Fig. 7: Diagram of Look Ahead range overflow

Look Ahead range overflow

```
N10 Z10
```

```
N20 Z[LIFT_START POS_LIMIT=30]
N30 X10
N40 X20
N50 X35
...
N550 X31
N560 X32
N570 X33
N580 X34
N600 Z[LIFT_END]
```

Special case 2: Lifting and explicit flushing of the channel

LIFT and flushing the channel (#FLUSH)

During lifting, the motion blocks are first stored to enable calculation of the optimum lifting motion from LIFT start to end. With various NC commands, however, immediate execution is necessary and this is achieved implicitly by "flushing the channel".

If channel output of the NC blocks is forced during lifting (e.g. NC command #FLUSH), the lifting motion is executed as if LIFT_END and a repeated LIFT_START were programmed at this point.

Lifting and explicit flushing of the channel

```
N20 X40 Z2
N30 Z[LIFT_START POS=12 POS_LIMIT=40]
N40 X50
N50 X40
N60 #FLUSH
N70 X30
N80 X20
N90 Z[LIFT_END]
```

Operating principle of #FLUSH with comparable programming

```
N20 X40 Z2
N30 Z[LIFT_START POS=40 POS_LIMIT=40]
N40 X50
N50 X40
N60 Z[LIFT_END]
N60 Z[LIFT_START POS=12 POS_LIMIT=40]
N70 X30
N80 X20
N90 Z[LIFT_END]
```

1.2.3 Permitted functions

Permitted CNC functions that may be active when lifting is selected:

- #ROTATION ON and #CS ON: but only if the lift axis is not affected by the rotation. When the Z axis is lifted, only one coordinate system rotation around the Z axis is permitted. Otherwise, the decoder outputs the error P-ERR-21071. If #ROTATION ON/OFF is programmed within the lift range, the path preparation application outputs the error P-ERR-120606.
- #TRAFO ON: If #TRAFO ON/OFF is programmed within the lift range, BAVO outputs the error P-ERR-120606.

1.2.4 Limitations and error response

The following limitations apply both to Lifting and Advanced Lifting.

If a programming error occurs during the lifting motion, the lifting motion is executed up to the error location and the axis stops at the specified maximum lifting height (POS_LIMIT).

If the end of the program is reached during the lifting motion without a prior, explicit LIFT_END, the lifting motion is executed as if LIFT_END was programmed at the end of the program.

Limitations during the lifting motion for both methods:

- The axis affected by lifting may not be programmed.
- Flushing the channel (#FLUSH, #FLUSH WAIT) interrupts the current lifting motion (this corresponds to implicit programming of LIFT_END followed by LIFT_START). The programmed target position of the lift axis is reached for a short time in the block in which #FLUSH was programmed.
- Channel-internal axis swapping is basically possible but the lift axis must not be affected by axis swapping. Additional path smoothing of the LIFT axis (contouring, G61/G261, G151, #SPLINE ON, #HSC ON) is not possible in the lifting range.
- During the lifting motion, tool radius compensation of the LIFT axis is not permitted, i.e. the LIFT axis may not be involved in tool radius compensation.

Limitations during the lifting motion in addition to conventional lifting:

- Path smoothing functions are temporarily suppressed at the start and end of the lifting motion. With Advanced Lifting path smoothing methods are suppressed if the lift axis is programmed directly before LIFT_START or directly after LIFT_END.
- Axis swapping leads to the end of the lifting motion.

1.2.5 Differences between Advanced Lifting and Lifting

Basically Advanced Lifting is recommended. It is independent of the path motion and a greater lifting height is reached. In exceptional cases it may be necessary to apply conventional lifting.

The table below provides a short comparison:

	1. Advanced Lifting	**2. Lifting**
Maximum lift height (is reached faster)	high	medium
Collision protection	high	lower
Computing time (real-time task)	high	very low
Path override changes	Limited increase possible	Z axis overload (=lift axis) possible
Feed rate change	No limitation	Z axis overload (=lift axis) possible
HSC slope (Type 3)	not possible	possible
Maximum lift profile length	unlimited	Number of NC blocks is limited

With Advanced Lifting profile planning must be executed in the real-time task of the controller. This method therefore requires much more real-time computing time than the lifting method calculated in the path preparation task.

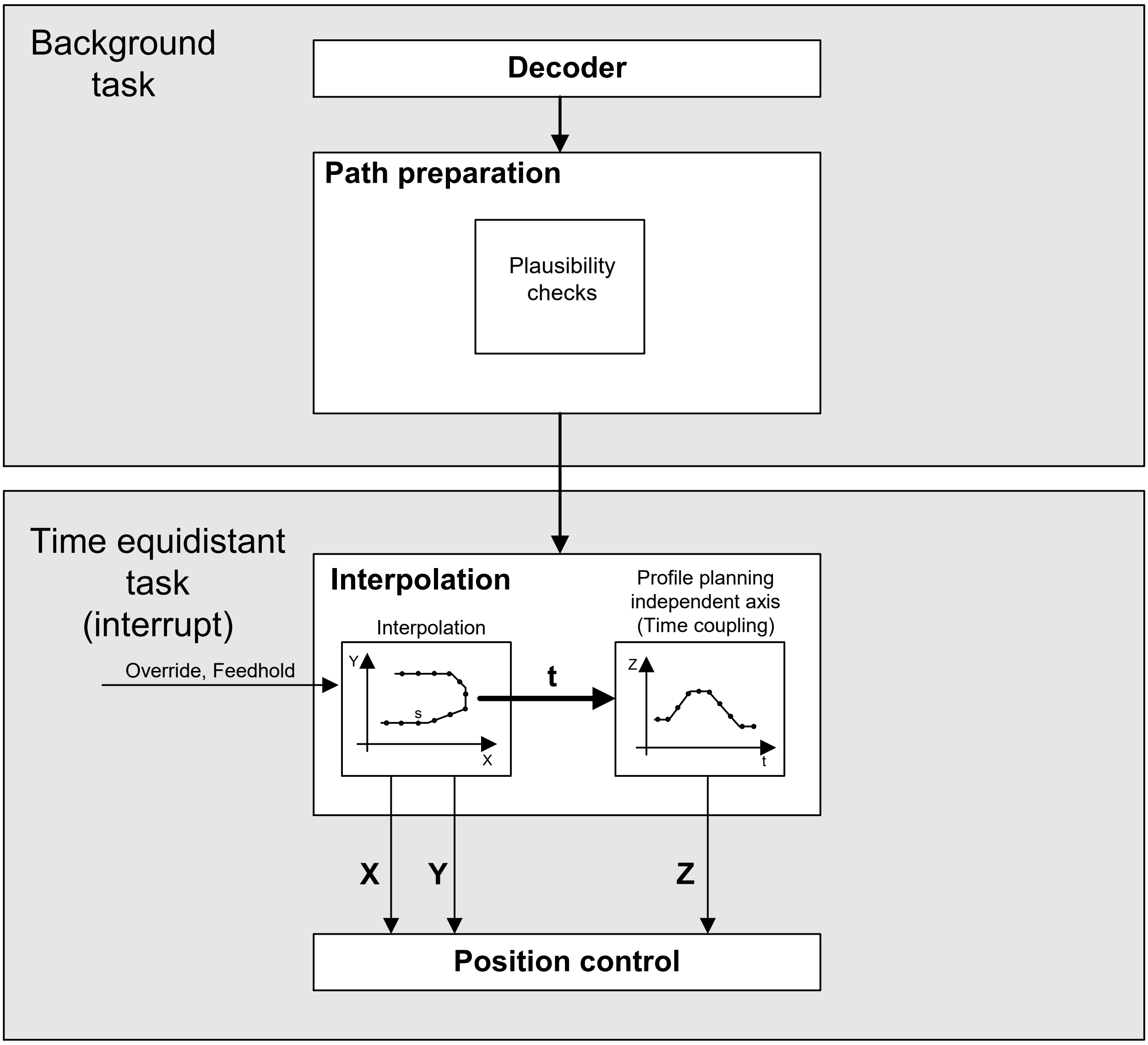


Fig. 8: Structure of the planning and processing of the lifting motion with time-based coupling

Compared with Lifting, Advanced Lifting achieves greater lifting heights:

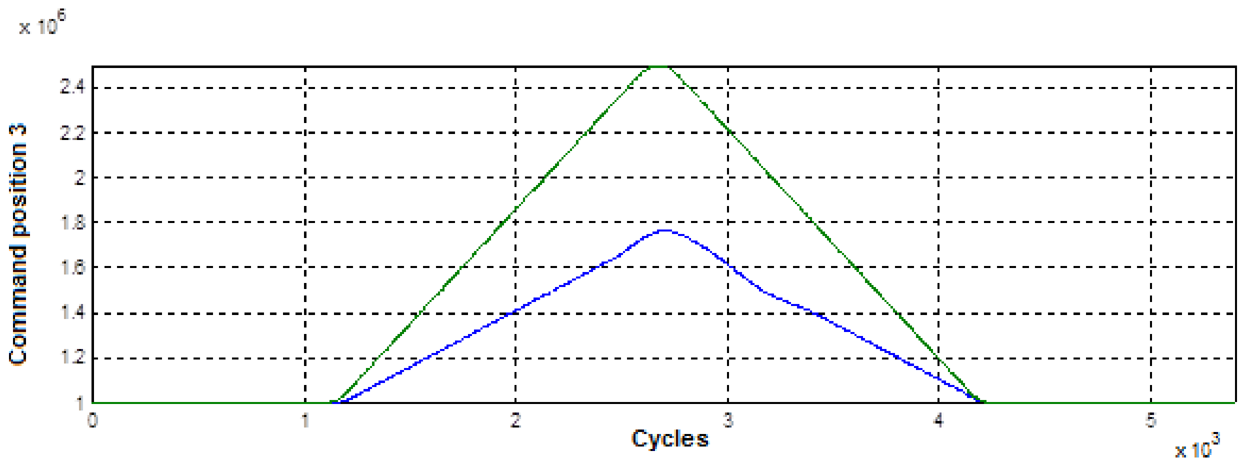


Fig. 9: Comparison of lifting heights reachable with Advanced Lifting (green curve) vs Lifting (blue curve)

In the lowering motion the path velocity override is limited to the value which was active at the start of the lowering motion.

In the upward motion of the lift axis a higher path override may no longer be accepted, otherwise the lift axis would not be able to reach the target position at the end of the lowering motion any more.

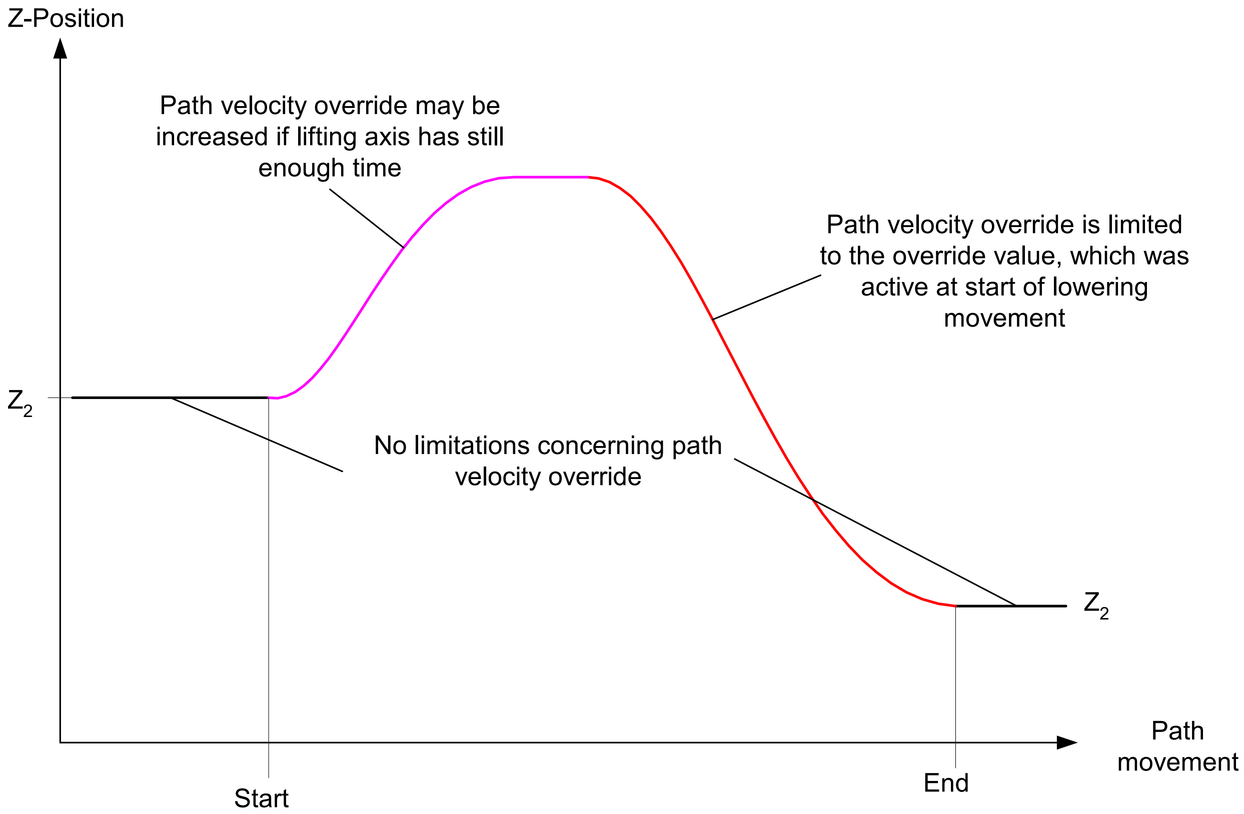


Fig. 10: Path velocity override with Advanced Lifting

1.3 Programming

Cross-block lifting/lowering

Programming is based on the syntax for independent axes. The corresponding parameters can be programmed at the start of lifting/lowering. These are non-modal parameters, i.e. if required they are reset for every start.

<axis_name> **[LIFT_START** [**DOWN**] [**G90** | **G91**] [**POS**<*expr*>] **POS_LIMIT**<*expr*> **]**

<axis_name>	Lift axis name
LIFT_START	Identifier for the start of the (cross-block) independent lifting motion of the axis.
DOWN	The axis motion direction can be inverted via DOWN, i.e. the motion is in the direction of the negative software limit switch. If nothing is specified, the default direction is in the direction of the positive software limit switch.
G90 / G91	Absolute/relative dimension; the default dimension is G90. G91 is non-modal and is only active for the lifting/lowering motion.
POS<*expr*>	Target position of the lift axis after the lifting motion. The current command position of the axis (see V.A.ABS.<*axis name*>) is the default.
POS_LIMIT<*expr*>	Maximum lifting height or lowering depth

<axis_name> **[LIFT_END]**

<axis_name>	Lift axis name
LIFT_END	Identifier for the end of the (cross-block) independent lifting motion of the axis.

Cross-block lifting/lowering

```
N10 X10 Y20 Z30    ;Cut with laser
N20 M5             ;Laser off
N30 Z[LIFT_START POS=12 POS_LIMIT=100]    ;Lift Z axis
N30 G01 X.. Y..
N40 G02 X.. Y..
N50 G03 X.. Y..
N60 G01 X.. Y..
N70 Z[LIFT_END]    ;Absolutely lower Z axis to target 12 mm
N80 M4             ;Laser on
N90 X20 Y20 ...

N10 X10 Y20 Z30
N30 Z[LIFT_START POS=12 POS_LIMIT=100] ;Lift Z axis
N40 G01 X.. Y..
N50 G01 X.. Y..
N60 Z[LIFT_END]    ;Absolutely lower Z axis to target 12 mm
N70 X100

alternative programming
N110 X10 Y20 Z30
N140 G01 X.. Y.. Z[LIFT_START POS=12 POS_LIMIT=100]
N150 G01 X.. Y.. Z[LIFT_END]
N170 X100
```

Lifting/lowering in an NC block

Programming is based on the syntax for independent axes. The corresponding parameters can be programmed at the start of lifting/lowering. These are non-modal parameters, i.e. if required they are reset for every start.

<axis_name> **[LIFT** [**DOWN**] [**G90** | **G91**] [**POS**<*expr*>] **POS_LIMIT**<*expr*> **]**

<axis_name>	Lift axis name
LIFT	Identifier for the start and end of the independent lifting motion of the axis in the current NC block
DOWN	The axis motion direction can be inverted via DOWN, i.e. the motion is in the direction of the negative software limit switch. If nothing is specified, the default direction is in the direction of the positive software limit switch (option not available as at 10/2011).
G90 / G91	Absolute/relative dimension. The default dimension is G90. G91 is non-modal and is only active for the lifting/lowering motion.
POS<*expr*>	Target position of the lift axis after the lifting motion. The current command position of the axis (see V.A.ABS.<*axis name*>) is the default.
POS_LIMIT<expr>	Maximum lifting height or lowering depth

Lifting/lowering in an NC block

```
; single-row programming
N200 Z40
N240 X10 Y.. Z[LIFT POS=30 POS_LIMIT=300]
N250 X20 Y.. Z[LIFT POS=20 POS_LIMIT=300]
N260 X30 Y.. Z[LIFT POS=25 POS_LIMIT=300]
N270 X.. Y.. Z[LIFT POS=30 POS_LIMIT=300]
N280 X.. Y.. Z[LIFT POS=30 POS_LIMIT=300]
```

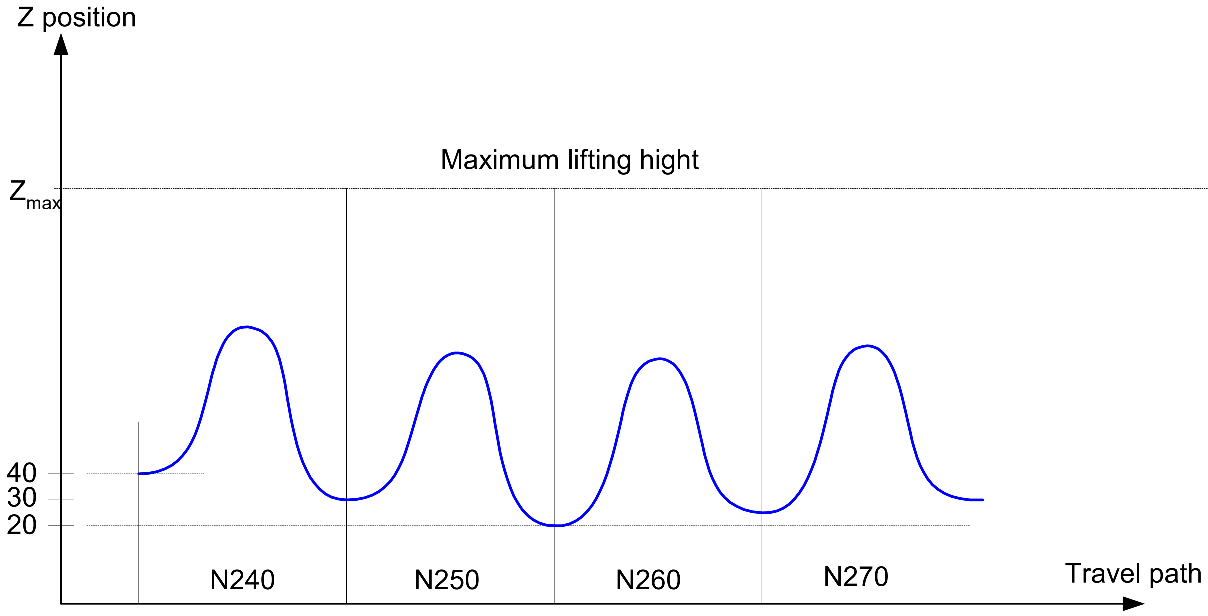


Fig. 11: Single-row lifting

Status query: Lifting/lowering active

In the NC program, the V.G. variable…

V.G.LIFT_ACTIVE

… of the Boolean type can determine whether lifting/lowering is active.

1.4 Parameter

1.4.1 Overview

ID	Parameter	Description
P-STUP-00060	function	Define functionalities in path preparation
P-STUP-00070	function	Define functionalities for decoding
P-CHAN-00244	lift_min_dist	Minimum path length for lifting motion
P-CHAN-00345	enable_time_based_lift	Switch to time-based approach for automatic lifting/lowering of an axis.
P-AXIS-00441	dyn_monitoring_a_warn	Output a warning in the event of a percentage excess in maximum axis acceleration Not necessary for Lifting (only for Advanced Lifting).
P-AXIS-00442	dyn_monitoring_a_err	Output an error message in the event of a percentage excess in maximum axis acceleration This maximum value is used to plan lift acceleration. This means that the following applies to the axis: $a_{act,Lift} \Leftarrow a_{max,Lift} = a_{max} * \frac{dyn\_monitor\_a\_err}{1000}$ Not necessary for Lifting (only for Advanced Lifting).

1.4.2 Description

1.4.2.1 Activate lift function

P-STUP-00060	**Defining functionalities for path preparation.**	
Description	This parameter defines the individual functionalities for path preparation. The individual functions can be enabled or disabled for testing or for performance reasons.	
Parameter	configuration.channel[i].path_preparation.function	
Data type	STRING	
Data range	FCT_DEFAULT	The functions FCT_FFM | FCT_PRESEGMENTATION | FCT_SPLINE | FCT_POLY | FCT_CAX | FCT_CAX_TRACK | FCT_SEGMENTATION are available.
	FCT_FFM	Free-form surface mode, #HSC [OPMODE 1 CONTERR 0.01], #HSC [OPMODE 2]
	FCT_PRESEGMENTATION	Linear pre-segmentation in HSC mode
	FCT_SPLINE	#HSC[], AKIMA, B-Spline, G150/G151
	FCT_POLY	#CONTOUR MODE[], G61, G261/G260
	FCT_CAX	C axis processing, i.e. the spindle is embedded in the NC channel.
	FCT_CAX_TRACK	#CAX TRACK, tracking an axis according to the contour angle
	FCT_SEGMENTATION	For dynamic segmentation of the path contour, e.g. if the curvature of a polynomial segment varies significantly.
	The following functions must also be enabled:	
	FCT_LIFT_UP	Automatic lifting/lowering of an axis (path-based coupling). Example: FCT_DEFAULT | FCT_LIFT_UP
	FCT_EMF	Edge machining (sharp angle contours). Example: FCT_DEFAULT | FCT_EMF
	FCT_EMF_POLY_OFF	Edge machining inactive with polynomials. Contrary to the setting with FCT_EMF, edge signal generation is masked when path polynomial generation is active in the channel. Polynomials are generated for smoothing G261 or when BSpline is active. The resulting geometry is then tangential. Example: FCT_DEFAULT | FCT_EMF_POLY_OFF

	FCT_SYNC	Optimised planning using #HSC[BSPLINE]. Example: FCT_DEFAULT | FCT_SYNC
	FCT_PRECON	Optimised planning using #HSC[BSPLINE]. Example: FCT_DEFAULT | FCT_PRECON
	FCT_LIFT_UP_TIME	Automatic lifting/lowering of an axis (time-based coupling). Example: FCT_DEFAULT | FCT_LIFT_UP_TIME
	FCT_PTP	Dynamically optimised smoothing of the complete contour. Example: FCT_DEFAULT | FCT_PTP
	FCT_M_PRE_OUTPUT	Pre-output of M/H functions (microwebs). Example: FCT_DEFAULT | FCT_M_PRE_OUTPUT
	FCT_SURFACE	HSC machining with Surface Optimiser Example: FCT_DEFAULT | FCT_SURFACE
	FCT_SEG_CHECK	Block segmentation in combination with path-controlled offset of M functions (dwell time), see P-STUP-00070 [▶ 29] Example: FCT_DEFAULT | FCT_SEG_CHECK
Dimension	----	
Default value	FCT_DEFAULT	
Remarks		

P-STUP-00070	Definition of interpolator functionalities	
Description	This parameter defines individual functionalities and the size of the look-ahead buffer in the interpolator, i.e. it defines the number of blocks to calculate deceleration distance and dynamic planning.	
Parameter	configuration.channel[i].interpolator.function	
Data type	STRING	
Data range	FCT_IPO_DEFAULT	FCT_LOOK_AHEAD_STANDARD
	FCT_LOOK_AHEAD_LOW	30 blocks
	FCT_LOOK_AHEAD_STANDARD	120 blocks
	FCT_LOOK_AHEAD_HIGH	190 blocks
	FCT_LOOK_AHEAD_CUSTOM	Any number of look-ahead blocks in the interval [0; 200]. Specification by parameter P-STUP-00071.
	FCT_SYNC	Synchronisation of an axis on a path group. Example: FCT_IPO_DEFAULT | FCT_SYNC
	FCT_LOOK_AHEAD_OPT	The path velocity curve can be further improved for HSC machining by additional calculations. This generally reduces machining time. The additional calculations place greater demands on the controller hardware.
	FCT_LIFT_UP_TIME	Automatic lifting/lowering of an axis (time-based coupling). Example: FCT_IPO_DEFAULT | FCT_LIFT_UP_TIME
	FCT_SHIFT_NCBL	Path-controlled offset of M functions (dwell time). Example: FCT_IPO_DEFAULT | FCT_SHIFT_NCBL
	FCT_CALC_STATE_AT_T	Calculation of path velocity at a time in the future. Function only available in combination with HSC slop and only as of V3.1.3057.0 Example: FCT_IPO_DEFAULT | FCT_CALC_STATE_AT_T
	FCT_CALC_TIME	Calculation of interpolation time to next feed block (G01,G02,G03).< Example: FCT_IPO_DEFAULT | FCT_CALC_TIME

Dimension	----	
Default value	FCT_IPO_DEFAULT	
Remarks	The look-ahead buffer size specified above applies as of CNC Builds V2.11.2800 and higher. The following values apply as of CNC Build V2.11.20xx:	
	FCT_LOOK_AHEAD_LOW	30 blocks
	FCT_LOOK_AHEAD_STANDARD	70 blocks
	FCT_LOOK_AHEAD_HIGH	120 blocks

1.4.2.2 Parameters for the Lift function

P-CHAN-00244	**Minimum path length for lift movements**
Description	This parameter defines a minimum path distance for lift movement. If the main axis motion is shorter than the parameter value, no lift movement is executed.
Parameter	lift_min_dist
Data type	UNS32
Data range	0: Not active (default). 1: Lift movements are suppressed if the main path motion is below the limit value.
Dimension	0.1µm
Default value	0
Remarks	

P-CHAN-00345	**Switch-over to time-based calculation when an axis is lifted.**
Description	When an axis is lifted (see [FCT-A11 [▶ 9]]), it can be lifted or lowered automatically independent of the path motion. The CNC limits the maximum lift height so that the axis can reach the target point of the lowering movement and not to influence the path motion. Normally this takes place during path preparation with a path-based coupling of the axis to the main motion path. Instead the 'enable_time_base_lift' parameter can enable a time-based consideration in the real-time GEO task of the controller. As a result, greater lifting height can be reached afterwards. However, time-based coupling requires considerably more computing power in the real-time task of the controller. The HSC slope profile and the time-based approach cannot be used at the same time.
Parameter	enable_time_based_lift
Data type	BOOLEAN
Data range	0: Path-based approach (default). 1: Time-based approach.
Dimension	----
Default value	0
Remarks	The time-based approach must also be included in the configuration data of path preparation and interpolation when the controller is started. Here, set the key word FCT_LIFT_UP_TIME in the parameters P-STUP-00060 and P-STUP-00070 . Example of the 1st CNC channel: configuration.channel[0].path_preparation.function. FCT_DEFAULT | FCT_LIFT_UP_TIME configuration.channel[0].interpolator.function. FCT_DEFAULT | FCT_LIFT_UP_TIME

2 MicroJoints

2.1 Pre-output of M functions (MicroJoint)

Use of this function requires a license for the “CuttingPlus” extension pack. It is not included in the scope of the standard license.

Requirements to use the function:

The function to pre-output in the run-up list must be enabled in P-STUP-00060.

```
configuration.channel[0].path_preparation.function
       FCT_DEFAULT | FCT_M_PRE_OUTPUT
```

If the run-up parameter P-STUP-00060 is not enabled, only M functions are offset in time with synchronisation MEP_SVS.

Activating and enabling the function

Pre-output of an M/H function is executed if:

a pre-output path is specified in P-CHAN-00070 or P-CHAN-00107

Path-related pre-output of M functions

A pre-output can automatically output an M function in advance at a specific point along the path.

For example, in the case of M functions with a time stamp MOS_TS, this can be used for advanced deactivation of a laser to briefly interrupt the cutting process. This leaves so-called MicroJoints.

Output of the advanced M function is not tied to the originally programmed block limits. The motion block is opened automatically by the CNC at the corresponding positions and the M function is inserted.

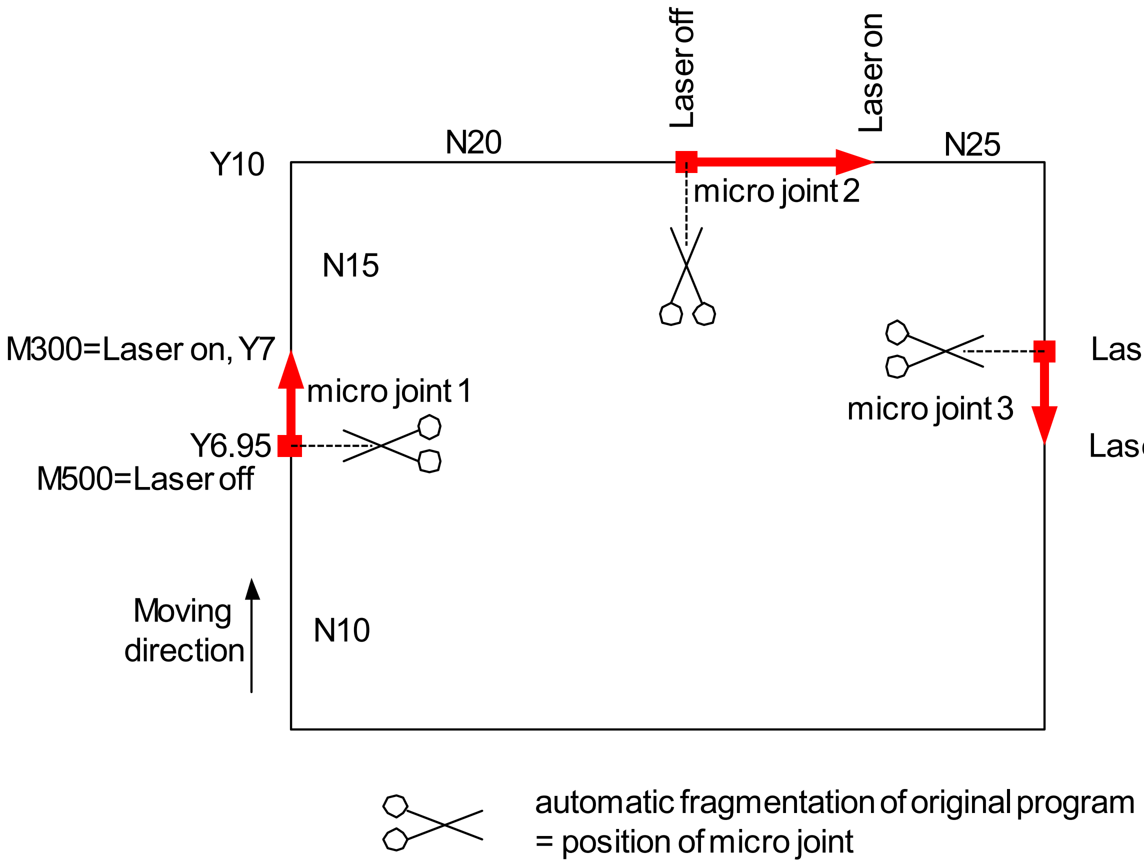


Fig. 12: Programmed MicroJoints in the part

Pre-output of M functions

```
; M300 - Laser on, M500 - Laser off
N05 V.G.M_FCT[500].PRE_OUTP_PATH = 0.05
N10 G00 G90 X0 Y0
N15 L Laser_on.sub
N20 G01 F5000
N25      Y7
N30 M500 M300          ;MicroJoint 1
N35      Y10
N40 X14
N45 M500 M300          ;MicroJoint 2
N50 X20
N55 L Laser_off.sub
N99 M30
```

Equivalent example with explicit programming

```
; M300 - Laser on, M500 - Laser off
N05 G00 G90 X0 Y0
N10 L Laser_on.sub
N15 G01 F5000
N20      Y6.95
N25 M500                 ;MicroJoint 1
N30      Y7
N35 M300
N40      Y10
N45 X13.95
N50 M500                 ;MicroJoint 2
N55 X14
N60 M300
N65 X20
…
N70 L Laser_off.sub
N99 M30
```

M/H functions for pre-output

In addition to the actual use of pre-output with high-resolution MOS_TS, output is basically also possible for other M or H functions.

The following synchronisation methods of the M and H functions are evaluated at pre-output:

MOS, MVS_SVS, MVS_SNS, MNS_SNS, MOS_TS

Reference position of the pre-output

If the M/H function is programmed together with a motion, then:

- the path of the pre-output is determined for its output time relative to the block.
- MOS, MOS_TS, MVS_SVS and MVS_SNS are determined relative to the block start position
- MNS_SNS is positioned relative to the block end position.

> Due to pre-output, however, it is basically no longer required to separate the output and synchronisation points.
>
> In other words, if the M/H function is synchronised (MVS_SVS, MVS_SNS, MNS_SNS), output and synchronisation take place at the same point. This corresponds to programming the M/H function in a separate NC line.

Parametrisation using lists

M functions with pre-output are parameterised in the channel list by P-CHAN-00041 (m_synch[..]) and P-CHAN-00070 (m_pre_outp[..]):

```
m_synch[100]      MOS_TS
m_pre_outp[100]   500                    ;in 0.1 µm
```

H functions with pre-output are parameterised in the channel list by P-CHAN-00027 (h_synch[..]) and P-CHAN-00107 (h_pre_outp[..]):

```
h_synch[50]       MVS_SVS
h_pre_outp[50]    400                    ;in 0.1 µm
```

Parametrisation by programming

As an alternative to the parametrisation of M/H functions, the synchronisation method and the path also can be specified directly in the NC program.

```
V.G.M_FCT[11].SYNCH = 1
V.G.M_FCT[11].PRE_OUTP_PATH = 14         ;in [mm]

V.G.H_FCT[200].SYNCH = 4
V.G.H_FCT[200].PRE_OUTP_PATH = 40        ;in [mm]
```

Synchronisation methods as macro

```
%MicroJoint
; Synchronisation methods as macro
"MOS" = "1"
"MVS_SVS" = "2"
"MVS_SNS" = "4"
"MNS_SNS" = "8"
"MOS_TS" = "262144" ;0x40000

V.G.M_FCT[11].SYNCH = "MOS_TS"
V.G.M_FCT[11].PRE_OUTP_PATH = 11   ;in [mm]
V.G.M_FCT[13].SYNCH = "MNS_SNS"
V.G.M_FCT[13].PRE_OUTP_PATH = 23   ;in [mm]

V.G.H_FCT[12].PRE_OUTP_PATH = 12   ;in [mm]
V.G.H_FCT[12].SYNCH = "MVS_SVS"

N01 X0 G01 F500
N10 X100
N20 X200    M11 H12 M13
N30 X300
M30
```

2.1.1 Limitations, special cases

Limitation of the look-ahead range

The described look-ahead range is limited due to resource limitation and the requirement for the NC program to run up as soon as possible after start.

In other words, the maximum number of described blocks is limited by default to 10 blocks. To increase this number, see P-STUP-00061. Depending on the block length, this results in a maximum joint width.

Limitation of the look-ahead range

```
%microjoint4
N01 G00 G90 X0 Y0
N02 G01 F10000

N03 V.G.M_FCT[100].PRE_OUTP_PATH = 28.6 ;in mm
N20 G91 Y1
N21 Y1   ; -> planned MicroJoint at Y1.4 mm
N22 Y1
N23 Y1
N24 Y1
N25 Y1
…
N37 Y1
N38 Y1
N39 Y1   ; -> real MicroJoint caused by block number limitation
N40 Y1
N41 Y1
N42 Y1
N43 Y1
N44 Y1
N45 Y1
N46 Y1
N47 Y1
N48 Y1
N49 Y1
N50 M100 M26
N99 M30
```

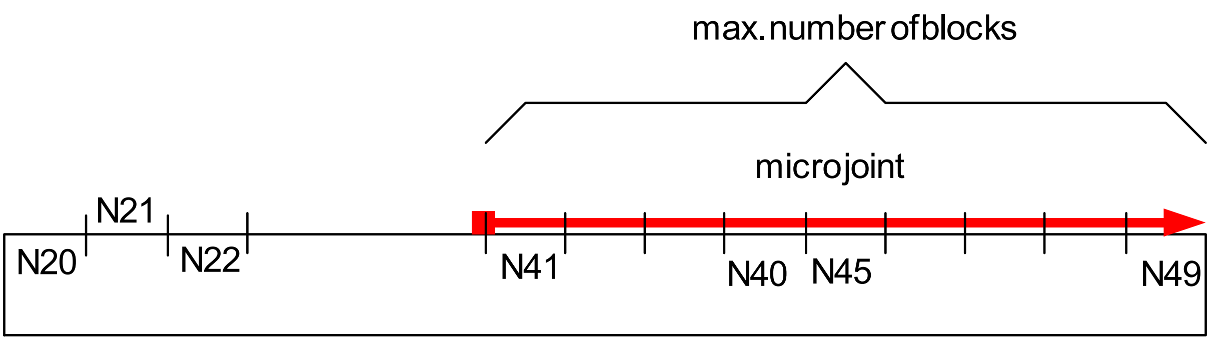


Fig. 13: Limitation of the pre-output path of the M function to 10 blocks

Explicit cancellation of the look-ahead range, #FLUSH, synchronous V.E variable

The look-ahead range of M functions is reset by flushing the channel (#FLUSH or #FLUSH WAIT). In other words, the pre-output of M functions cannot be reversed beyond the #FLUSH point.

An implicit #FLUSH WAIT, i.e. the channel is flushed, can also be executed when a synchronous V.E variable (see [EXTV]) is read. A pre-output via a synchronous V.E variable is therefore not possible either.

Explicit cancellation of the look-ahead range, #FLUSH, synchronous V.E variable

```
%microjoint6
N01 G00 G90 X0 Y0
N02 G01 F10000

N10 V.G.M_FCT[100].PRE_OUTP_PATH = 28.6; in mm
N20 G91 Y1
N21 Y1 ; -> planned MicroJoint at Y1.4 mm
N22 Y1
N23 Y1
…
N38 Y1
N39 Y1
N40 Y1
N41 Y1
N42 Y1
N43 Y1
N44 Y1
N400 #FLUSH ; -> MicroJoint inserted at Y24
N45 Y1
N46 Y1
N47 Y1
N48 Y1
N49 Y1
N50 M100 M26
N99 M30
```

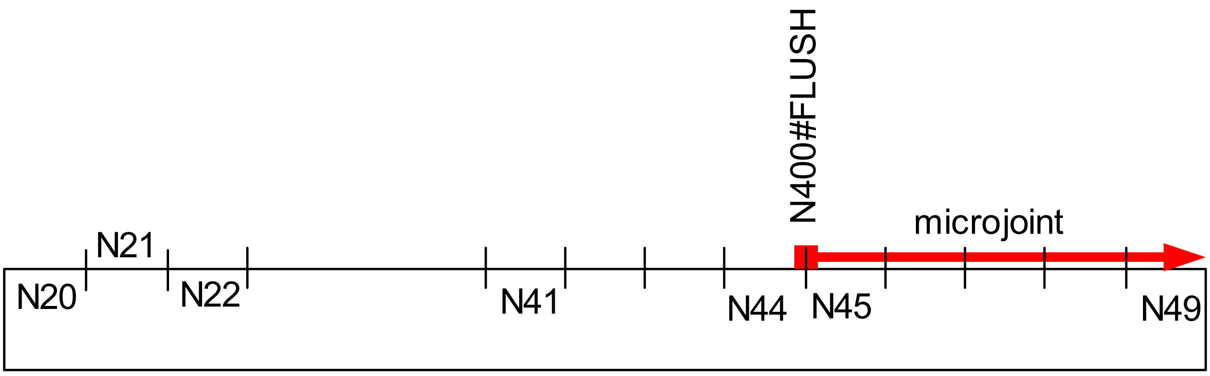


Fig. 14: Explicit limitation of the lead distance of the M function

"Overlapping" path-related pre-output

After a path-related pre-output of the M function is detected, all previously stored motion blocks are output. This corresponds to explicit flushing of the channel (see #FLUSH), thus avoiding delayed processing of the motion blocks.

As a result, it is not possible to overlap the path range of several M functions.

"Overlapping" path-related pre-output

```
%microjoint5
(* M100 - Laser off, M26 - Laser on *)
N01 G00 G90 X0 Y0
N02 G01 F10000
N03 V.G.M_FCT[101].PRE_OUTP_PATH = 5   ;in mm
N04 V.G.M_FCT[102].PRE_OUTP_PATH = 23
N05 V.G.M_FCT[103].PRE_OUTP_PATH = 31
N20 X10
N30 M101 M26
N40 X30
N50 M102 M26
N60 X40
N70 M103 M26
N80 M30
```

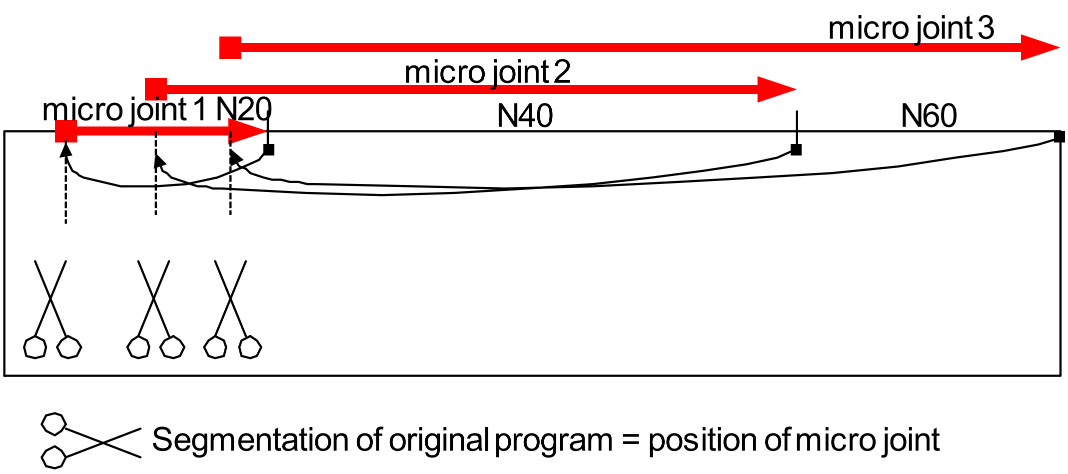


Fig. 15: Theoretical overlapping of MicroJoints in the part

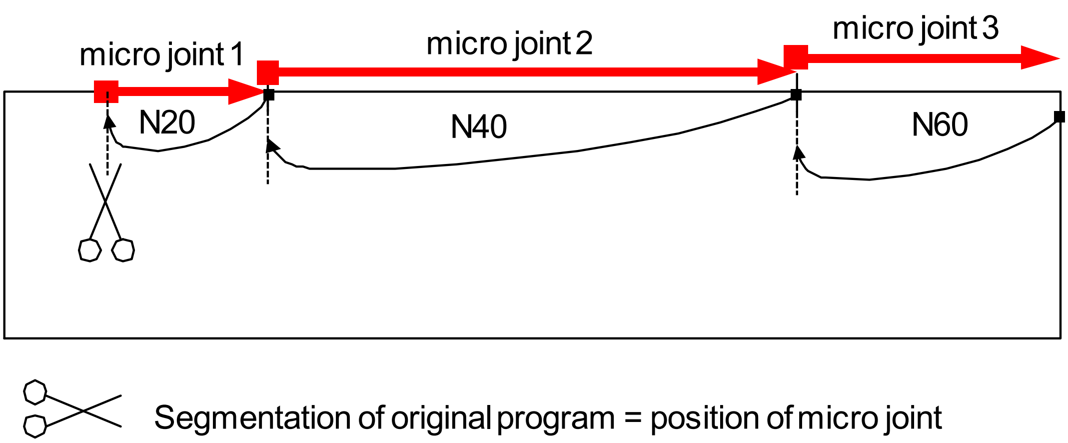


Fig. 16: Limitation of overlapping of MicroJoints in the part

Leading MNS_SNS

A leading M function of the type MNS_SNS limits the output range of subsequent M functions with pre-output.

In other words, it is similar to a programmed #FLUSH at the output point of the MNS_SNS M function.

Leading MNS_SNS

```
%microjoint
N01 G01 G90 X0 Y0 F10000

N02 V.G.M_FCT[100].PRE_OUTP_PATH = 35.6   ;in mm

N03 V.G.M_FCT[100].SYNCH = 1   ;MOS
N04 V.G.M_FCT[200].SYNCH = 8   ;MNS_SNS

N20 X10   M200
N40 X30
N60 X40   M100

N99 M30
```

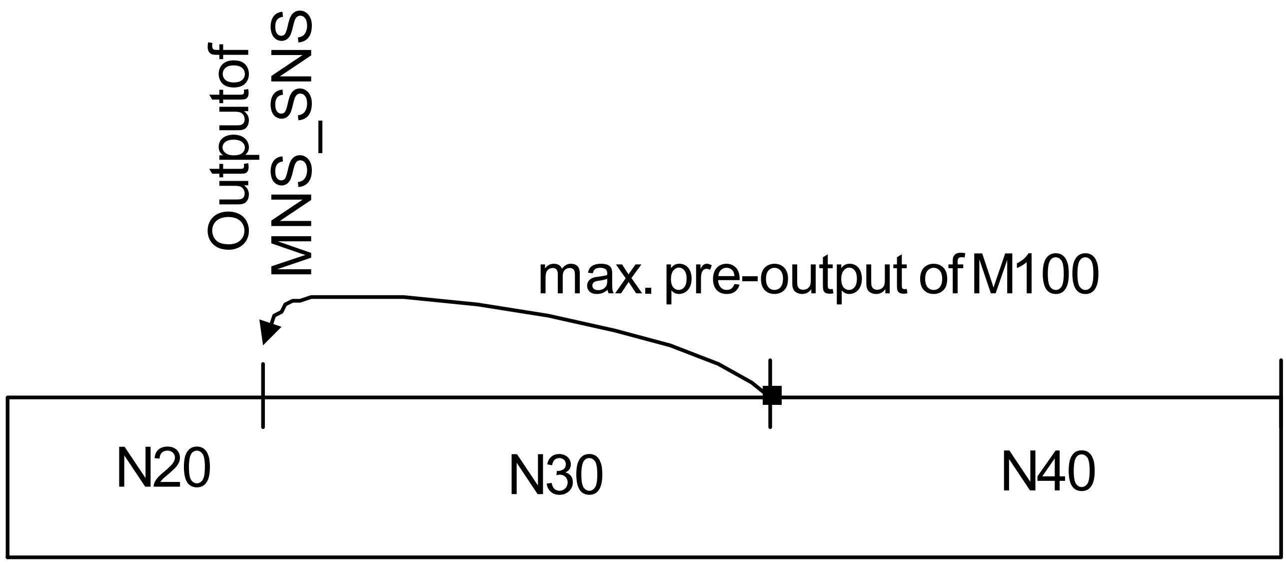


Fig. 17: Explicit limitation of the lead distance of the M function

Combination of MNS_SNS with and without pre-output path

Currently, it is not permitted to execute the simultaneous programming of MNS_SNS M functions with and without pre-output path in the same NC block including an axis motion.

Combination of MNS_SNS with and without pre-output path

```
%microjoint9
N01 G01 G90 X0 Y0 F10000

N02 V.G.M_FCT[100].PRE_OUTP_PATH = 35.6 ;in mm

N04 V.G.M_FCT[100].SYNCH = 8 ;MNS_SNS
N04 V.G.M_FCT[200].SYNCH = 8 ;MNS_SNS

N20 X10
N40 X30 M100 M200
N60 X40

N99 M30
```

2.1.2 Explicit feed programming for MicroJoints

Feed at / behind a MicroJoint

For technical process reasons, it may be necessary to limit path velocity for a MicroJoint (in particular with an M function MOS which requires no acknowledgement). In addition, the path after the advanced M function (MicroJoint path) is completely traversed to the end at a change in velocity.

This can be defined by the following feed settings in the NC command #CHANNEL SET (see figure below “Feed definition with MicroJoints”).

#CHANNEL SET [M_PRE_OUTPUT [**E**<*expr*>] [**F**<*expr*>] [**VECTOR_LIMIT_OFF**] **]** (non-modal)

E<*expr*>	Block end velocity E of the previous MicroJoint (start of MicroJoint)
F<*expr*>	Feed velocity within the MicroJoint (path between the position of the advanced M function and the originally programmed position of the M function)
VECTOR_LIMIT_OFF	Deselecting a possible dynamic limitation. If one of the previously programmed dynamic influences is active via #VECTOR LIMIT (VEL, ACC, DEC), it is suppressed within the MicroJoint range.

Explicit feed programming for MicroJoints

```
%microjoint16
N01 G00 G90 X0 Y0
N02 G01 F100

N05 #CHANNEL SET [M_PRE_OUTPUT E=20 F=5000]

N10 V.G.M_FCT[100].PRE_OUTP_PATH = 8; in mmN10 V.G.M_FCT[100].PRE_OUTP_PATH = 8; in mm
N20 G91 Y1
…
N40 Y10
N50 M100 M26
N99 M30
```

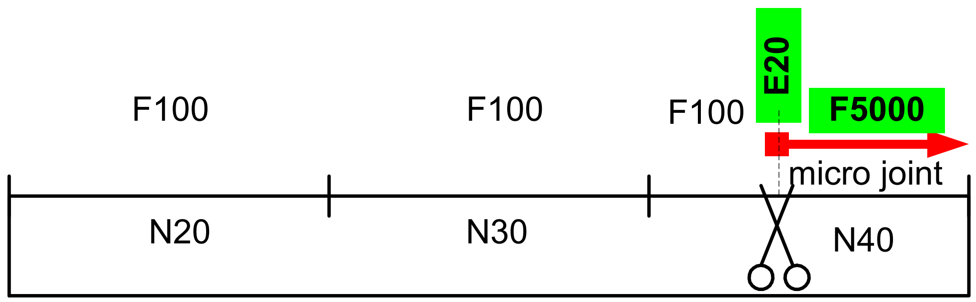


Fig. 18: Feed definition with MicroJoints

> If the F or E word is not specified, the feed for the advanced M function and subsequent motion blocks is not changed.

MicroJoint feed across multiple blocks

When the pre-output of the M function is advanced across multiple blocks, the feed of all MicroJoint motion blocks is also changed to the specified value.

A possibly explicitly programmed feed is replaced by the specific MicroJoint feed.

MicroJoint feed across multiple blocks

```
%microjoint17
N01 G01 G90 X0 Y0 F100

N05 #CHANNEL SET [M_PRE_OUTPUT E=20 F=5000]
N10 V.G.M_FCT[100].PRE_OUTP_PATH = 15; in mm
…
N40 G91 Y10 F7500
N50 M100 M26
N99 M30
```

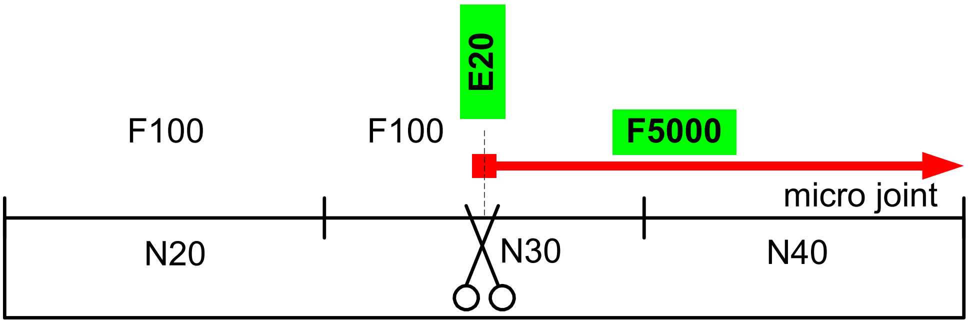


Fig. 19: Feed with block global MicroJoints

Specifying a MicroJoint feed replaces the other possible explicitly programmed feeds in the NC block.

See example above:

F7500 in N40 is replaced by F5000.

Increased feed with M11, decreased feed with M12

```
%microjoint16
V.G.M_FCT[11].SYNCH = "MOS"
V.G.M_FCT[11].PRE_OUTP_PATH = 125
V.G.M_FCT[12].SYNCH = "MOS"
V.G.M_FCT[12].PRE_OUTP_PATH = 325

N300 #CHANNEL SET [M_PRE_OUTPUT E=250 F=1500]
N01 X-222 G01 F1000

N10       X10
N20       X100
N30       X200 M11 (125mm)

N32 #VECTOR LIMIT ON[VEL=500]

N35 #CHANNEL SET [M_PRE_OUTPUT E=150 F=750]

N40       X300
N41       X310
N42       X320
N43       X330
N44       X340
N45       X350
N46       X360
N47       X370
N48       X380
N49       X390
N50       X500
N60       M12 (325mm)
N70       X600
N80       X700
M30
```

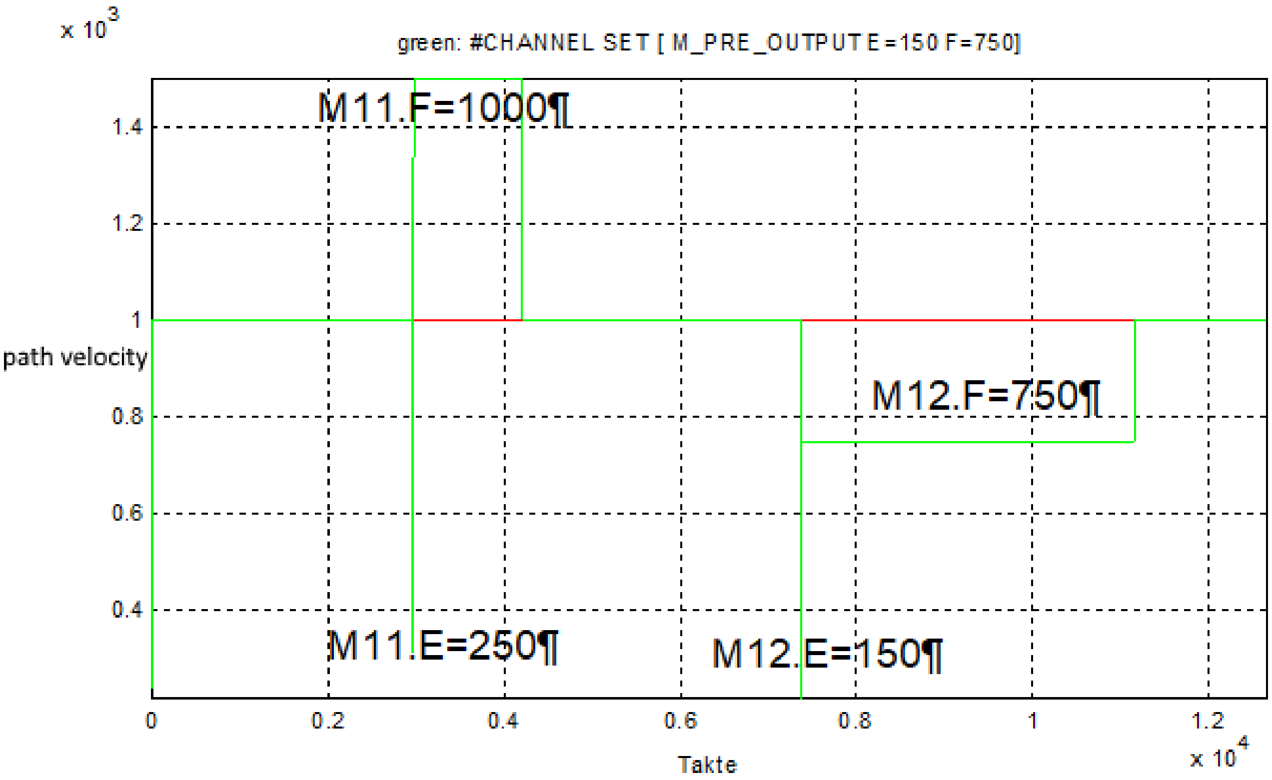


Fig. 20: Increased feed with M11, decreased feed with M12

Suppress VECTOR_LIMIT during MicroJoint

```
%microjoint18
V.G.M_FCT[11].SYNCH = "MOS"
V.G.M_FCT[11].PRE_OUTP_PATH = 125
V.G.M_FCT[12].SYNCH = "MOS"
V.G.M_FCT[12].PRE_OUTP_PATH = 325

N300 #CHANNEL SET [M_PRE_OUTPUT E=250 F=1500]
N01 X-222 G01 F1000

N10        X10
N20        X100
N30        X200 M11 (125mm)

N32 #VECTOR LIMIT ON[VEL=500]

N35 #CHANNEL SET [M_PRE_OUTPUT E=150 F=750 VECTOR_LIMIT_OFF]

N40        X300
N41        X310
N42        X320
N43        X330
N44        X340
N45        X350
N46        X360
N47        X370
N48        X380
N49        X390
N50        X500
N60        M12 (325mm)
N70        X600
N80        X700
M30
```

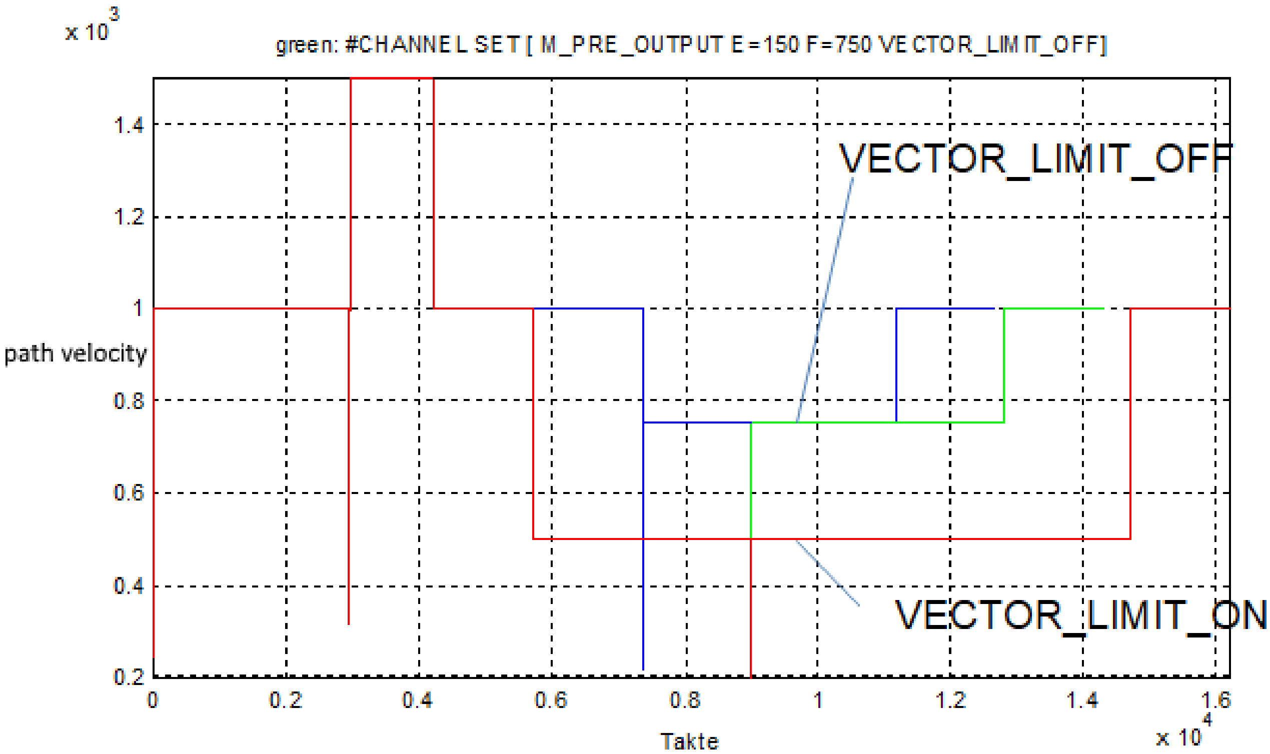


Fig. 21: Suppress VECTOR_LIMIT during MicroJoint

3 Tube processing

3.1 Overview

Task

The functions permit a simplified programming for the surface machining of:

- round tubes,
- polygonal tubes (profiled tubes) and
- open polygonal tubes (L/U profiles)

Depending on the application, the geometry is specified as Cartesian either on the lateral surface projection on as a parallel projection onto the workpiece. Different machining variants are possible here on 3/4-axis or 5/6-axis machines.

Characteristics

The function can only be enabled exclusively for Cartesian and kinematic transformations.

Parametrisation

Specific kinematics with corresponding parameter sets are required for machining variants (see chapter Parameters [▸ 108]).

Programming

A kinematic transformation is actually selected by specific variants of the #CYL command. In this case, a kinematic is implicitly selected (#KIN ID [..]).

Transformations are additional options and subject to the purchase of a license.

Links to other documents

For the sake of clarity, links to other documents and parameters are abbreviated, e.g. [PROG] for the Programming Manual or P-AXIS-00001 for an axis parameter.

For technical reasons, these links only function in the Online Help (HMTL5, CHM) but not in pdf files since pdfs do not support cross-linking.

3.2 Description

Classic lateral surface machining

Classic lateral surface machining of cylindrical workpieces typically takes place on machine structures that are designed and conceived for pure turning work. These machines have only 2 translatory tool axes Z, X and one rotary workpiece axis C.

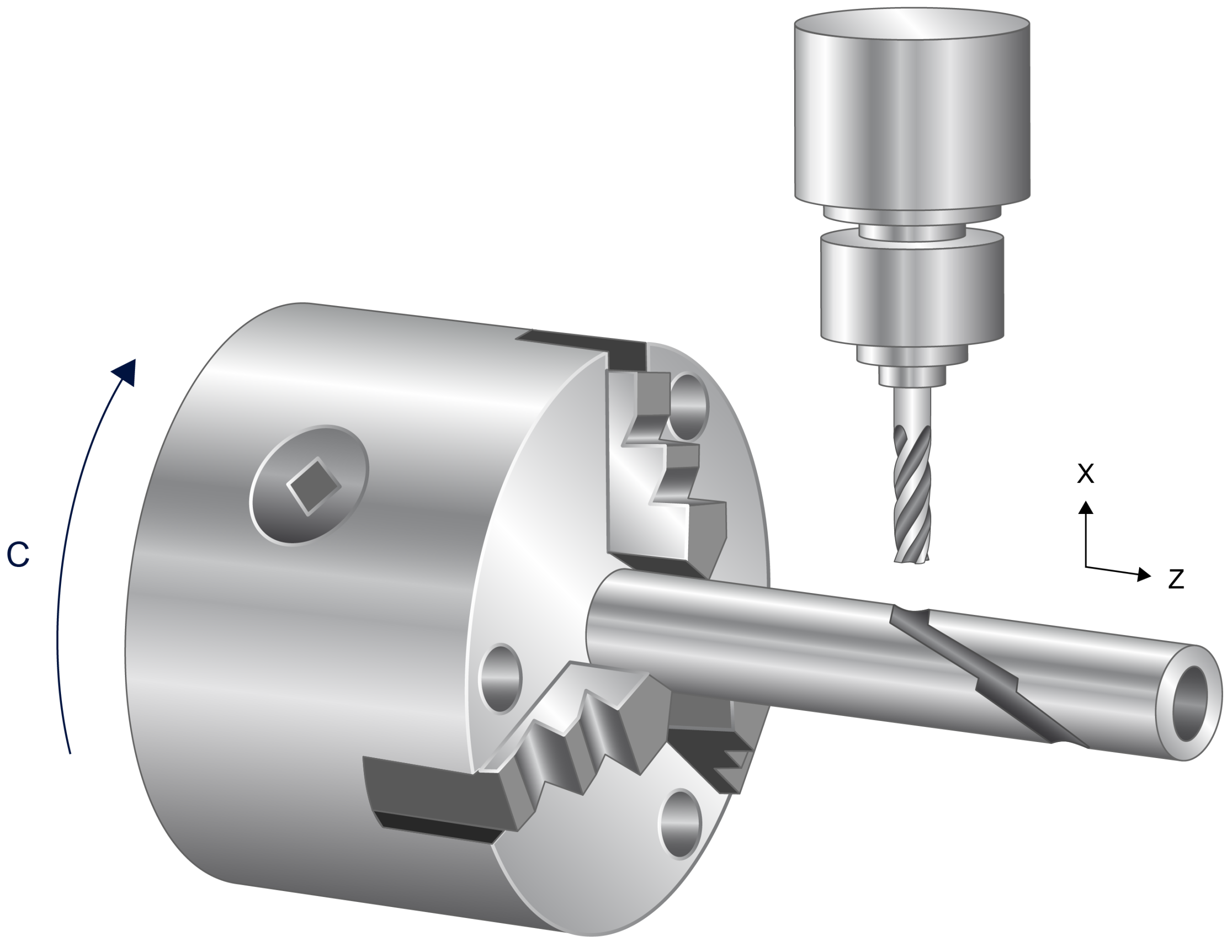


Fig. 22: Round tube lateral surface machining

Rotation-symmetrical workpiece

Besides its use in machining centres, this function is also used on other machine structures with 3 Cartesian axes X, Y, Z. With the aid of an additionally arranged rotary axis, e.g. A, these machines can also be used to machine rotation-symmetrical workpieces.

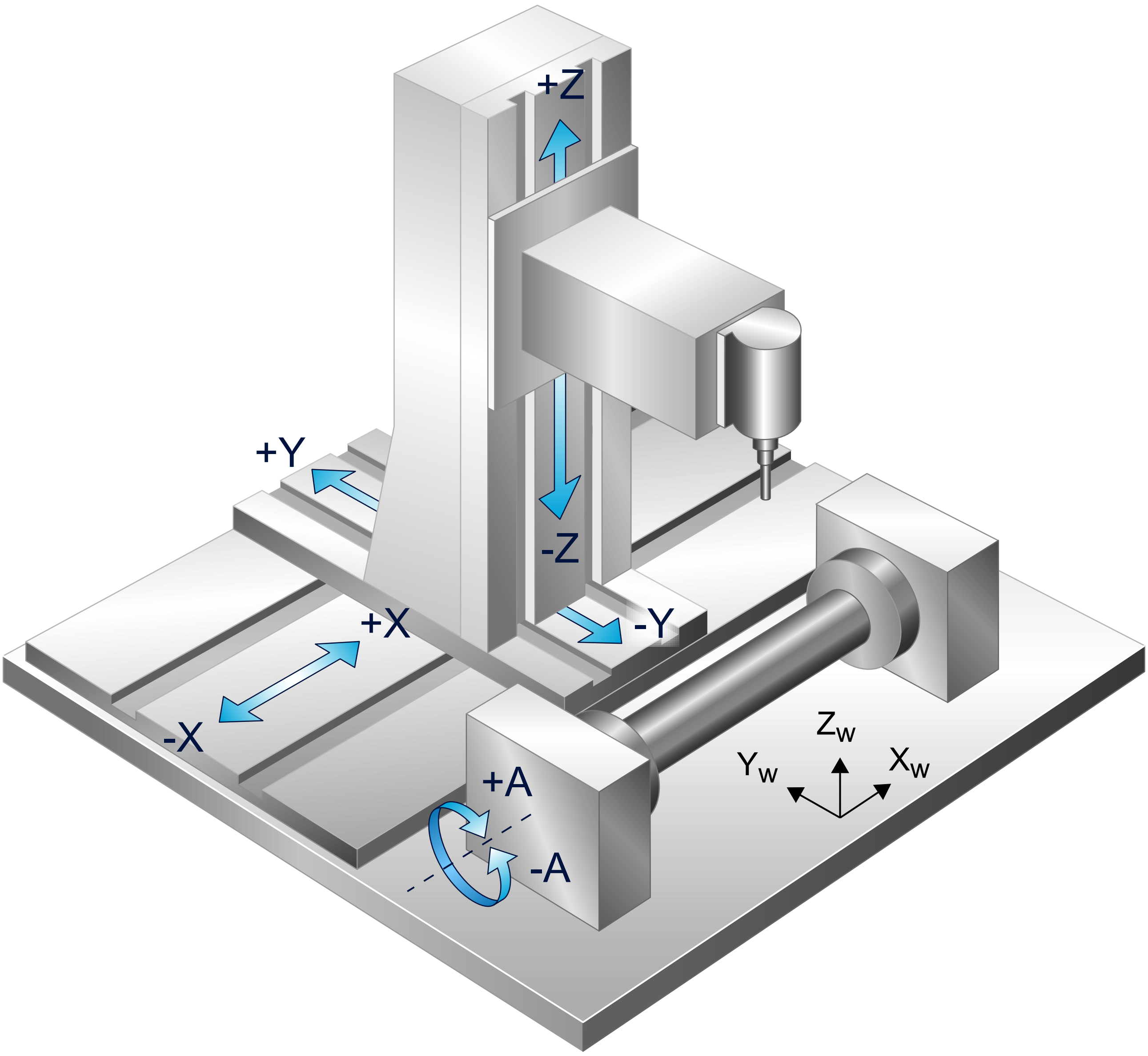


Fig. 23: Tube machining with Cartesian 3-axis machine

Besides round tube machining on the lateral surface, the functions for tube projection and profiled tube machining are described below.

Programming kinematic parameters

The kinematic parameters can be set in the channel parameters (kinematik[*].param[*] or trafo[*].*) or in the NC program by suitable V.G variables.

Note on CNC Build up to V2.11.28xx and as of V3.00 and higher

Up to Build 2.11.28xx, parameterising the kinematics was only possible in the NC program. As of V3.00 the associated kinematic ID must be set in the channel parameters:
e.g. trafo[0].id 15

Channel parameter

Setting example (for CNC Builds up to V2.11.28xx):

```
...
kinematik[15].param[0]   1230000
kinematik[15].param[1] 0
kinematik[15].param[2]   0
kinematik[15].param[3]   0
kinematik[15].param[4]   0
kinematik[15].param[5]   0
kinematik[15].param[6]   0
kinematik[15].param[7]   0
kinematik[15].param[8]   0
kinematik[15].param[9]   0
...
```

or

Setting example (for CNC Builds as of V3.00 and higher):

```
...
trafo[0].id              15
trafo[0].param[0] 1230000
trafo[0].param[1]        0
trafo[0].param[2]        0
trafo[0].param[3]        0
trafo[0].param[4]        0
trafo[0].param[5]        0
trafo[0].param[6]        0
trafo[0].param[7]        0
trafo[0].param[8]        0
trafo[0].param[9]        0
...
```

NC program

Setting example in the NC program:

```
...
V.G.KIN[15].PARAM[0] = 123000
V.G.KIN[15].PARAM[1] = 0
V.G.KIN[15].PARAM[2] = 0
V.G.KIN[15].PARAM[3] = 0
V.G.KIN[15].PARAM[4] = 0
V.G.KIN[15].PARAM[5] = 0
V.G.KIN[15].PARAM[6] = 0
V.G.KIN[15].PARAM[7] = 0
V.G.KIN[15].PARAM[8] = 0
V.G.KIN[15].PARAM[9] = 0
...
```

3.3 Machining variants (3/4-axis)

A distinction is made between 4 different machining variants:

- Round tube, lateral surface [▸ 48]
- Round tube, projection [▸ 53]
- Polygonal tube, profiled tube [▸ 57]
- Open polygonal tube / profiled tube (L/U profiles) [▸ 66]

3.3.1 Round tube, lateral surface

3.3.1.1 Programming #CYL [..]

The path is programmed in Cartesian coordinates on the lateral surface projection in X and U where U is the rotary axis identifier. When selected, the reference radius R on the cylindrical workpiece must also be programmed.

The tool must be located above the rotation centre when selected.

If required, PCS (Programming Coordinate System) modulo calculation can be activated by a kinematic parameter (see below Parameter HD10 in section Description [▶ 109]). In this case, the PCS U axis is treated as a rotary modulo axis. After it crosses the modulo limit of the rotary axis, the circumferential position is also corrected.

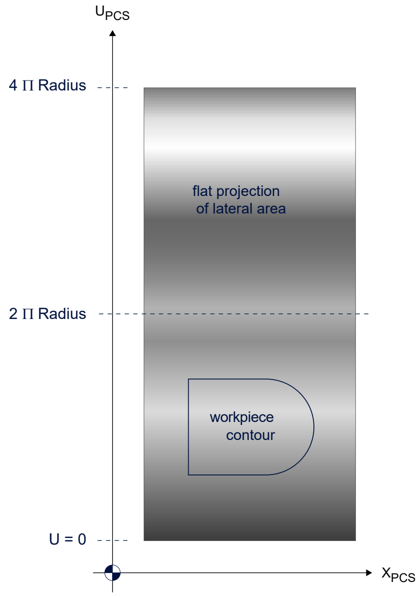


Fig. 24: Path programming on the lateral surface

A position on the tube circumference is always approached **in absolute programming** along the shortest path. The section "Programming modulo axes" in [PROG] must be observed when programming the sign. This must also be taken into account for circular motion blocks (G02, G03) with absolute target point programming.

The kinematic parameters in ID 15 [▶ 109] must be set for this machining type.

Syntax to select lateral surface machining with round tube:

#CYL [<1st main_axis_name>**,** <2nd main_axis_name>**,** <3rd main_axis><expr>] (modal)

<1st main_axis_name>	Name of the first main axis according to the current main plane.
<2nd main_axis_name>	Name of the second main axis according to the current main plane (virtual linear axis, development).
<3rd main_axis_name><expr>	Axis name of the third main axis according to the current main plane with specification of the reference radius in [mm, inch].

Syntax to deselect lateral surface machining with round tube

#CYL OFF (modal)

#CYL [..]

```
(* Example with axis identifier U for 2nd main axis *)
N05 G00 Y0              (tool over centre of rotation)
N10 G01 X60 U45 F5000
N20 #CYL [X, U, Z60]    (Select lateral surface, radius 60 mm)
N30 G00 G90 X0 U0       (X: 0mm  U:0mm!)
N40 G01 U100 F500
N50 G02 X100 R50
N60 G01 U0
N70 Z0
```

```
N80 #CYL OFF
```

3.3.1.2 Axis configuration

The following axis configuration must be set in the NC channel.

Axis configuration in NC channel		
Axis identifier	X, Y, Z, U	
Axis index	0, 1, 2, 3	
Kinematic structure (ID 15)		
	Tool axes	**Workpiece axes**
NC axes	X, Y, Z	U

Axis structure

The Z tool axis must intersect with the rotary axis U, i.e. the tool axis lies at the tube centre point. To achieve this, place the Y axis in the correct position before selecting the transformation.

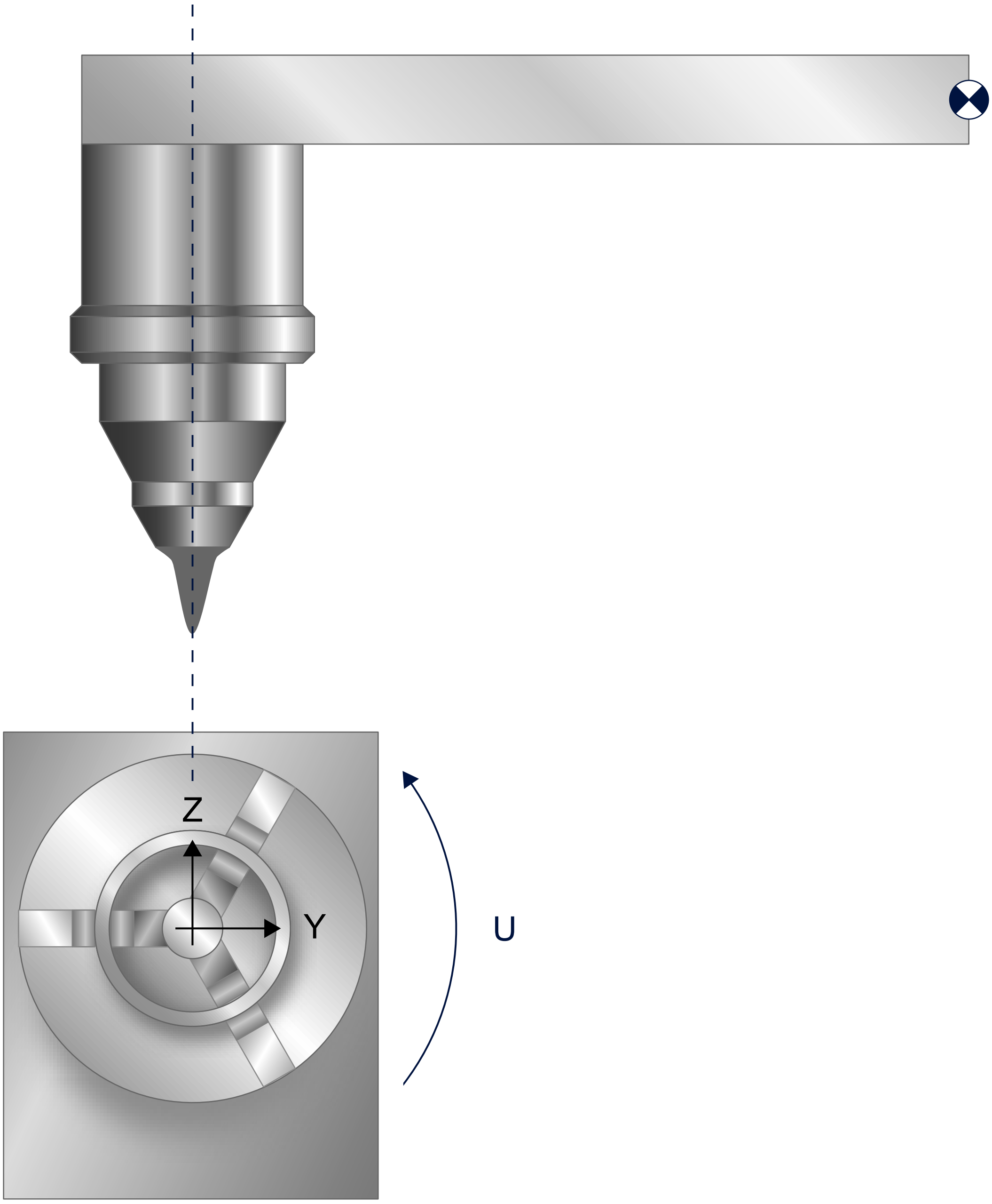


Fig. 25: Axis structure

3.3.1.3 Path example

Lateral surface transformation

```
(* Lateral surface transformation *)

N30 #SLOPE [TYPE=STEP]
N40 G00 X0 Y0 Z100 U0

N50 #CYL [X, U, Z35]  (* Select lateral surface machining *)

N70 G01 G90 X0 U0 F5000
N80 G01 Z10 G90  F50000
N90 $FOR P1=1, 4, 1
N100 G00 G90 X0 U[P1*90]
N110 $FOR P2=1, 5, 1
N120  P3=P2*4
N130  P4=P3+2
N140  G01 G91 U-P3
N150          XP3
N160          U[2*P3]
N170          X-P3
N180 G90 U0
N190 G91 XP4
N190 $ENDFOR
N200 $FOR P2=1, 5, 1
N210  P3=P2*4
N220  P4=P3*2+2
N230  G90 G02 IP3
N240      G91 G01 XP4
N250 $ENDFOR
N260 $ENDFOR

N290 #CYL OFF
M30
```

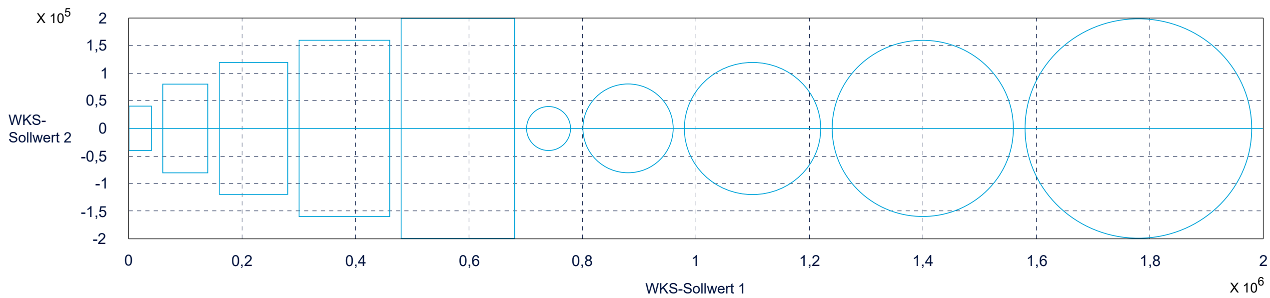


Fig. 26: X-U contour line projection

3.3.2 Round tube, projection

With projected round tube machining, the programmed X/Y path is mapped by parallel projection onto the lateral surface of a tube. The distance from the tube (Z height) is kept constant by transformation on the curved tube. If the distance is changed, a Z height change can be additionally programmed.

Machining is possible up to a programmable radius limit. This value is always less than the tube radius. Machining is aborted if a position outside this limit is programmed. This results in an error message.

Before selecting the transformation, the tube must be positioned so that the Y axis is within the set limit 'LIMIT' (see NC command #CYL [...]).

The specified feed rate refers to the original path programmed. Especially in the edge zone of the tube, the real feed rate of the tool in the round tube is higher.

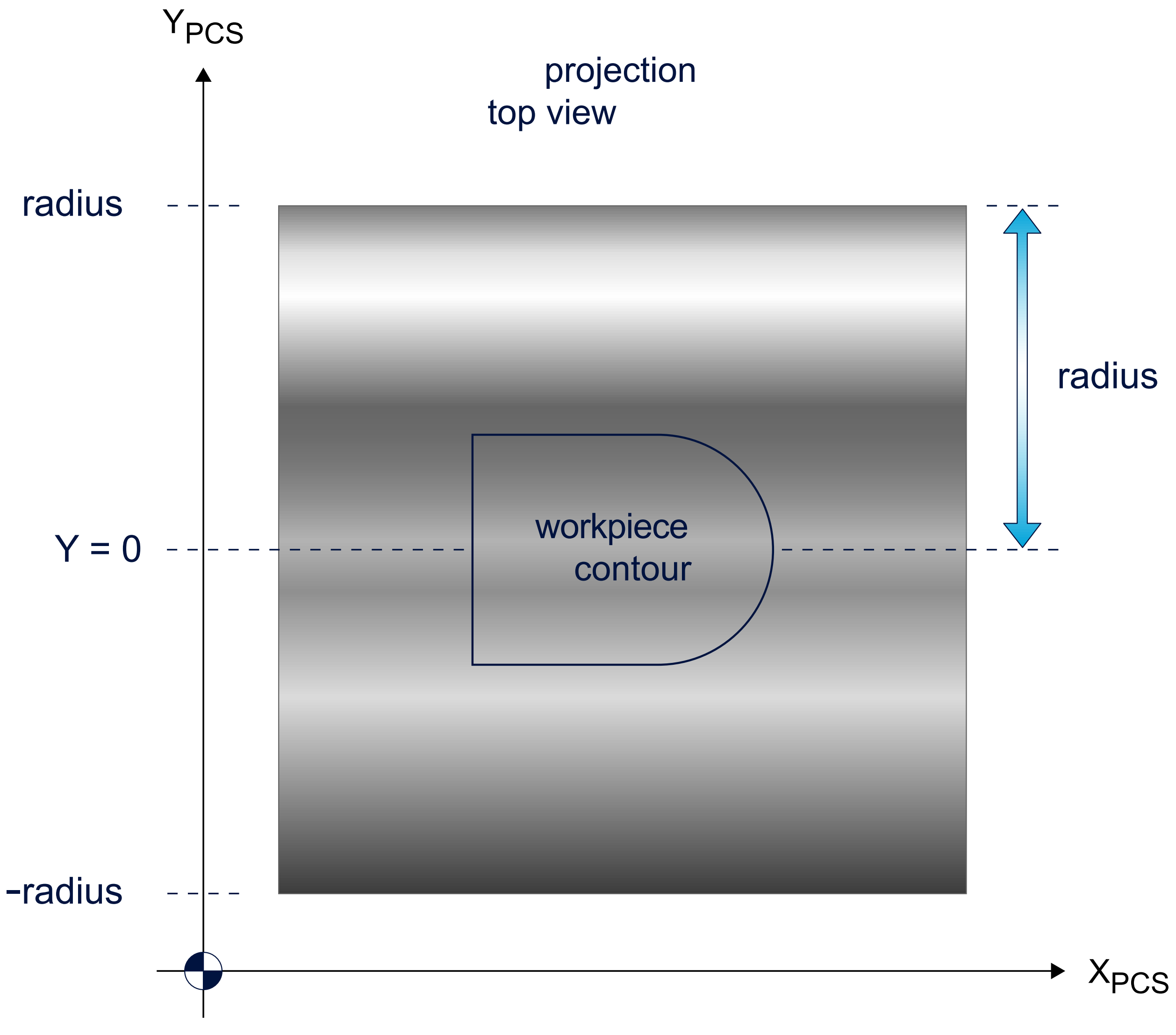


Fig. 27: Programming with path projection

3.3.2.1 Programming #CYL [RADIUS..]

The kinematic parameters in ID 78 [▸ 111] must be set for this machining type.

Syntax to select round tube projection:

#CYL [RADIUS<*expr*> [**LIMIT**<*expr*>] **]**	(modal)

RADIUS<*expr*>	Radius of the round tube or of the lateral surface to be machined, [mm, inch]
LIMIT<*expr*	Machining limit, symmetrically relative to the tube centre. [mm, inch] If no limit is explicitly specified, LIMIT = 0.25* RADIUS applies.

Syntax to deselect round tube projection:

#CYL OFF	(modal)

#CYL [RADIUS..]

```
N10 X0 Y-1000 Z100 U0
N20 #CYL [RADIUS=35 LIMIT=31]  ;Selecting tube projection
N30 G01 G90 X0 Y0 F5000
N40 G01 Z10
N50 $FOR P1=1, 4, 1
N60 G00 G90 X0 Y0 U[P1*90]
N70 $FOR P2=1, 5, 1
N80  P3=P2*4
N90  P4=P3+2
N100  G01 G91 Y-P3
N110          XP3
N120          Y[2*P3]
N130          X-P3
N140 G90 Y0
N150 G91 XP4
N160 $ENDFOR
N170 $FOR P2=1, 5, 1
N180  P3=P2*4
N190  P4=P3*2+2
N200  G90 G02 IP3
N210      G91 G01 XP4
N220 $ENDFOR
N230 $ENDFOR
N240 #CYL OFF                  ;Deselecting tube projection
```

3.3.2.2 Axis configuration

The kinematic structure consists of three translatory axes in the tool. The rotary workpiece axis is not changed by the transformation.

The following axis configuration must be set in the NC channel.

Axis configuration in the NC channel		
Axis identifier	X, Y, Z, U	
Axis index	0, 1, 2, 3	
Kinematic structure (ID 78)		
	Tool axes	**Workpiece axes**
NC axes	X, Y, Z	U

Axis structure

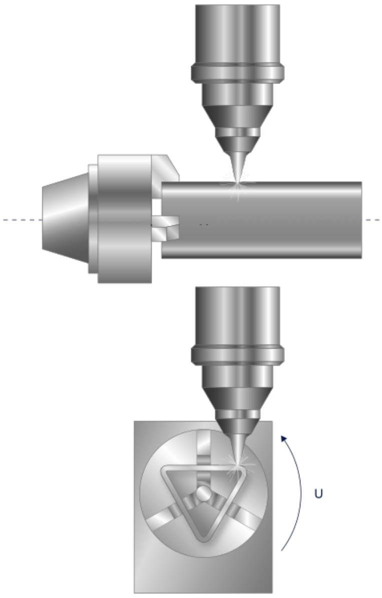


Fig. 28: Axis structure

3.3.2.3 Path example

Tube projection

```
(* Tube projection *)

#SLOPE [TYPE=STEP]
X0 Y-1000 Z100 U0

N50 #CYL [RADIUS=35 LIMIT=31]  (* Selecting tube projection*)

N70 G01 G90 X0 Y0 F5000
N80 G01 Z10 G90  F50000
N90 $FOR P1=1, 4, 1
N100 G00 G90 X0 Y0 U[P1*90]
N110 $FOR P2=1, 5, 1
N120  P3=P2*4
N130  P4=P3+2
N140  G01 G91 Y-P3
N150          XP3
N160          Y[2*P3]
N170          X-P3
N180 G90 Y0
N190 G91 XP4
N190 $ENDFOR
N200 $FOR P2=1, 5, 1
N210  P3=P2*4
N220  P4=P3*2+2
N230  G90 G02 IP3
N240      G91 G01 XP4
N250 $ENDFOR
N260 $ENDFOR

N290 #CYL OFF
M30
```

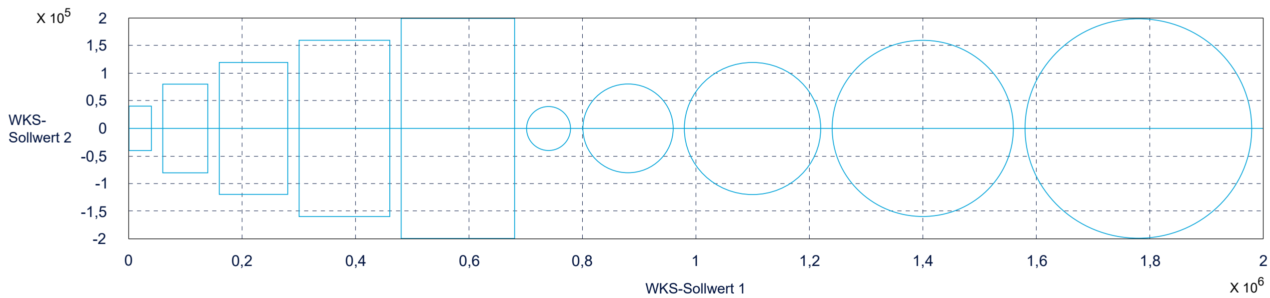


Fig. 29: X-Y contour line projection

3.3.3 Polygonal tube, profiled tube

This function places the programmed contour onto the projected lateral surface of a profiled tube.

The controller guides the workpiece during machining (Y deflection) so that the tool is always perpendicular to the workpiece surface. The distance from the workpiece (Z height) is kept constant without Z programming. A Z height can also be programmed. The programming coordinates of U, X and Z height of the TCP (Tool Centre Point) refers to the lateral surface.

With lateral surface machining, the path feed rate for round tubes refers to the programmed projected path.

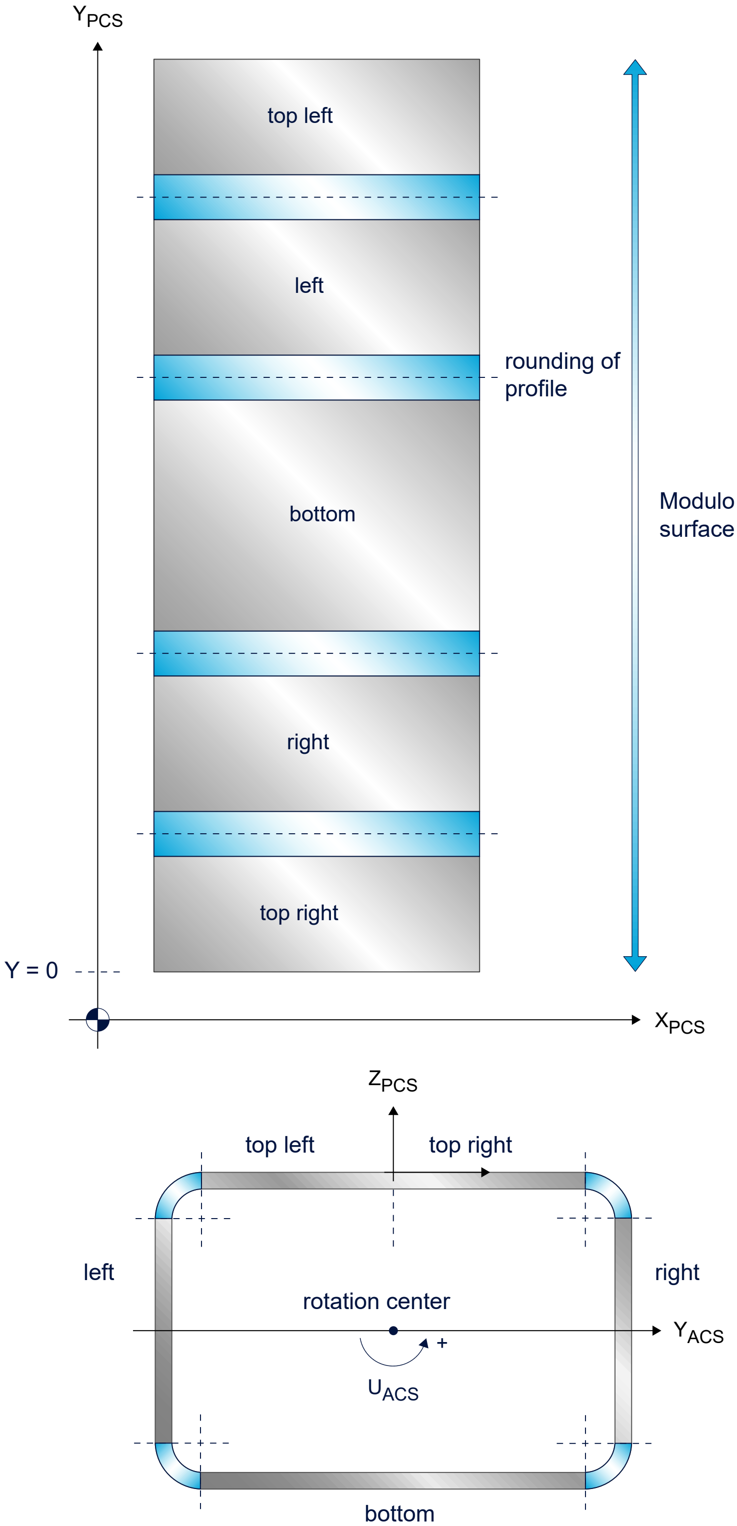


Fig. 30: Programming on the lateral surface

3.3.3.1 Programming #CYL [EDGES..]

The kinematic parameters in ID 79 [▶ 113] must be set for this machining type.

Syntax to select profiled tube machining:

#CYL [EDGES<*expr*> **ROUNDING**<*expr*> **LENGTH1**<*expr*> [**LENGTH2**<*expr*>] [**VEL**<*expr*>] [**ACC**<*expr*>] **]** (modal)

EDGES<*expr*>	Number of edges (corners) of the profiled tube, positive integer The minimum number of corners on the profile is limited to 3 and the maximum number to 16.
ROUNDING<*expr*>	Edge rounding radius (corner radius), [mm, inch].
LENGTH1<*expr*>	Side length for symmetrical tubes or first side length for rectangular tubes, [mm, inch]
LENGTH2<*expr*>	Second side length for rectangular tubes, [mm, inch]
VEL<*expr*>	Path velocity on edge rounding [mm/min]
ACC<*expr*>	Path acceleration on edge rounding [mm/min^2]

Syntax to deselect profiled tube machining:

#CYL OFF (modal)

#CYL [EDGES..]

```
(Symmetrical square profile with 100 mm edge length)
(and 10 mm edge rounding radius)
N10 #CYL [EDGES=4 ROUNDING=10 LENGTH1=100]
...
(Asymmetrical square profile with edge lengths of 100 mm)
(and 80 mm and 15 mm edge rounding radius)
N10 #CYL [EDGES=4 ROUNDING=15 LENGTH1=100 LENGTH2=80]
...
(Reduced path dynamics on the profile rounding)
N10 #CYL [EDGES=4 ROUNDING=5 LENGTH1=50 LENGTH2=50
          ACC=1000000]
```

NOTICE

With relative programming, the number of profile rotations is limited for each block due to resources. An error message is generated if the maximum number is exceeded.

Tube profile machining

```
(* Tube profile machining *)
%main
N10 #SLOPE [TYPE=STEP]
N20 G90 X0 Y0 Z100 U0
N30 U0 X0
N40 #CYL[EDGES=4 ROUNDING=5 LENGTH1=20 LENGTH2=20]
N50 G01 G91 X10 F5000
N60 U50
N70 G03 U-100 I300 J-50
N80 #CYL OFF
N90 M30
```

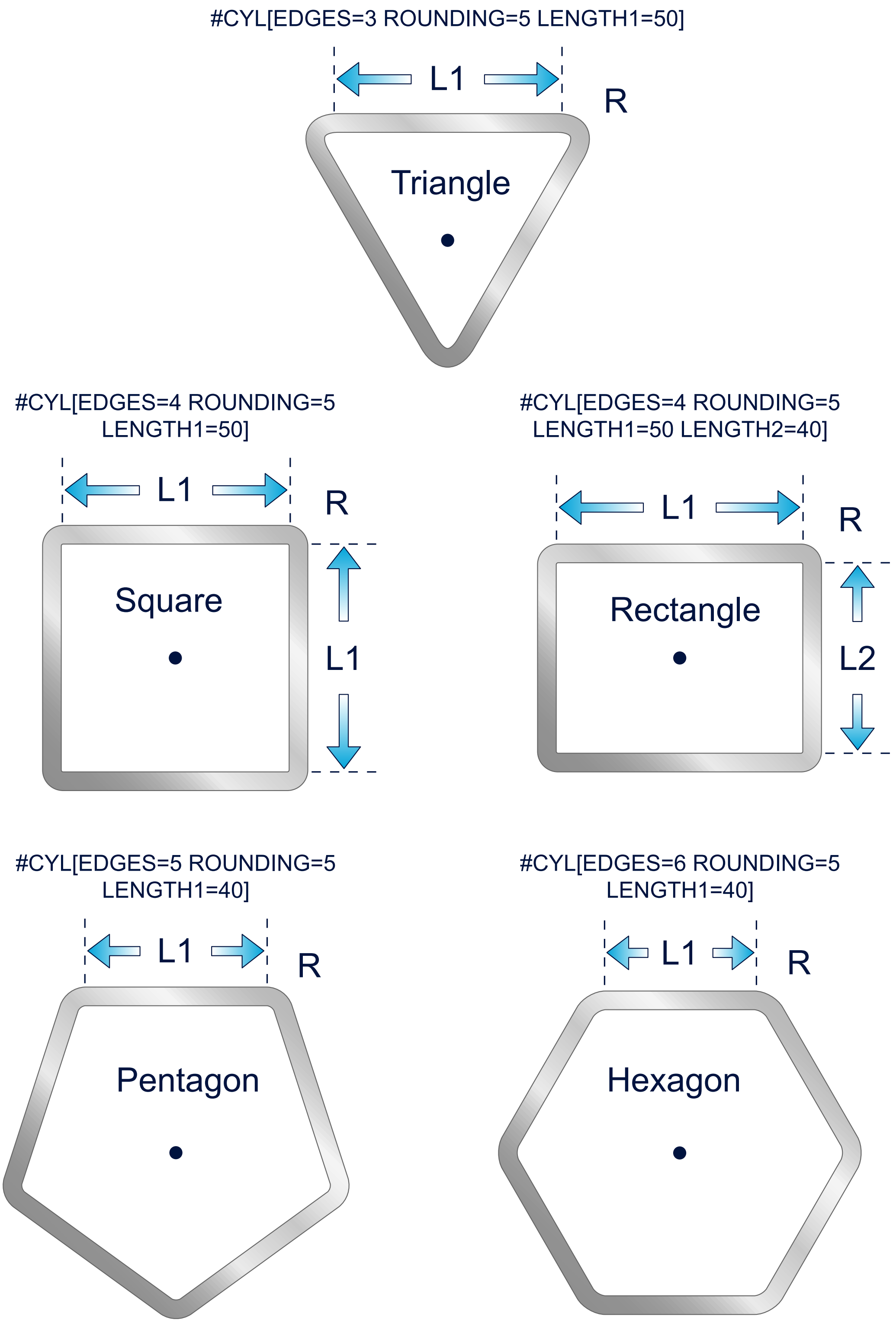


Fig. 31: Parameterisation examples for profiled tubes

Rectangular profile

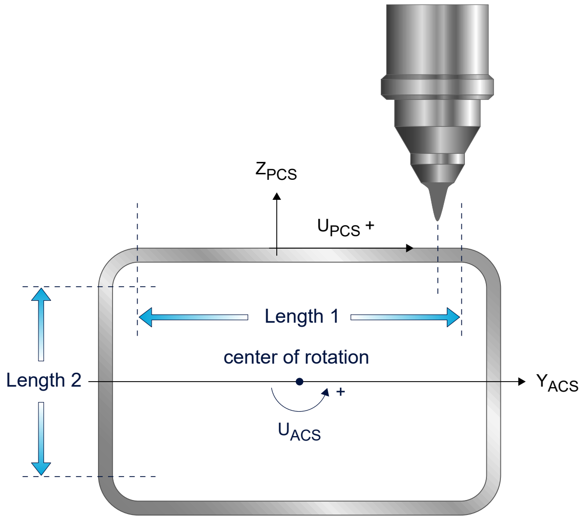


Fig. 32: Lateral surface coordinate system with rectangular profile

Activation condition

Default case: Selecting on plane surface

The transformation is selected when the workpiece is aligned flat. The angle of the U axis then displayed with horizontal workpiece alignment is set by means of a U offset (kinematic parameters).

When #CYL[..] is selected, the Y axis position of the tool is located within the plane surface of the workpiece (side length LENGTH1), otherwise an error message is output.

Special case: Selecting on profile rounding

A U angle offset may possibly have to be set in the same way as described before.

The transformation should be selected on the profile rounding. This variant can be used when machining was stopped with active transformation on the profile rounding or a profile rounding position was approached using #PTP ON. The CNC checks whether selection is possible with the current active U and Y axis positions. An error message is generated if an axis position are invalid.

With G90 absolute programming, positioning on the circumference is always based on the "shortest path” without specifying the direction of rotation.

Please note the section "Programming modulo axes" in [PROG] when programming the sign for the direction of rotation.

This must also be taken into account for circular motion blocks (G02, G03) with absolute target point programming.

3.3.3.2 Axis configuration

The kinematic structure consists of 3 translatory axes in the tool and one rotary axis in the workpiece.

The following axis configuration must be set in the NC channel.

Axis configuration in the NC channel		
Axis identifier	X,Y, Z, U	
Axis index	0, 1, 2, 3	
Kinematic structure (ID 79)		
	Tool axes	**Workpiece axes**
NC axes	X, Y, Z	U

Axis structure

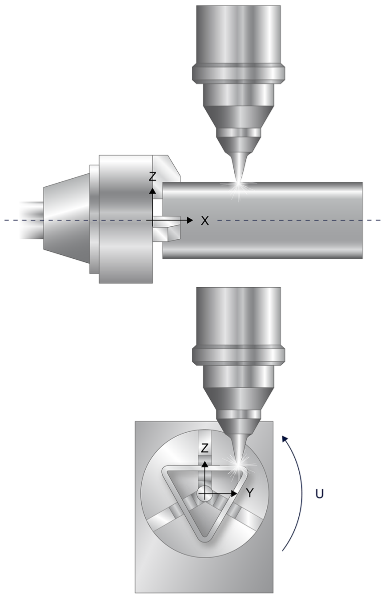


Fig. 33: Axis structure

3.3.3.3 Profile rounding, technology and dynamics during feed motion

Machining on profile roundings

In comparison to straight sections, there may be deviations in material characteristics (e.g. wall thickness) in the area of the profile roundings. When the limits to the profile roundings are crossed, this can be signalled by M/H functions. As a result, the process can be influenced by the PLC. The M/H functions are always of the MOS type (M functions without synchronisation).

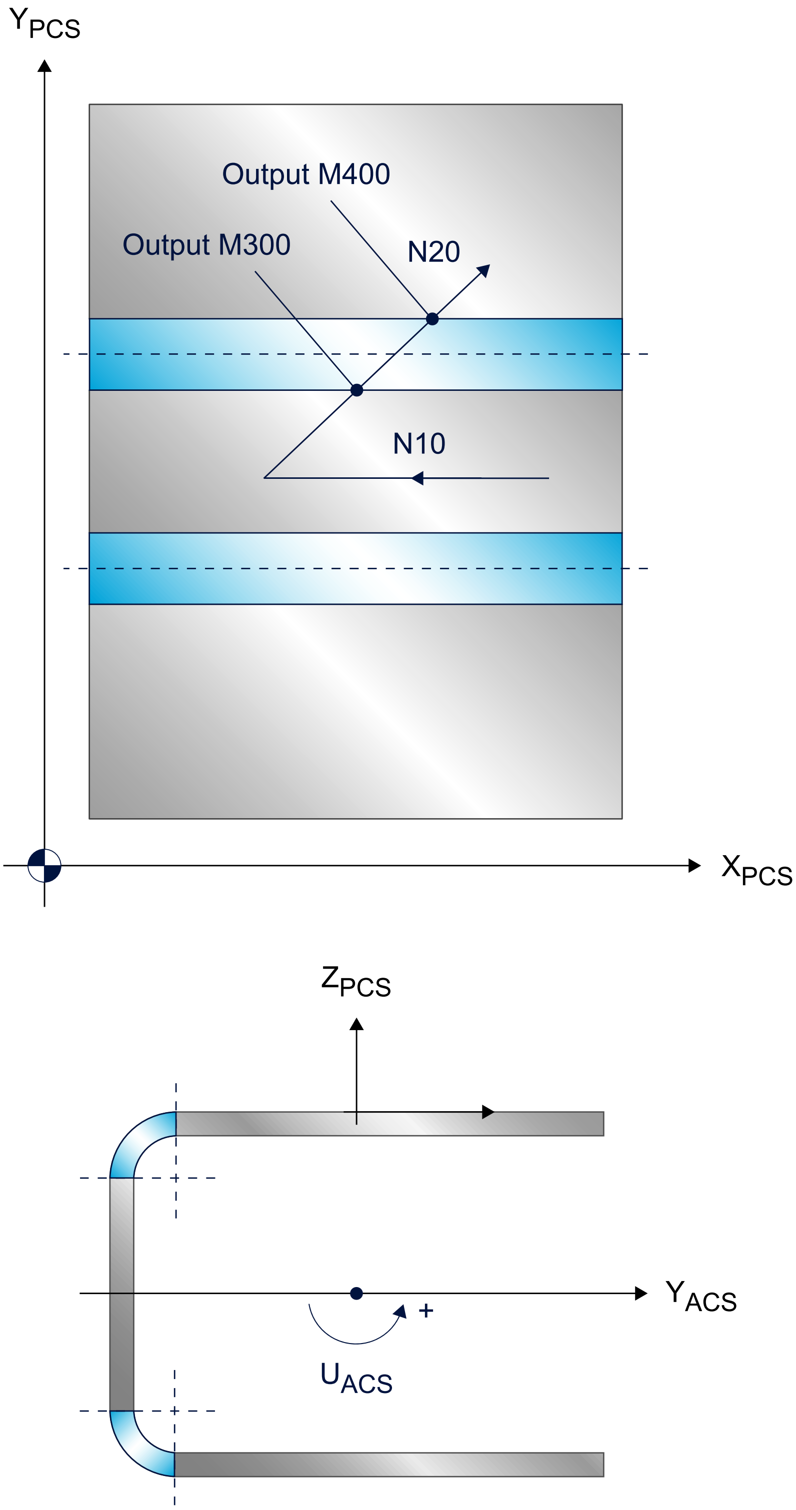


Fig. 34: Output of a technology function at a profile rounding

Dynamics in the profile rounding

At the transition points of the profile roundings, the CNC may possibly reduce the feed rate due to the acceleration of other axes depending on the parameterised axis dynamics of the participating axes.

The dynamics on the profile rounding can be influenced by parameters in the NC command #CYL[...]. In addition to the normal path velocity and acceleration limit (cf. #VECTOR LIMIT[VEL ACC]), the values from the #CYL[...] command are also considered in the profile rounding.

Machining on profile roundings

```
#CYL[EDGES=4 ROUNDING=5 LENGTH1=50 LENGTH2=50
                             ACC=500000 VEL=1000]
```

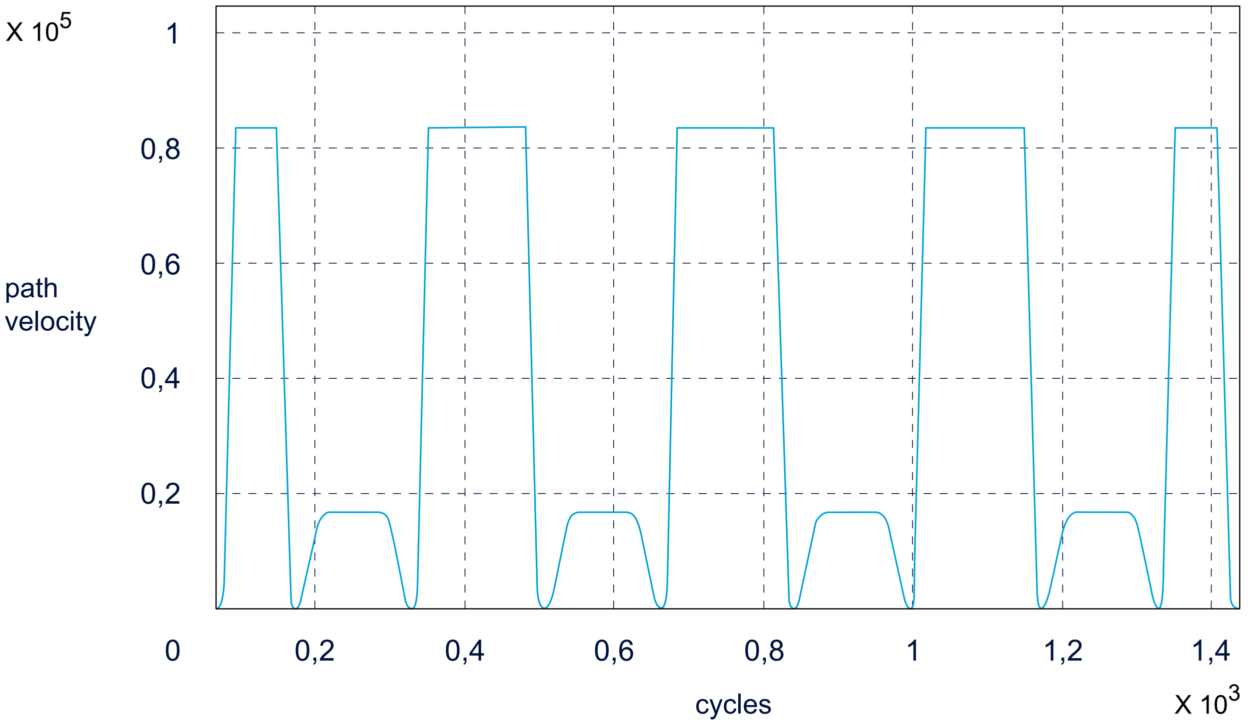


Fig. 35: Path dynamics adjustment on profile rounding

3.3.3.4 Path example

Polygonal tube transformation

```
(* Polygonal tube transformation *)

%L SUB_CONT
N[10+P30] G00 G90 X0 Z100 U0
N[20+P30] G162
P1=5   (* Radius inner circle *)
P2=25  (* Radius outer circle *)
P3=22.5
P4=2*P3
$FOR P10=0, 8 , 1
          P6=P10*P4
          P7=SIN[P6]
          P8=COS[P6]
N[40+P10] G01 X[P2*P8] U[P2*P7] F5000
          P20=SIN[P3 + P6]
          P21=COS[P3 + P6]
N[50+P10] G01 X[P1*P21] U[P1*P20] F5000
$ENDFOR
M29
%t_tube_prof.nc
N10 #SLOPE [TYPE=STEP]
N20 G00 X0 Y0 Z100 U0

N70 #CYL[EDGES=4 ROUNDING=5 LENGTH1=20 LENGTH2=20]
(* Profile circumference approx. 111.41592653589793 mm *)

P30=2000
N35 G92 X30 U30
N40 LL SUB_CONT
N45 G92 X-30 U30
N50 LL SUB_CONT
N60 G92 X30 U-[-30]
N70 LL SUB_CONT
N80 G92 X-30 U-[-30]
N90 LL SUB_CONT
N100 G92 X0 U0

N110 #CYL OFF
M30
```

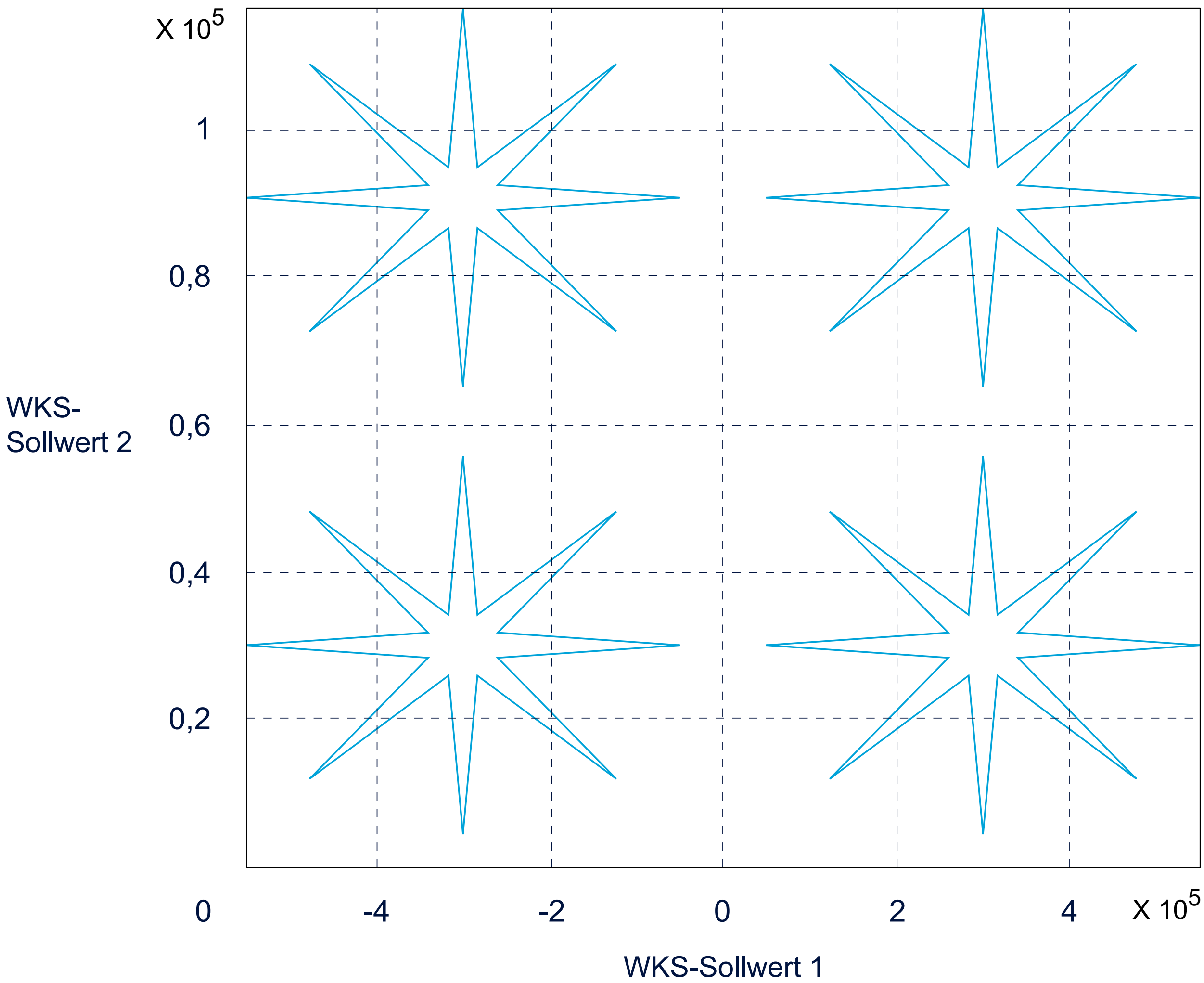


Fig. 36: X-U contour line projection

3.3.4 Open polygonal tube / profiled tube (L/U profiles)

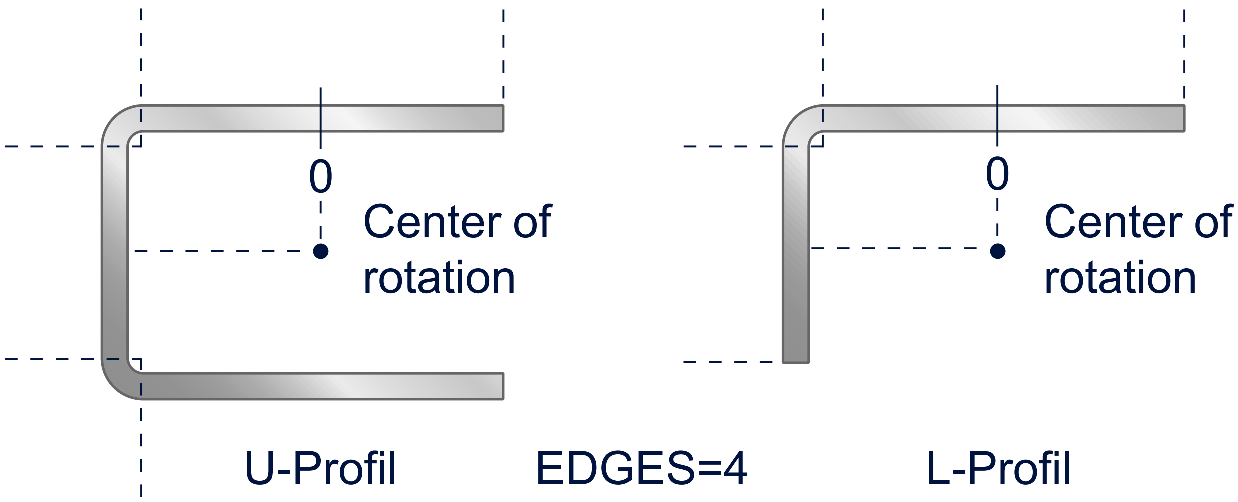
This function is available as of CNC Build **V2.11.2807.01** .

Characteristics

An extension of the definition permits the machining of **non-closed** profiles. An open profiled tube (L/U tube) is detected as a limited lateral surface.

There is no limitation of the path motion or modulo calculation of the PCS coordinate when "virtual edges" are crossed. For this reason, the coordinate system on a lateral surface is linear (see also linear coordinate system for round tube machining). Starting from the zero point, the lateral surface is divided into a positive and a negative direction.

Programming is always related to the closed edges of the tube profile. This means that it is possible to cross virtual edges when profile transformation is active but there is no rotation of the workpiece or Z height adjustment.



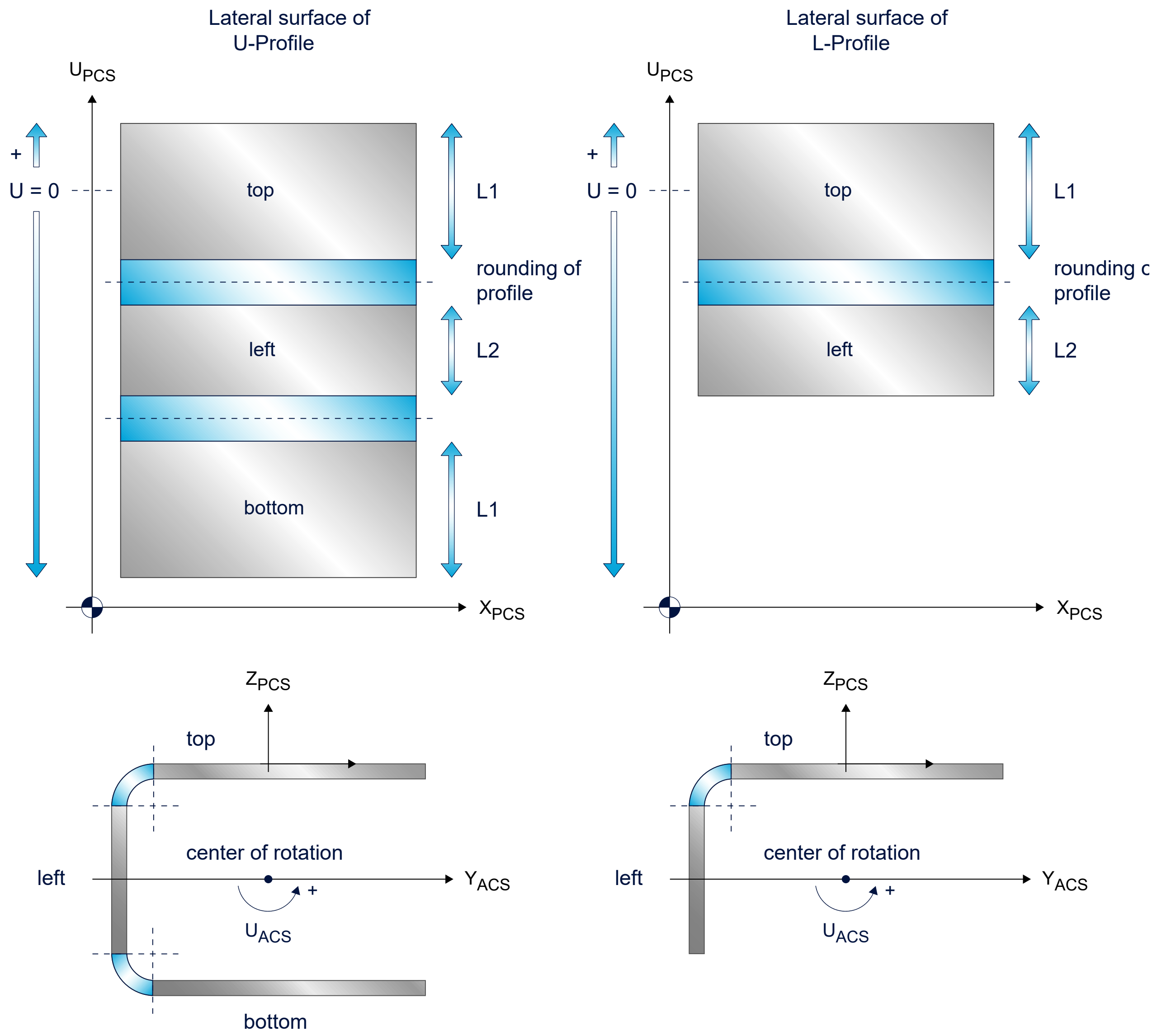


Fig. 37: Examples of open profiles, U and L profile

Clamping examples of open rectangular profiles:

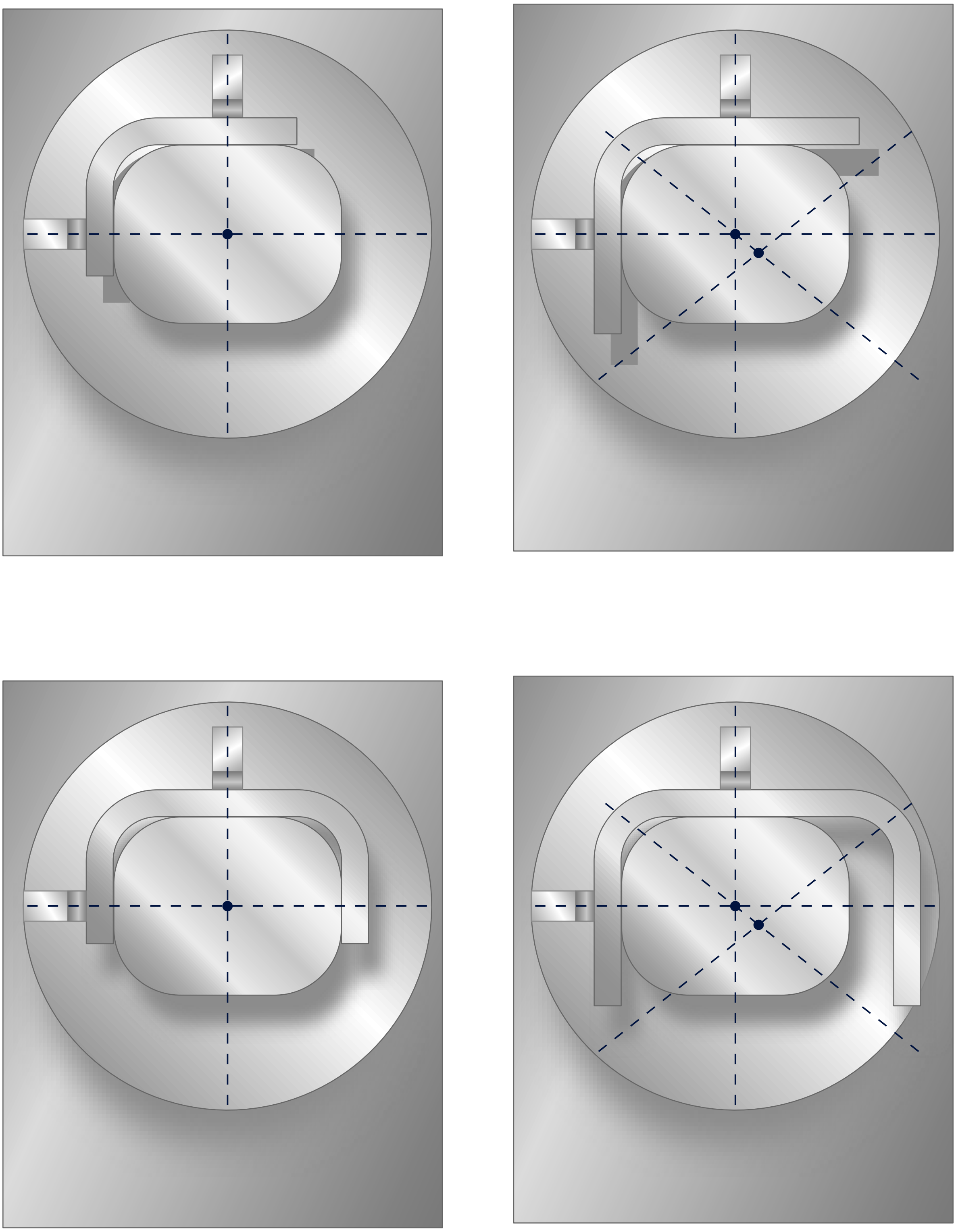


Fig. 38: Clamping examples

3.3.4.1 Programming #CYL [EDGES.. OPEN..]

Open edges

This extension permits the user to define 2 edges between which the profile is opened.

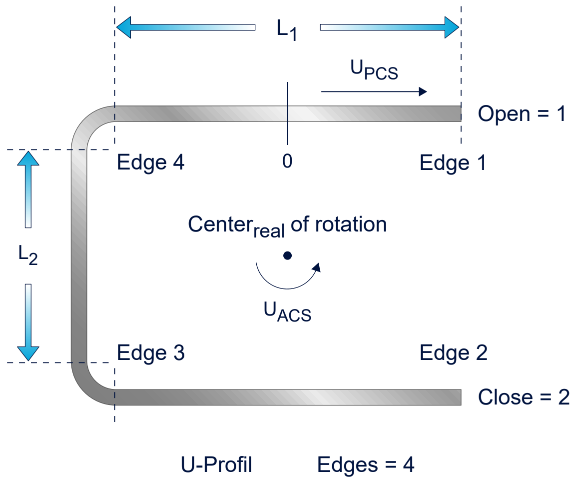


Fig. 39: Defining an open U profile specifying the open edges

The kinematic parameters in ID 79 [▶ 113] must be set for this machining type.

Syntax to select open profiled tube machining:

```
#CYL [ EDGES<expr>  ROUNDING<expr>  LENGTH1<expr>  [ LENGTH2<expr> ]
        [ OPEN<expr>  CLOSE<expr> ] ]                              (modal)
```

EDGES<*expr*>	Number of edges (corners) of the closed profiled tube, positive integer. The number of profile edges is limited to minimum 3 and maximum 16.
ROUNDING<*expr*>	Edge rounding radius (corner radius), [mm, inch].
LENGTH1<*expr*>	Side length for symmetrical tubes or first side length for rectangular tubes, [mm, inch]
LENGTH2<*expr*>	Second side length for rectangular tubes, [mm, inch]
OPEN<*expr*>	Number of the edges [1; <EDGES>] where the workpiece is open. Ascending number in lateral surface projection (positive U_{PCS} direction).
CLOSE<*expr*>	Number of the corner [1; <EDGES>] where the workpiece closes again (positive U_{PCS} direction).

Syntax to deselect open profiled tube machining:

#CYL OFF	(modal)

Programming #CYL [EDGES.. OPEN..]

```
…
N3 U0 X0
N4 #CYL [EDGES=4 ROUNDING=5 LENGTH1=60 LENGTH2=45 OPEN=1 CLOSE=2]
N5 G01 G91 X10 F5000
```

To determine the edge numbers for 'OPEN' and 'CLOSE', start with '1 PCS' in the positive PCS direction (clockwise, CW) from 'OPEN' to 'CLOSE' across the profile. This ensures that all profiled parts between 'OPEN' and 'CLOSE' are in the open range.

OPEN=1 / CLOSE=2: -> U open right

OPEN=3 / CLOSE=4 -> U open left

OPEN=1 / CLOSE=3: -> L open right

OPEN=2 / CLOSE=4: -> L open right

NOTICE

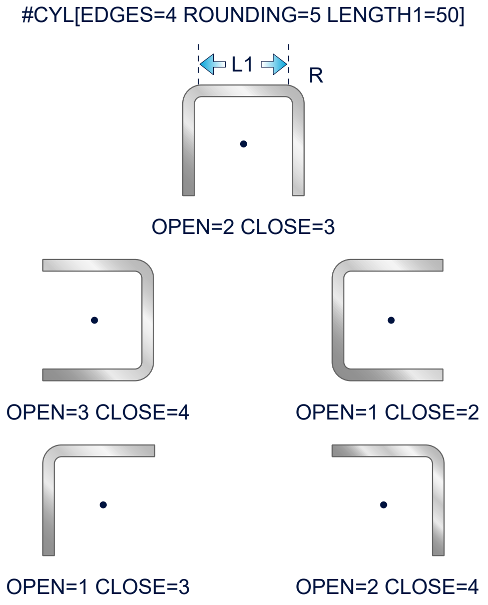
It is only possible to select profile machining if a closed profile edge is orientated towards the tool when the rotating axis is in zero position.

For example the following command is not permitted:

#CYL [EDGES=4 ROUNDING=5 LENGTH1=60 OPEN=4 CLOSE=1]

If it is necessary to cross an open profile edge to the adjacent surface (e.g. if the path to the new target position is shorter), deselect the profile transformation (#CYL OFF) or possibly retract the tool, reposition the rotating axis and repeat selection of the profile transformation with #CYL [EDGES…].

Examples of open profiles



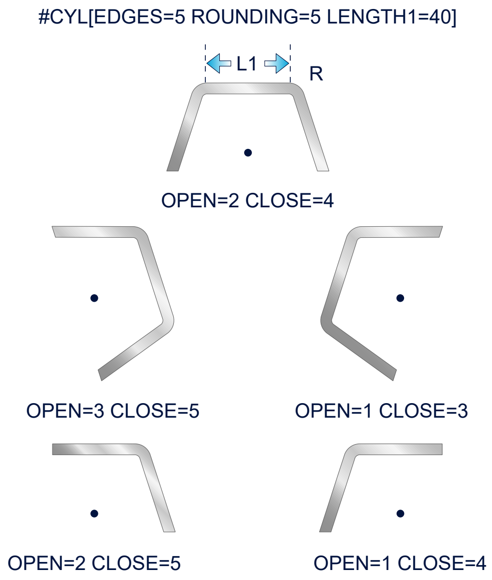


Fig. 40: Examples of programming parameters for open profiles

Profile transformation of square profile

```
(* Polygonal tube transformation, square tube, segmentation at circumference, *)
(* Absolute programming *)
(* Open profile *)

%L SUB_CONT
N[10+P30] G00 G90 X0 Z100 U0
N[20+P30] G162
P1=20  (* Radius inner circle *)
P2=50  (* Radius outer circle *)
P3=22.5
P4=2*P3
G261
$FOR P10=0, 8 , 1
          P6=P10*P4
          P7=SIN[P6]
          P8=COS[P6]
N[40+P10] G01 X[P2*P8] U[P2*P7] F5000
          P20=SIN[P3 + P6]
          P21=COS[P3 + P6]
N[50+P10] G01 X[P1*P21] U[P1*P20] F5000
$ENDFOR
G260
M29

%prof_open_close_.nc
N10 #SLOPE [TYPE=STEP]
N20 G00 X0 Y0 Z100 U0
N25 #CONTOUR MODE[DEV PATH_DEV 2]
N65 G00 G90 Y0 U0
N70 #CYL[EDGES=4 ROUNDING=5 LENGTH1=20 LENGTH2=20 OPEN=2 CLOSE=3]
P30=2000
N80 LL SUB_CONT
N90 #CYL OFF
M30
```

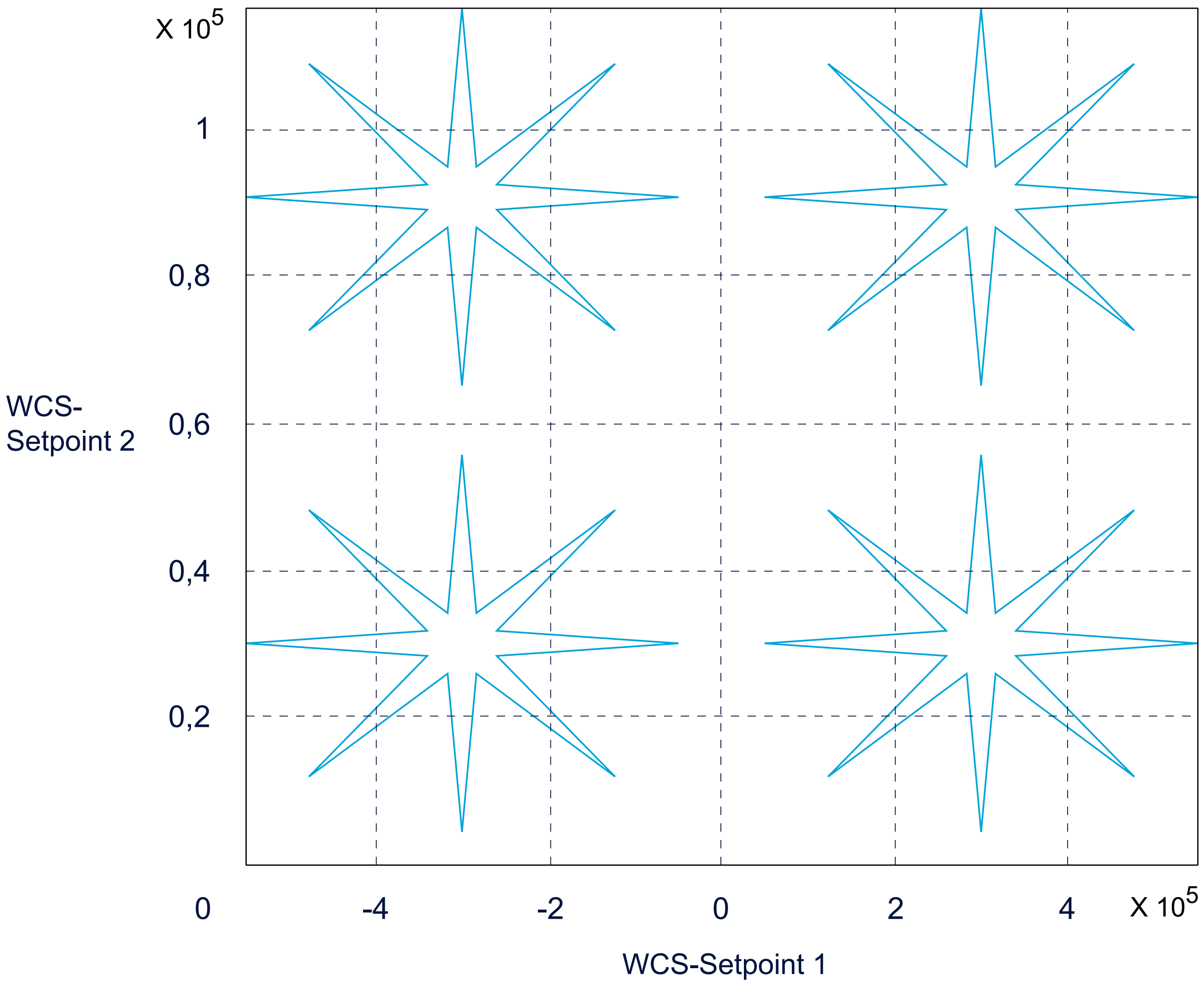
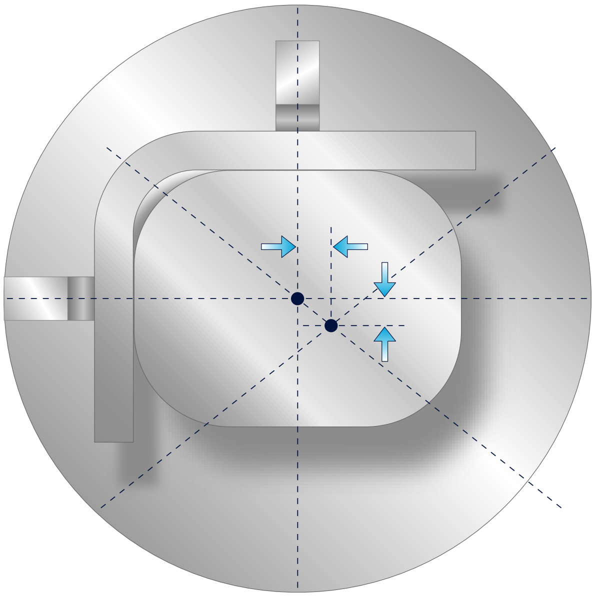


Fig. 41: X-U flat projection of geometry

3.3.4.2 Eccentric rotation centre point

Open edges

When the workpiece is not clamped centrally, it results in an offset between the workpiece centre point and the rotation centre. This offset can be additionally specified when it is selected.



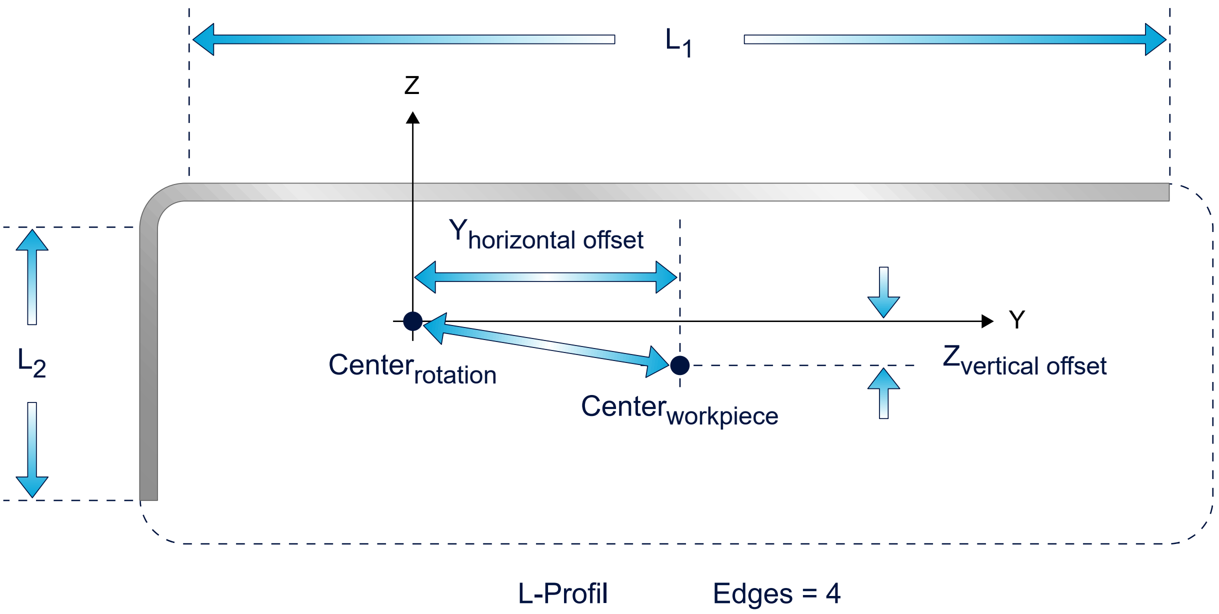


Fig. 42: Defining an open L profile with rotation centre point offset

Syntax to select open profiled tube machining with offset of rotation centre point:

#CYL [EDGES<expr> … CLOSE<expr> [HOR_OFFSET<expr> VERT_OFFSET<expr>]]

EDGES<*expr*> ...	Syntax of profile description
CLOSE<*expr*>	
HOR_OFFSET<*expr*>	Offset of the workpiece centre point in horizontal direction (Y here) towards the actual rotation centre point in [mm, inch].
VERT_OFFSET<*expr*>	Offset of the workpiece centre point in vertical direction (Y here) towards the actual rotation centre point in [mm, inch].

3.4 Machining variants (5/6-axis)

A distinction is made between 2 different machining variants:

- Round tube, lateral surface [▶ 75]
- Polygonal tube, profiled tube [▶ 105]

3.4.1 Round tube, lateral surface

3.4.1.1 6-axis, 2 orientation axes in the tool head available

This function is available as of CNC Build **V2.11.2019.00** .

Combined machining of plate/round tube

The kinematics here consist of 6 axes and are intended for use on machine tools which have an optional tube axis in addition to the 5 axes of a classic plate machining machine.

The machining orientation is defined by the 2 rotation axes in the tool. To machine the tube, the TCP (tool centre point) and the X/Y axis remain positioned above the tube rotation axis. The X/Y position of the TCP remains at the top point of the tube during machining. The path is programmed on the lateral surface by the axes U, Y and X, V. The orientation is programmed dependent on the existing axis structure in the tool head:

- With the structure with machine angle A-B or B-A directly with the assigned angle values, or with the virtual angles C and A.
- Programming is executed directly using angle values CA, CB for the head structure CA, CB. In these cases (virtual or real C axis) the bevel angle can be kept constant to the path using the function "tangential tracking”.

Set one of the following 6-axis configurations. Depending on the machine configuration, the tube axis lies parallel to the X or Y machine axis. This is controlled by the command #CYL ORI LATERAL[..].

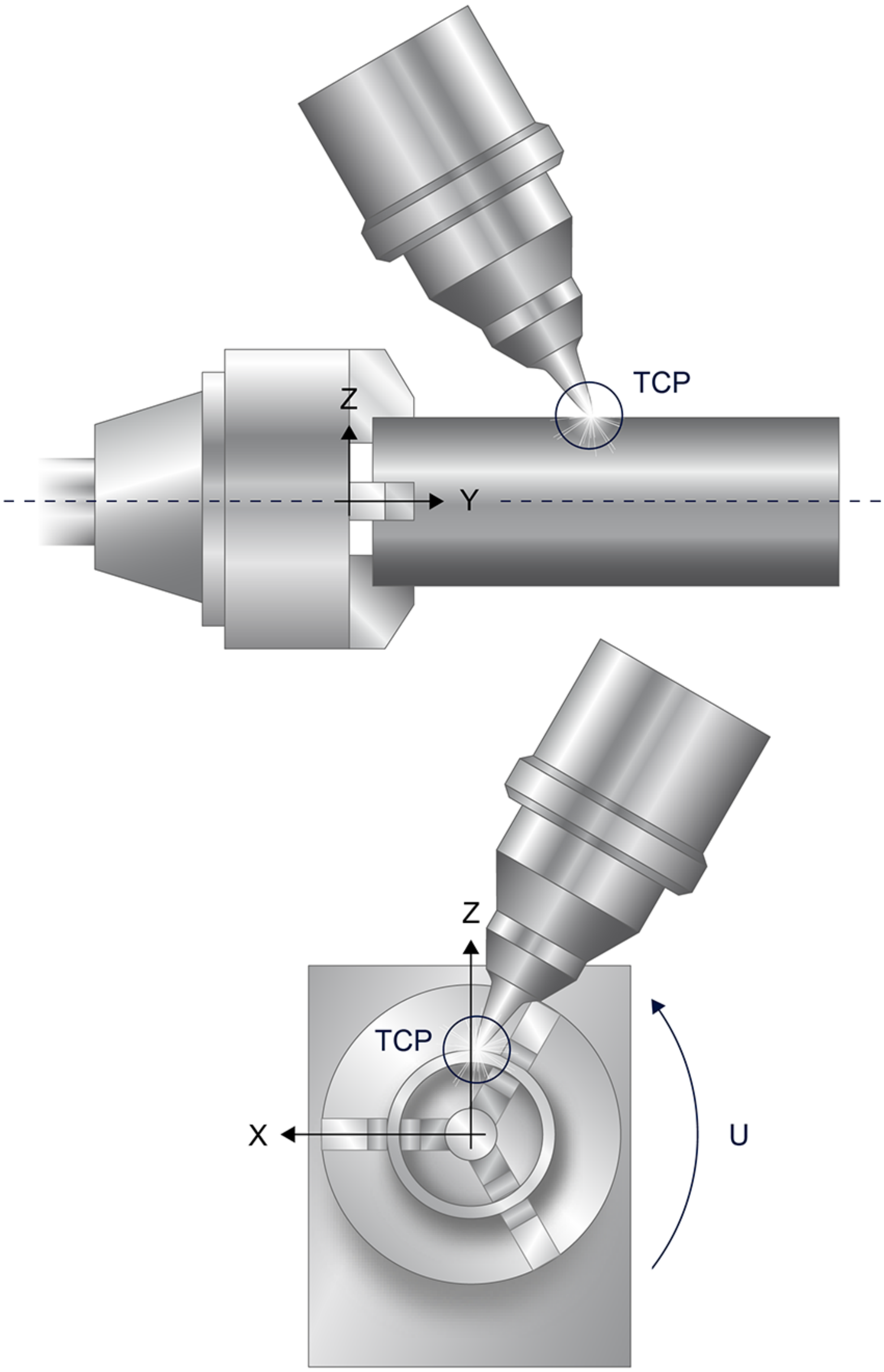


Fig. 43: TCP rotates about the tube centre axis, tube top point

3.4.1.1.1 Tube machining with AB orientation head

Axis configuration in NC channel		
Axis identifier	X, Y, Z, A/(C), B/(A), U	
Axis index	0, 1, 2, 3, 4, 5	
Kinematic structure (ID 90)		
	Tool axes	**Workpiece axes**
NC axes	X, Y, Z, A/(C), B/(A)	U

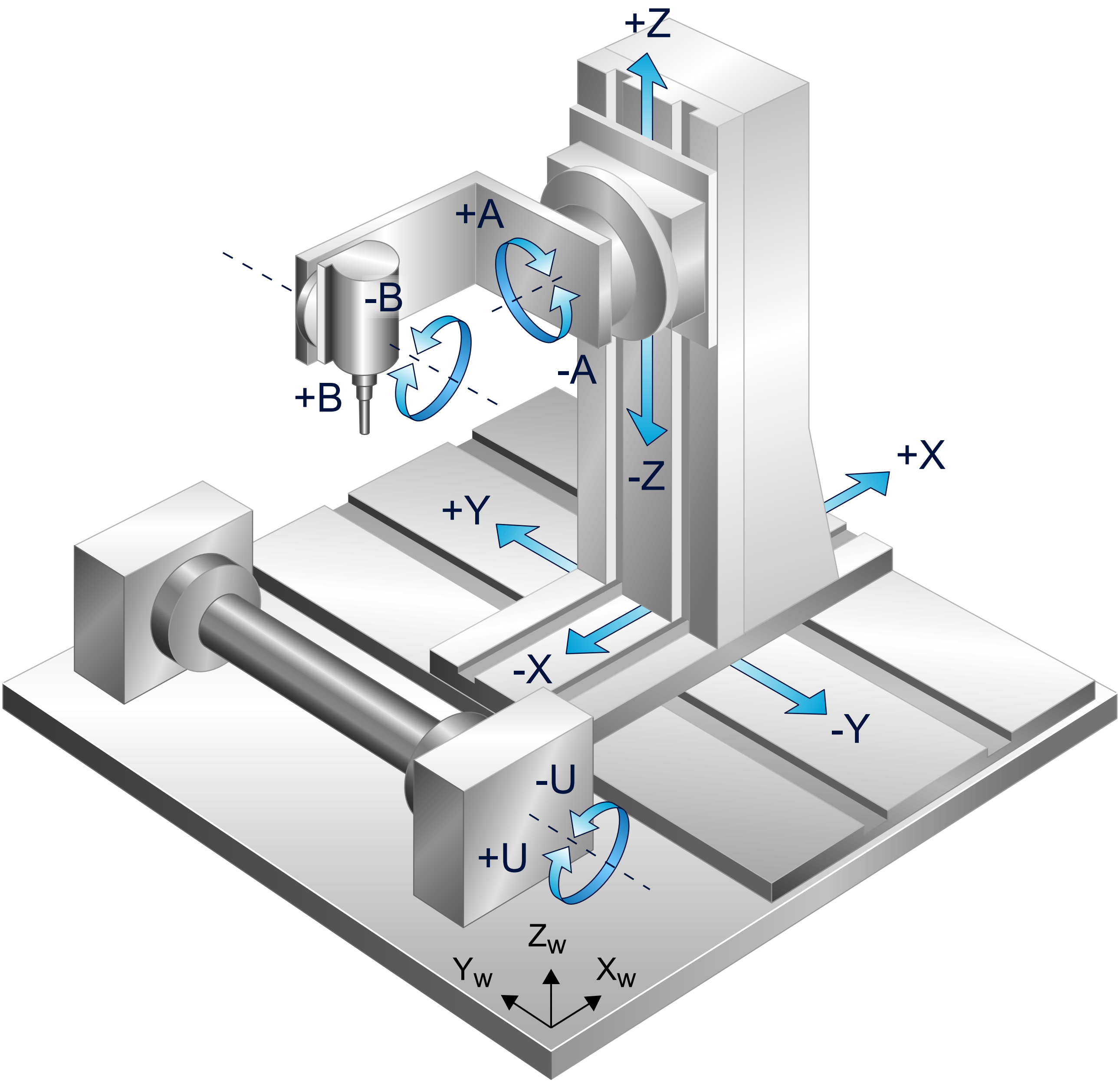


Fig. 44: Lateral surface machining with tube axis parallel to Y

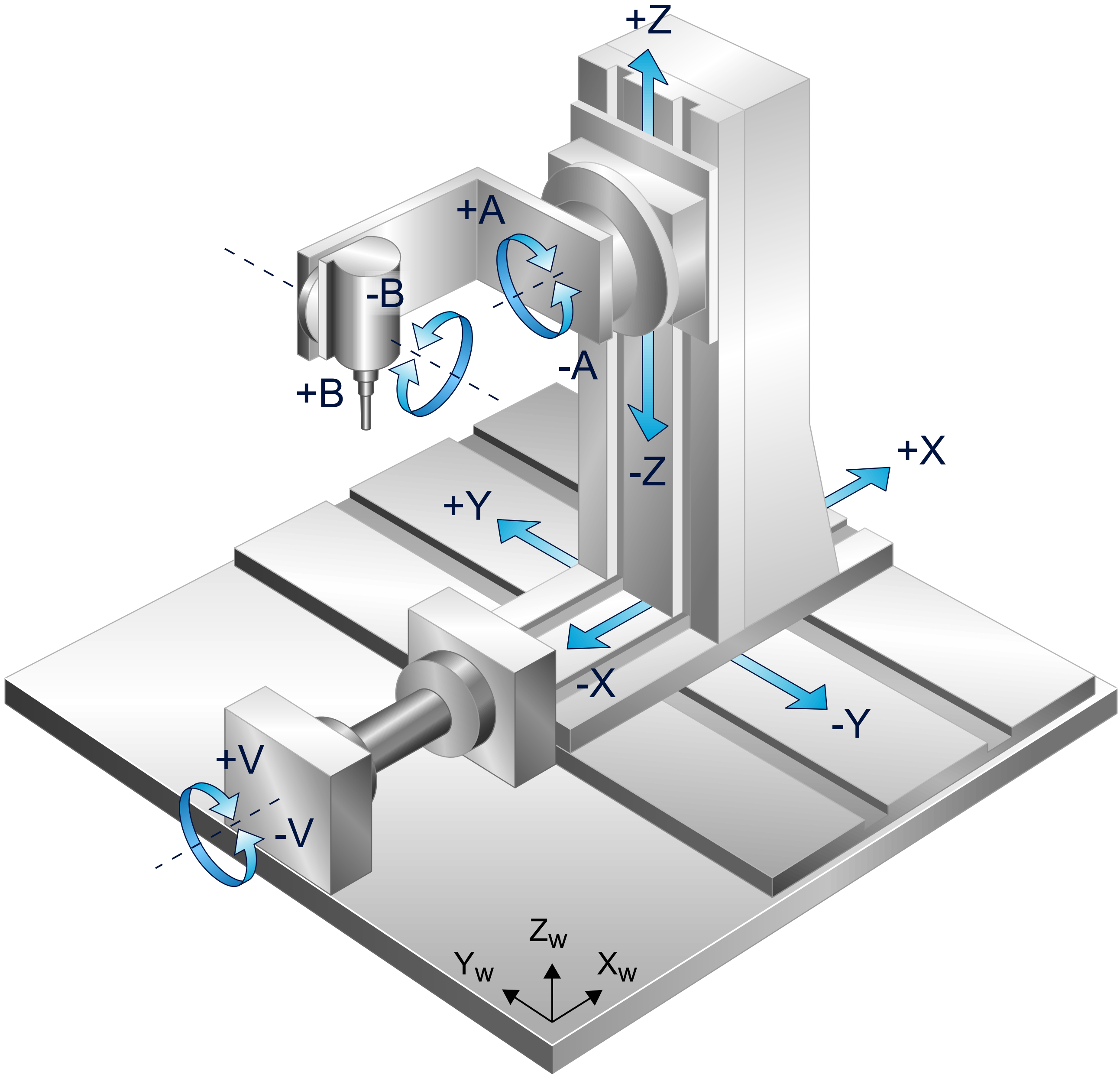


Fig. 45: Lateral surface machining with tube axis parallel to X

3.4.1.1.2 Tube machining with BA orientation head

Axis configuration in NC channel		
Axis identifier	X, Y, Z, B/(C), A/(A), V	
Axis index	0, 1, 2, 3, 4, 5	
Kinematic structure (ID 90)		
	Tool axes	**Workpiece axes**
NC axes	X, Y, Z, B/(C), A/(A)	V

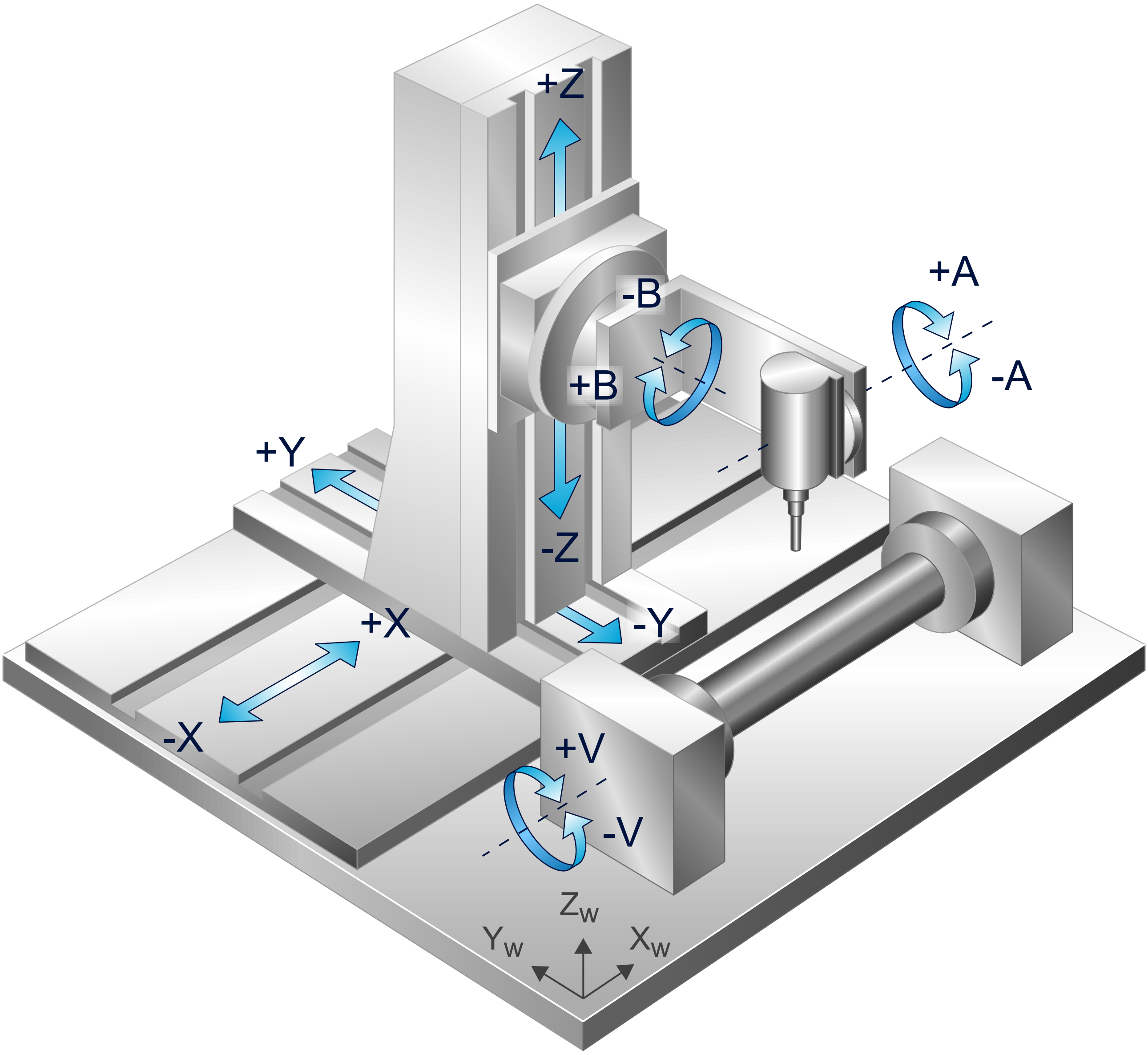


Fig. 46: Lateral surface machining with tube axis parallel to X

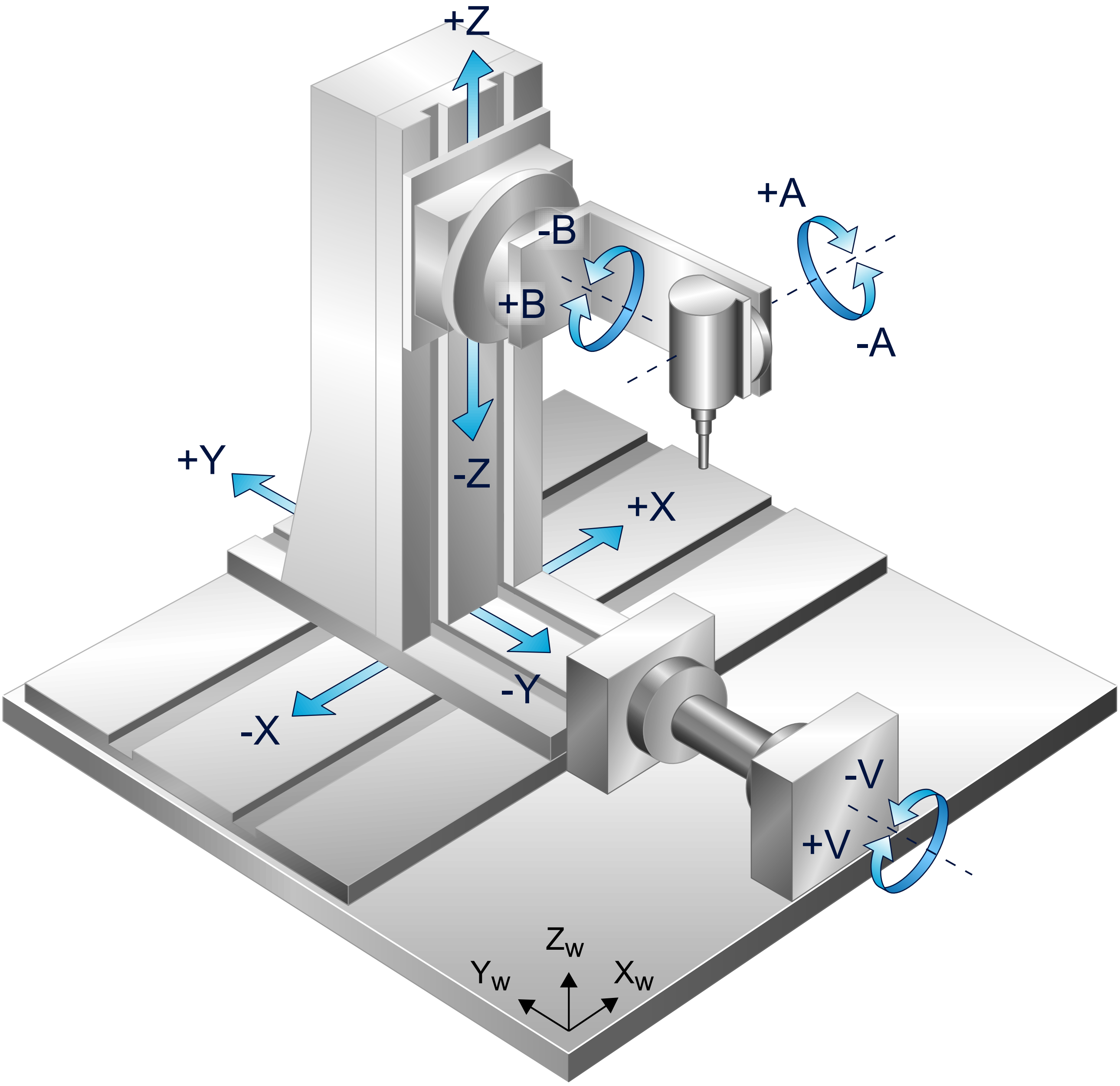


Fig. 47: Lateral surface machining with tube axis parallel to Y

3.4.1.1.3 Tube machining with CA orientation head

Axis configuration in NC channel		
Axis identifier	X, Y, Z, C, A, U	
Axis index	0, 1, 2, 3, 4, 5	
Kinematic structure (ID 90)		
	Tool axes	**Workpiece axes**
NC axes	X, Y, Z, C ,A	U

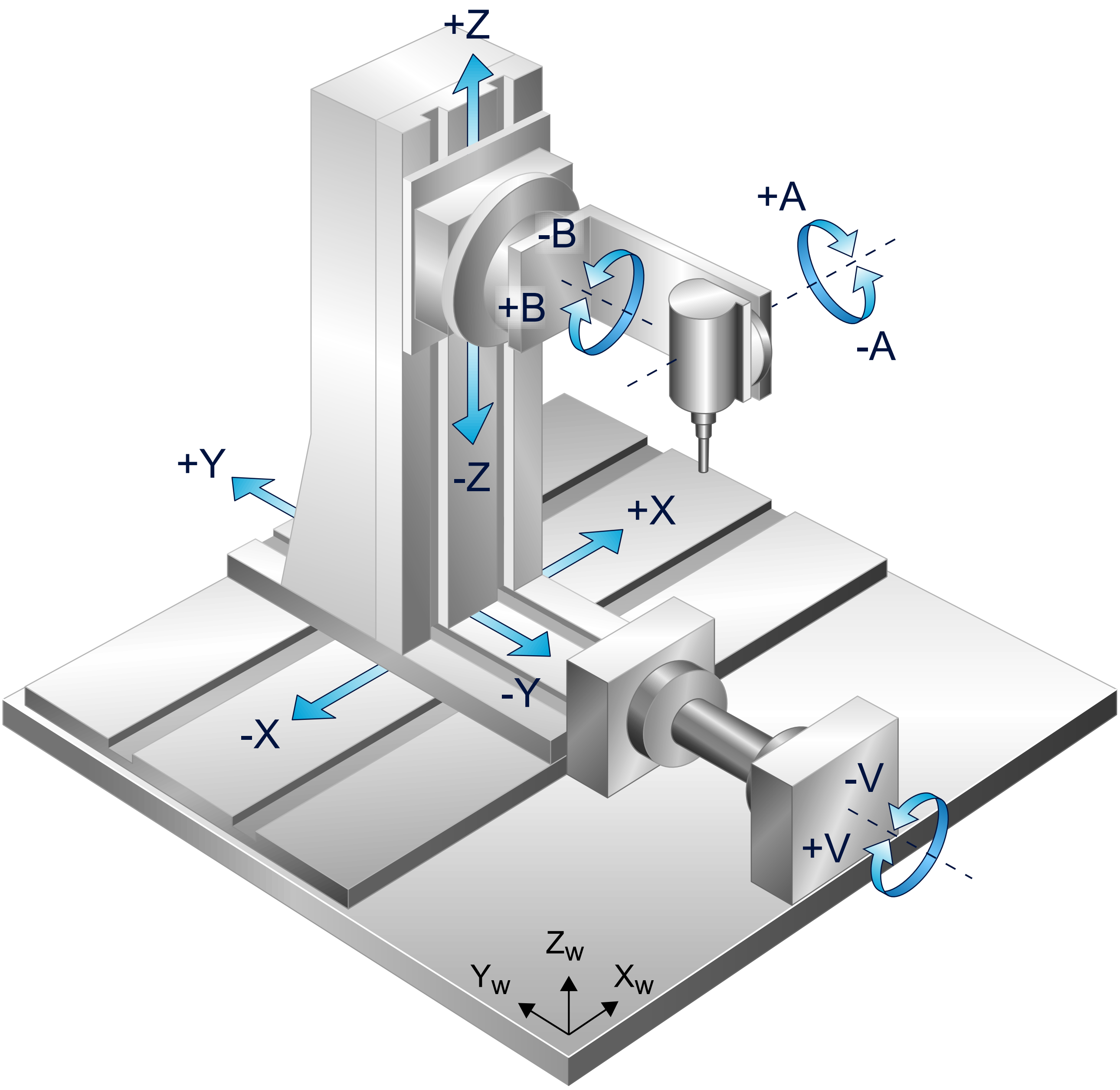


Fig. 48: Lateral surface machining with tube axis parallel to Y

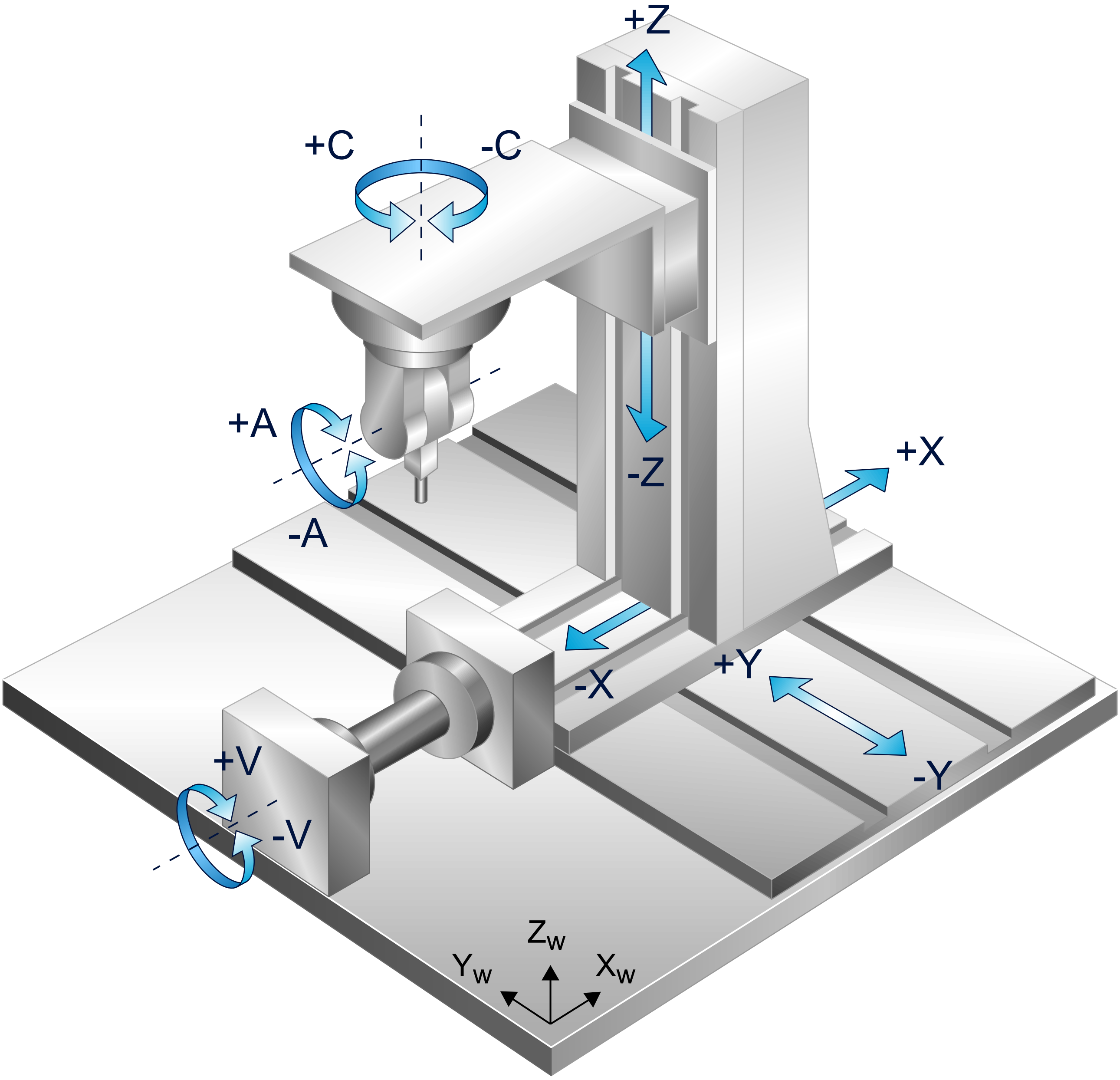


Fig. 49: Lateral surface machining with tube axis parallel to X

3.4.1.1.4 Tube machining with CB orientation head

Axis configuration in NC channel		
Axis identifier	X, Y, Z, C, B, V	
Axis index	0, 1, 2, 3, 4, 5	
Kinematic structure (ID 90)		
	Tool axes	**Workpiece axes**
NC axes	X, Y, Z, C, B	V

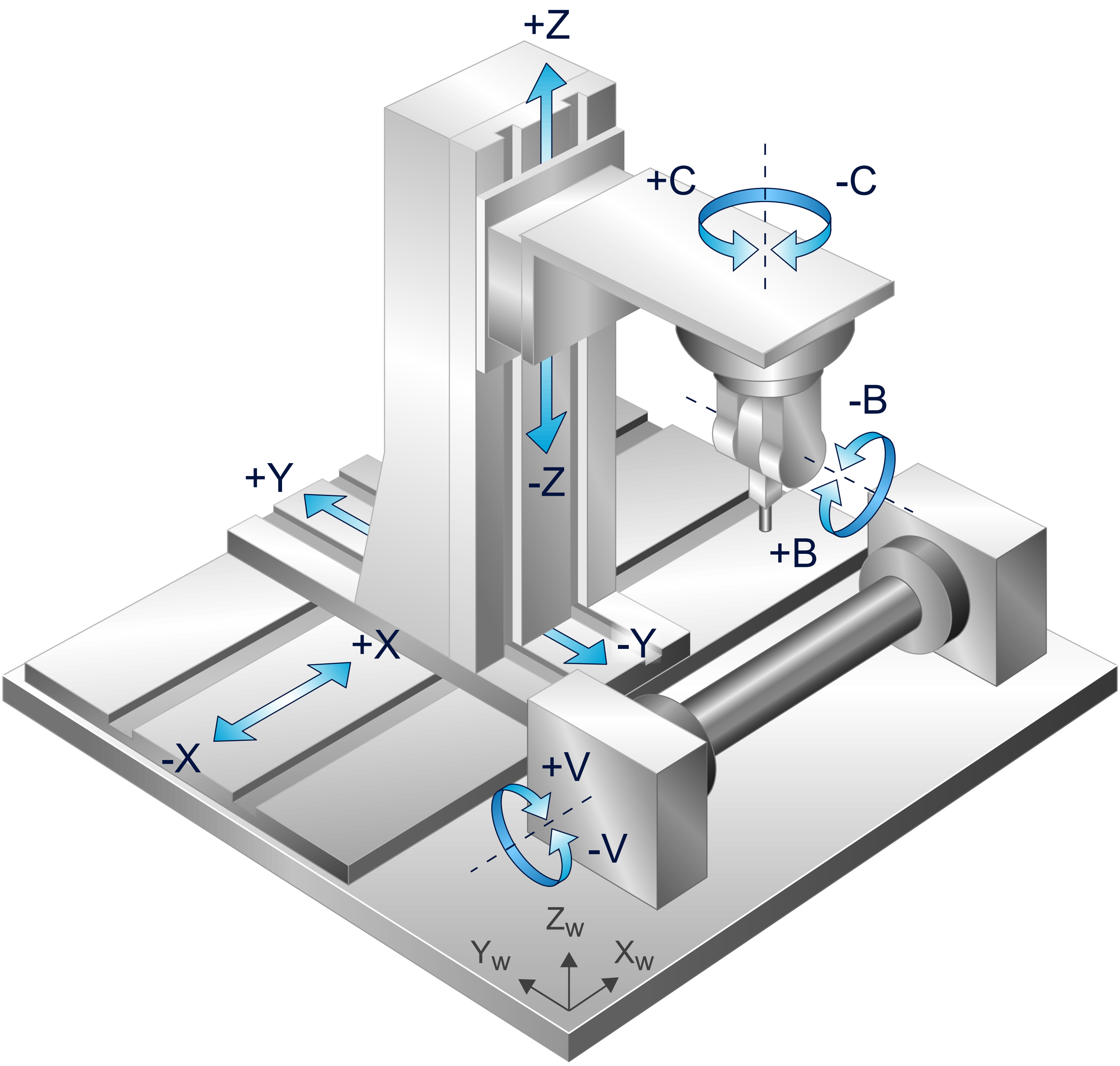


Fig. 50: Lateral surface machining with tube axis parallel to X

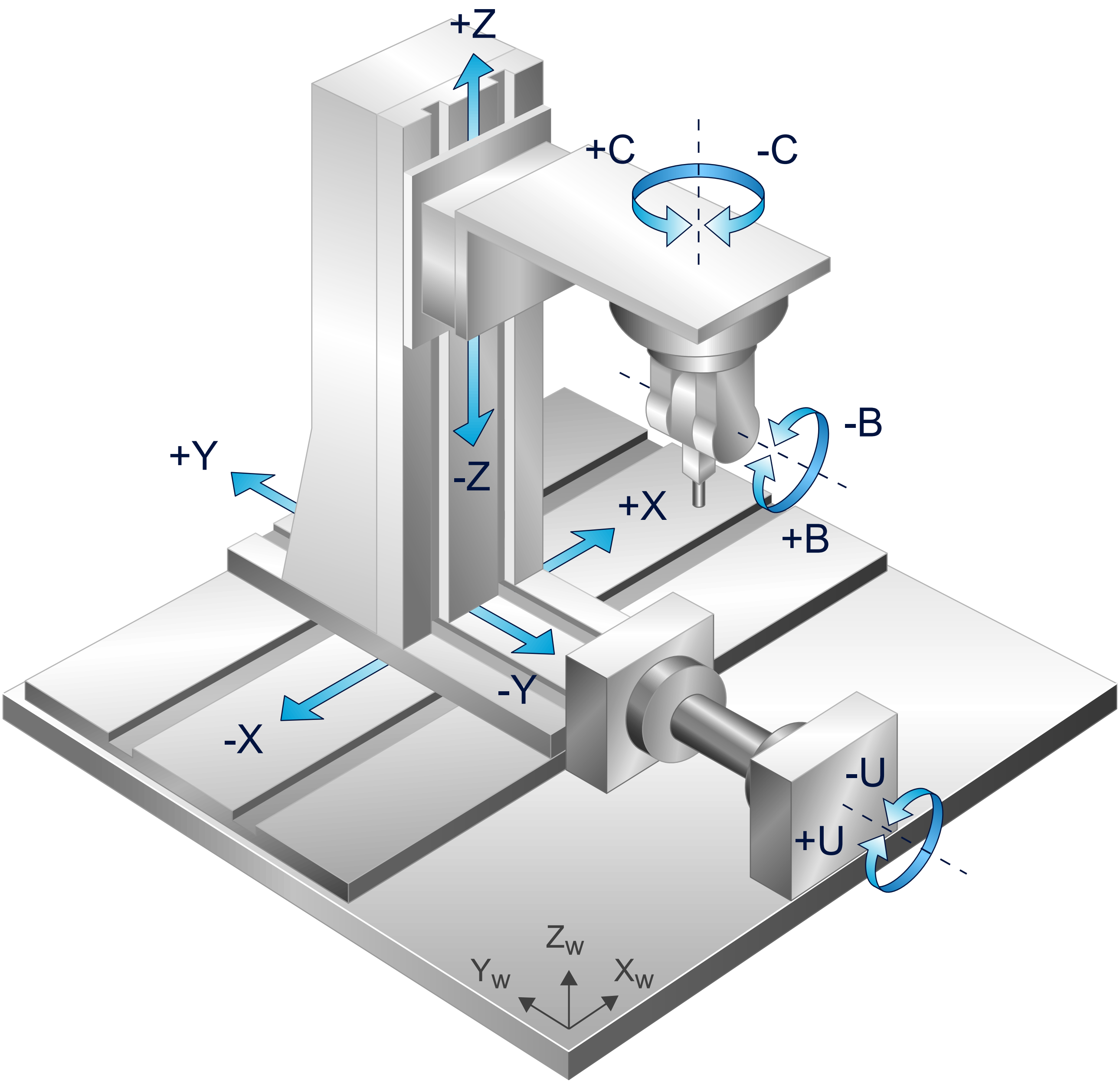


Fig. 51: Lateral surface machining with tube axis parallel to Y

3.4.1.1.5 Tube machining with CA cardanic orientation head

Axis configuration in NC channel		
Axis identifier	X, Y, Z, C, A, U	
Axis index	0, 1, 2, 3, 4, 5	
Kinematic structure (ID 90)		
	Tool axes	**Workpiece axes**
NC axes	X, Y, Z, C ,A	U

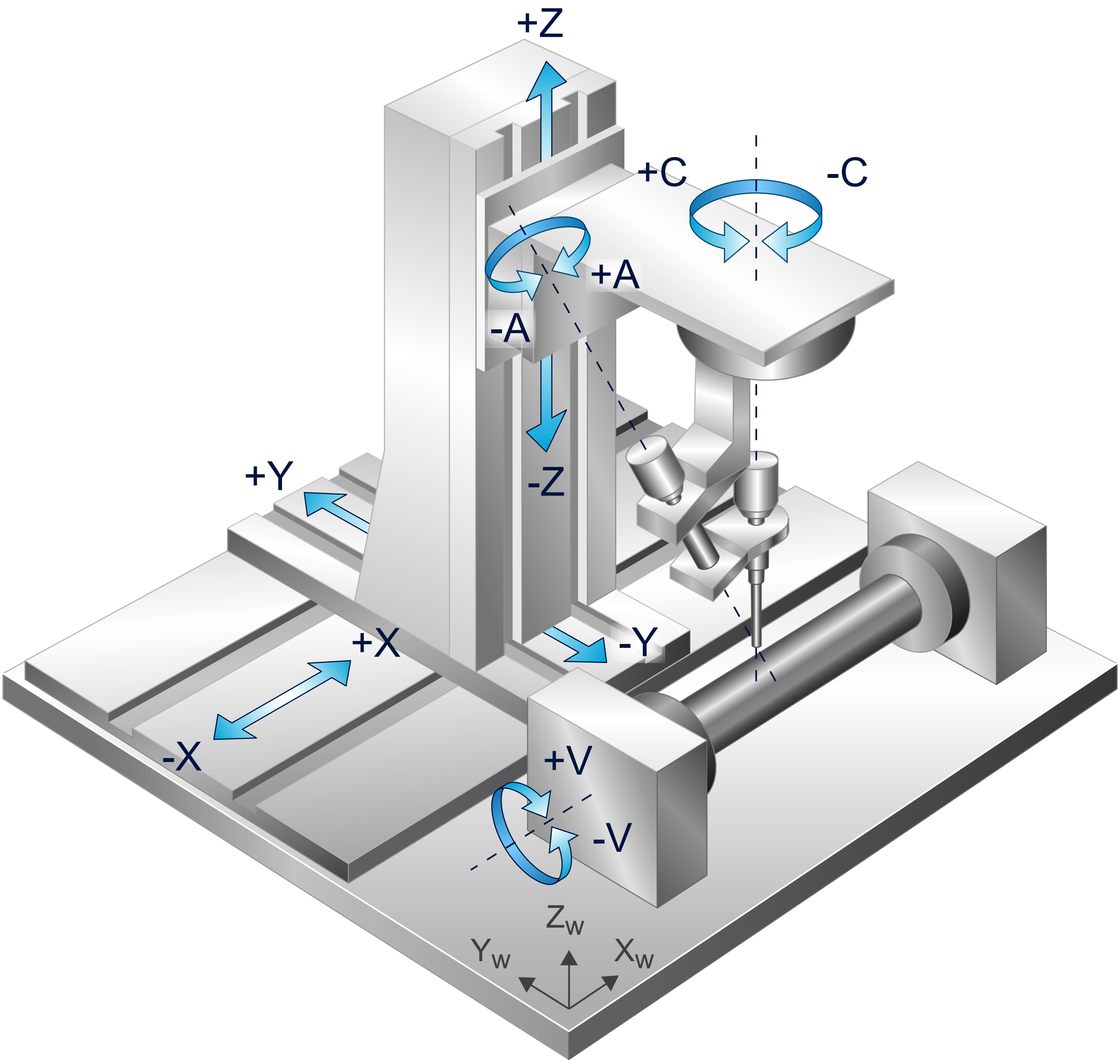


Fig. 52: Lateral surface machining with tube axis parallel to X

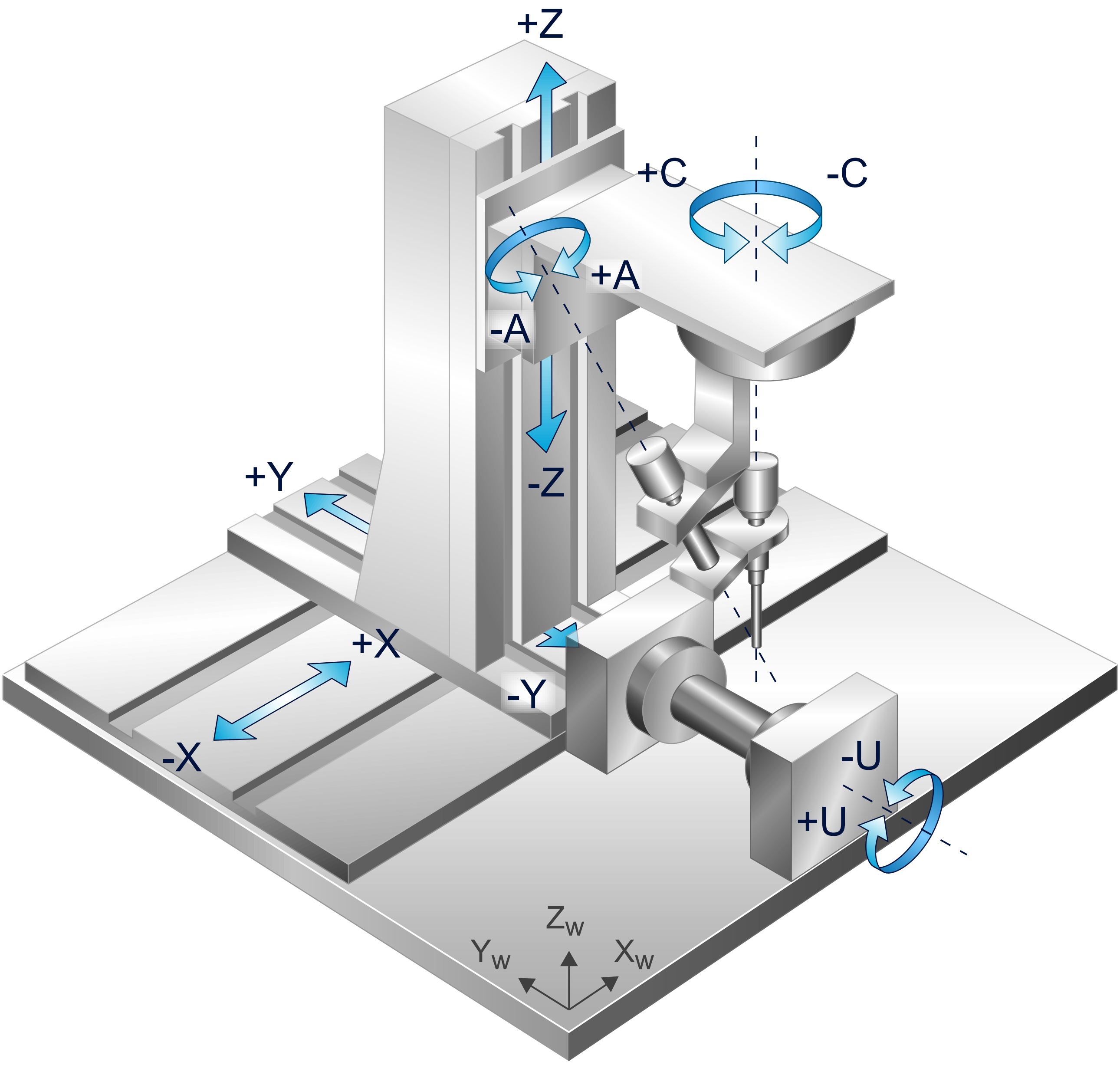


Fig. 53: Lateral surface machining with tube axis parallel to Y

3.4.1.2 5-axis, one orientation axis in both workpiece and tool

This function is available as of CNC Build
V2.11.2807.20 .

Round tube machining

These kinematics are intended for machine tools with 5 machine axes which are specialised for tube machining only.

This requires a configuration of 5 real machine axes and one virtual axis or one simulation axis. The machining orientation is defined by one rotation axis in the tool and one in the workpiece.

The TCP is positioned for tube machining with the X/Y axis above the top point of the tube. As opposed to 6-axis kinematics [▶ 75] the TCP does not remain at the top point of the tube when there is a change in orientation but drifts along the surface of the cylinder. This must be considered to avoid collisions between the workpiece and the tool holder.

The path is programmed on the lateral surface by the axes U, Y and X, V. Orientation is programmed dependent on the existing kinematics.

- A-U or B-V structures are programmed directly using the assigned angle values A-B or B-A.
- When virtual axes CA are used for paremeterisation, these angles are used for programming.

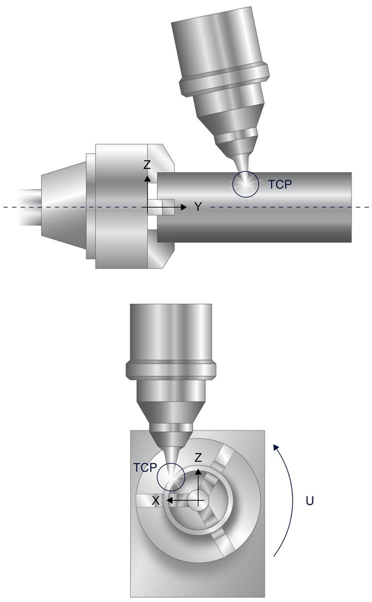


Fig. 54: TCP drifts along the XZ, YZ plane

3.4.1.2.1 Tube machining with AU kinematics

Axis configuration in NC channel		
Axis identifier	X, Y, Z, B*, A, U	
Axis index	0, 1, 2, 3, 4, 5	
Kinematic structure (ID 90)		
	Tool axes	**Workpiece axes**
NC axes	X, Y, Z, B*, A	U

(*) Virtual axis or simulation axis

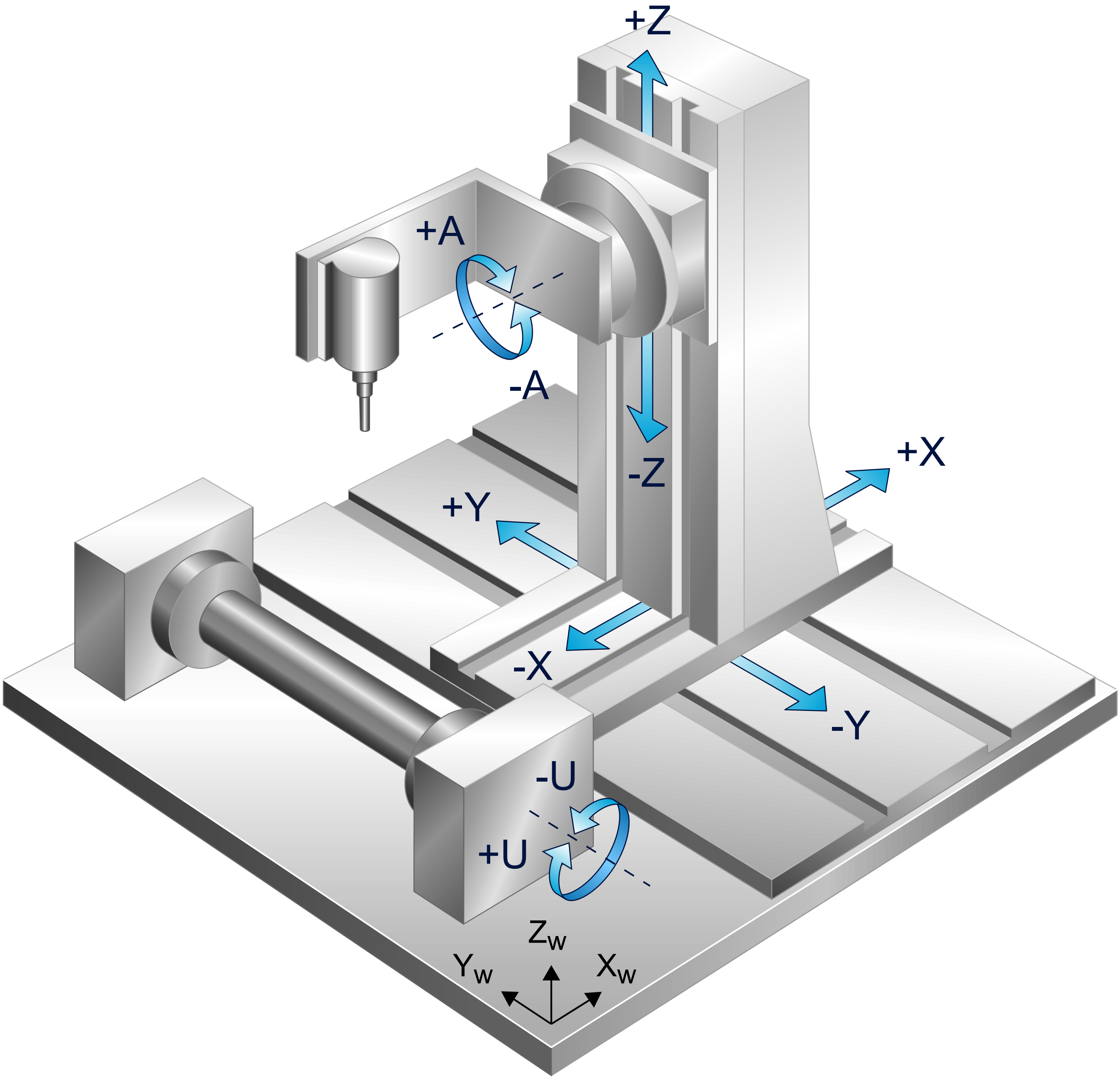


Fig. 55: Lateral surface machining with AU kinematics

3.4.1.2.2 Tube machining with BV kinematics

Axis configuration in NC channel		
Axis identifier	X, Y, Z, A*, B, V	
Axis index	0, 1, 2, 3, 4, 5	
Kinematic structure (ID 90)		
	Tool axes	**Workpiece axes**
NC axes	X, Y, Z, A*, B	V

(*) Virtual axis or simulation axis

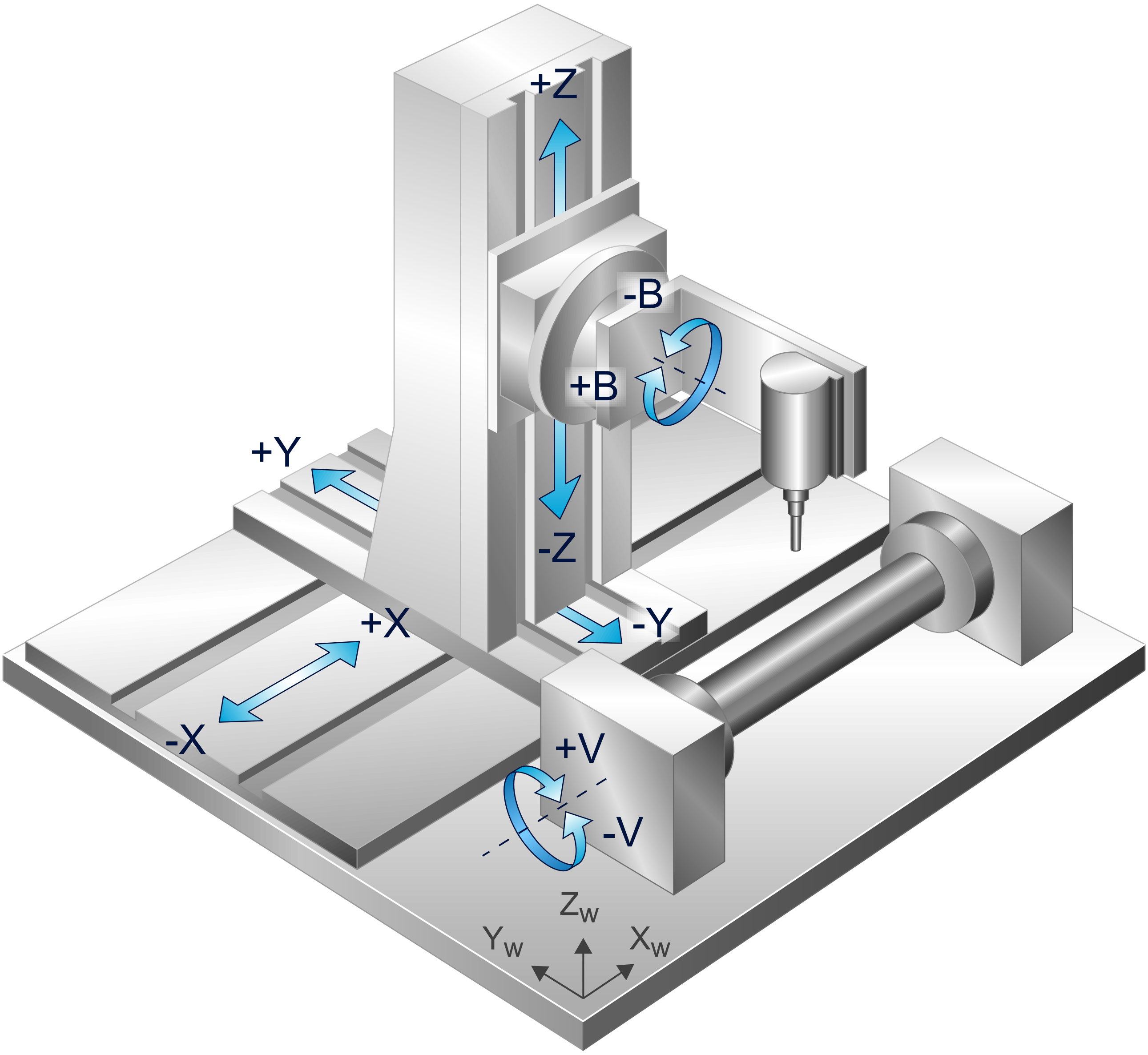


Fig. 56: Lateral surface machining with BV kinematics

3.4.1.3 Programming #CYL ORI LATERAL [..]

Kinematic structure and axis identifiers

Normally the U machine axis rotates about the X axis, the V axis about Y and the W axis about Z. However, the configurations and programming examples differ from this definition. The axis identifiers for the tube system are defined to achieve logical programming in a virtual right-handed G17 lateral surface system. Therefore, tube machining is dependent on the orientation of the tube axis in the U-Y or X-V plane.

Of course, identifiers used in the NC program may also be the name of the rotary axis in **both** cases, e.g. U.

For tube machining the function is selected by the command #CYL ORI LATERAL […]. The kinematic structure is then selected implicitly. A kinematic parameter defines which kinematic structure is activated in the tool head on selection. The sequence of axes during selection defines whether it is a U projection (tube axis is in Y direction) or a V projection (tube axis is in X direction).

The same kinematic can be used for plate machining. Selection takes place using the command #KIN ID[90]; the kinematic is activated by #TRAFO ON. The tube axis U can be programmed as tracking axis.

The programming variant with virtual C-A axis is only required for AB, BA head configurations if the application requires machining at a bevel angle to the path. In this case the tangential tracking function can be activated. For all other head configurations there is a real C machine axis.

3.4.1.3.1 Tube machining

The kinematic parameters in ID 90 [▸ 119] must be set for this machining type.

Syntax for selecting and parameterising, active as of the next motion block:

#CYL ORI LATERAL [AX1<*axis_name*> **| AXNR1**<*expr*> **AX2**<*axis_name*> **| AXNR2**<*expr*>
RADIUS<*expr*> **]**

AX1<*axis_name*>	Axis identifier of the first main axis (X or virtual linear axis U, flat projection)
AXNR1<*expr*>	Logical axis number of first main axis (X or virtual linear axis U, flat projection), positive integer
AX2<*axis_name*>	Axis identifier of the second main axis (Y or virtual linear axis V, flat projection)
AXNR2<*expr*>	Logical axis number of the second main axis (Y or virtual linear axis V, flat projection), positive integer
RADIUS<*expr*>	Tube (bending) radius, [mm, inch]

Syntax for deselection:

#CYL OFF

3.4.1.3.2 Plate machining

A general description is contained in the programming manual in *Section 5-axis functionality* [PROG]:

N10 **#KIN ID[90]** (* Select kinematics *)

N20 **#TRAFO ON** (* Select kinematics *)

N30 G00 X100 Y100 Z10 (* Path motions *)

....

N100 **#TRAFO OFF** (* Deselection *)

For plate machining the tube rotary axis (e.g. U) must be located on index 5 in the axis configuration.

The tube axis (e.g. U) is configured for C axis mode as a rotary modulo axis (operation mode 0x204, see P-AXIS-00015).

3.4.1.4 Examples of tube machining (6-axis)

3.4.1.4.1 AB head, AB programming

```
%L SUB_1
N100 G01 G90 U50 F2000
N150          B15
N200     Y40
N250          B0   A-15
N300 G01                U[-40]
N350          B-15 A0
N400 G01 Y-40
N450          B0 A15
N500 G01                U40
N550         B15 A0
N600 G01 Y0
N700 G01 G90 U20 F2000
N1040 M29
```

```
%tube_5ax
V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 0   (* AB head *)
V.G.KIN[90].PARAM[13] = 0   (* AB programming *)
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N05 #SLOPE [TYPE=TRAPEZ]
N20 #KIN ID[90]
N40 G01 X500 Y0 Z50 A0 B0 F2000
N50 #CYL ORI LATERAL[AX1=U AX2=Y RADIUS=30]
N40 G01 U0 Y0 Z30 A0 B0 F2000
N80 LL SUB_1
N110 #CYL OFF

M30
```

3.4.1.4.2 BA head, BA programming

```
%L SUB_1
N100 G01 G90 U50 F2000
N150          A15
N200     Y40
N250          A0   B-15
N300 G01                U[-40]
N350          A-15 B0
N400 G01 Y-40
N450          A0   B0
N500 G01                U40
N550         A15   B0
N600 G01 Y0
N700 G01 G90 U20 F2000
N1040 M29
```

```
%tube_5ax
V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 1   (* BA head *)
V.G.KIN[90].PARAM[13] = 0   (* BA programming *)
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N05 #SLOPE [TYPE=TRAPEZ]
N20 #KIN ID[90]
N40 G01 X500 Y0 Z50 B0 A0 F2000
N50 #CYL ORI LATERAL[AX1=U AX2=Y RADIUS=30]
N40 G01 U0 Y0 Z30 B0 A0 F2000
N80 LL SUB_1
N110 #CYL OFF

M30
```

3.4.1.4.3 AB head, CA programming

```
%L SUB_1
N100 G01 G90 U50 F2000
N200      Y40
N300  G03 Y50  U40     I-10
N500  G01      U[-40]
N700  G03 Y40  U[-50]  J-10
N900  G01 Y-40
N1100 G03 Y-50 U[-40]  I10
N1300 G01      U40
N1500 G03 Y-40 U50     J10
N1700 G01 Y0
N1900 G01 G90  U20 F2000

N1040 M29
```

```
%tube_5ax

V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 0   (* AB head *)
V.G.KIN[90].PARAM[13] = 1   (* CA programming *)
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N05 #SLOPE [TYPE=TRAPEZ]
N40 G01 X500 Y0 Z50 A0 B0 F2000
N45 #SET AX[X,1,0][Y,2,1][Z,3,2][C,4,3][A,5,4][U,6,5]
N50 #CYL ORI LATERAL[AX1=U AX2=Y RADIUS=30]
N40 G01 U0 Y0 Z30 C0 A15 F2000
N70 #CAXTRACK ON[ANGLIMIT 0.1]
N80 LL SUB_1
N90 #CAXTRACK OFF
N110 #CYL OFF

M30
```

3.4.1.4.4 BA head, CA programming

```
%L SUB_1
N100  G01 G90  U50 F2000
N200      Y40
N300  G03 Y50  U40    I-10
N500  G01      U[-40]
N700  G03 Y40  U[-50] J-10
N900  G01 Y-40
N1100 G03 Y-50 U[-40] I10
N1300 G01      U40
N1500 G03 Y-40 U50    J10
N1700 G01 Y0
N1900 G01 G90  U20 F2000

N1040 M29
```

```
%tube_5ax

V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 1    (* AB head *)
V.G.KIN[90].PARAM[13] = 1    (* CA programming *)
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N05 #SLOPE [TYPE=TRAPEZ]
N40 G01 X500 Y0 Z50 A0 B0 F2000
N45 #SET AX[X,1,0][Y,2,1][Z,3,2][C,4,3][A,5,4][U,6,5]
N50 #CYL ORI LATERAL[AX1=U AX2=Y RADIUS=30]
N40 G01 U0 Y0 Z30 C0 A15 F2000
N70 #CAXTRACK ON[ANGLIMIT 0.1]
N80 LL SUB_1
N90 #CAXTRACK OFF
N110 #CYL OFF

M30
```

3.4.1.4.5 CA head, CA programming

```
%L SUB_1
N100  G01 G90 U50 F2000
N200      Y40
N300  G03 Y50   U40     I-10
N500  G01       U[-40]
N700  G03 Y40   U[-50]  J-10
N900  G01 Y-40
N1100 G03 Y-50  U[-40]  I10
N1300 G01       U40
N1500 G03 Y-40  U50     J10
N1700 G01 Y0
N1900 G01 G90 U20 F2000

N1040 M29
```

```
%tube_5ax

V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 2   (* CA head *)
V.G.KIN[90].PARAM[13] = 0
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N05 #SLOPE [TYPE=TRAPEZ]
N40 G01 X500 Y0 Z50 C0 A0 F2000
N45 #SET AX[X,1,0][Y,2,1][Z,3,2][C,4,3][A,5,4][U,6,5]
N50 #CYL ORI LATERAL[AX1=U AX2=Y RADIUS=30]
N40 G01 U0 Y0 Z30 C0 A15 F2000
N60 #CAXTRACK ON[ANGLIMIT 0.1]
N70 LL SUB_1
N80 #CAXTRACK OFF
N90 #CYL OFF

M30
```

3.4.1.4.6 CB Kopf, CB Programmierung

```
%L SUB_1
N100 G01 G90    U50 F2000
N200       Y40
N300  G03 Y50   U40    I-10
N500  G01       U[-40]
N700  G03 Y40   U[-50] J-10
N900  G01 Y-40
N1100 G03 Y-50  U[-40] I10
N1300 G01       U40
N1500 G03 Y-40  U50    J10
N1700 G01 Y0
N1900 G01 G90   U20 F2000

N1040 M29
```

```
%tube_5ax

V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 4   (* CA head *)
V.G.KIN[90].PARAM[13] = 0
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N05 #SLOPE [TYPE=TRAPEZ]
N40 G01 X500 Y0 Z50 C0 B0 F2000
N45 #SET AX[X,1,0][Y,2,1][Z,3,2][C,4,3][B,5,4][U,6,5]
N50 #CYL ORI LATERAL[AX1=U AX2=Y RADIUS=30]
N40 G01 U0 Y0 Z30 C0 B15 F2000
N60 #CAXTRACK ON[ANGLIMIT 0.1]
N70 LL SUB_1
N80 #CAXTRACK OFF
N90 #CYL OFF

M30
```

3.4.1.4.7 CA cardanic head, CA programming

```
%L SUB_1
N100 G01 G90   U50 F2000
N200       Y40
N300  G03 Y50  U40    I-10
N500  G01      U[-40]
N700  G03 Y40  U[-50] J-10
N900  G01 Y-40
N1100 G03 Y-50 U[-40] I10
N1300 G01      U40
N1500 G03 Y-40 U50    J10
N1700 G01 Y0
N1900 G01 G90  U20 F2000

N1040 M29
```

```
%tube_5ax

V.G.KIN[90].PARAM[0] = 0
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 450000
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 8   (* CA cardan head *)
V.G.KIN[90].PARAM[13] = 0
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N05 #SLOPE [TYPE=TRAPEZ]
N40 G01 X500 Y0 Z50 C0 B0 F2000
N45 #SET AX[X,1,0][Y,2,1][Z,3,2][C,4,3][A,5,4][U,6,5]
N50 #CYL ORI LATERAL[AX1=U AX2=Y RADIUS=30]
N40 G01 U0 Y0 Z30 C0 B15 F2000
N60 #CAXTRACK ON[ANGLIMIT 0.1]
N70 LL SUB_1
N80 #CAXTRACK OFF
N90 #CYL OFF

M30
```

3.4.1.5 Examples of plate machining (6-axis)

3.4.1.5.1 AB Kopf, CA Programming

```
%t_tube
V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 0   AB Kopf
V.G.KIN[90].PARAM[13] = 1   (* CA programming *)
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N10 #SLOPE [TYPE=TRAPEZ]
N20 #KIN ID[90]
N30 G01 X0 Y0 Z0 A0 C0 U0 F2000
N40 #SET AX[X,1,0][Y,2,1][Z,3,2][C,4,3][A,5,4][U,7,5]
N45 #CONTOUR MODE[DEV PATH_DEV 0.1 TRACK_DEV 1]

N50 #TRAFO ON
N55 G01 U0 X0 Y0 Z0 C0 A45
N56 #CAXTRACK ON[ANGLIMIT 1]

N57 G261
N58  G01 G91 X50
N60  G90 G02 J-30
N61  G01 G91 X50
N62 G260
N63 #CAXTRACK OFF

N80 #TRAFO OFF

N90 M30
```

3.4.1.5.2 AB Kopf, AB Programming

```
%t_tube
V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 0   AB Kopf
V.G.KIN[90].PARAM[13] = 0   (* AB programming *)
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N10 #SLOPE [TYPE=TRAPEZ]
N20 #KIN ID[90]
N30 G01 X0 Y0 Z0 A0 C0 U0 F2000
N40 #SET AX[X,1,0][Y,2,1][Z,3,2][A,4,3][B,5,4][U,7,5]
N45 #CONTOUR MODE[DEV PATH_DEV 0.1 TRACK_DEV 1]

N50 #TRAFO ON
N55 G01 U0 X0 Y0 Z0 A0 B45

N57 G261
N58  G01 G91 X50
N60  G90 G02 J-30
N61  G01 G91 X50
N62 G260

N80 #TRAFO OFF

N90 M30
```

3.4.1.6 Examples of tube machining (5-axis)

3.4.1.6.1 AU kinematics, BA programming

```
(* B is simulation axis *)

%L SUB_1
N570 G261
N580  G01 G90 Y50 B15
N600  G90 G02 J-30
N610  G01 G90 Y-50 B-15
N620  G90 G02 J-30
N630  G01 G91 Y50 B0
N640 G260
M29


%t_tube
V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 9  (* Kinematic 9: A WZ, U  10: B WZ, V *)
V.G.KIN[90].PARAM[13] = 0  (* Progr. orientation 0: same as Kin. 1: CA *)
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N05 #SLOPE [TYPE=STEP]
N10 #SET AX[X,1,0][Y,2,1][Z,3,2][B,4,3][A,5,4][U,6,5]

N20 G01 X0 Y0 Z150 A0 B0 U0 F2000
N30 #CONTOUR MODE[DEV PATH_DEV 0.1 TRACK_DEV 1]
N40 #CYL ORI LATERAL[AX1=U AX2=Y RADIUS=25]
N50 G01 U0 X0 Y0 Z30 A0 B0
N60 LL SUB_1
N120 #CYL OFF

M30
```

3.4.1.6.2 BV kinematics, AB programming

```
(* A is simulation axis *)

%L SUB_1
N570 G261
N580  G90 G01 X50 A15
N600      G02 J-30
N610      G01 X-50 A-15
N600      G02 J-30
N610      G01  X50 A0
N620 G260
M29

%t_tube
V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 10  (* Kinematic 9: A-U  10: B-V *)
V.G.KIN[90].PARAM[13] = 0   (* Progr. orientation 0: same as Kin 1: CA *)
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N05 #SLOPE [TYPE=STEP]
N10 #SET AX[X,1,0][Y,2,1][Z,3,2][A,4,3][B,5,4][V,6,5]
N20 G01 X0 Y0 Z150 A0 B0 V0 F2000
N30 #CONTOUR MODE[DEV PATH_DEV 0.1 TRACK_DEV 1]

N40 #CYL ORI LATERAL[AX1=X AX2=V RADIUS=25]
N50 G01 V0 X0 Y0 Z30 A0 B0
N60 LL SUB_1
N120 #CYL OFF

M30
```

3.4.1.6.3 AU kinematics, CA programming

```
(* C is simulation axis *)

%L SUB_1
N570 G261
N575          A15
N580  G01 G90 U50
N590          Y50
N600          U0
N610          Y0
N620          U[-50]
N630          Y-50
N640          U0
N650          Y0
N620 G260
M29


%t_tube
V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 9  (* Kinematic 9: A-U  10: B-V *)
V.G.KIN[90].PARAM[13] = 1  (* Progr. orientation 0: same as Kin. 1: CA *)
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N05 #SLOPE [TYPE=STEP]
N10 #SET AX[X,1,0][Y,2,1][Z,3,2][C,4,3][A,5,4][U,6,5]
N20 G01 X0 Y0 Z150 C0 A0 U0 F2000
N30 #CONTOUR MODE[DEV PATH_DEV 0.1 TRACK_DEV 1]

N40 #CYL ORI LATERAL[AX1=U AX2=Y RADIUS=25]
N50 G01 U0 X0 Y0 Z30 C0 A0
N56 #CAXTRACK ON[AX=C ANGLIMIT 0.1]
N60 LL SUB_1
N70 #CAXTRACK OFF
N110 #CYL OFF

M30
```

3.4.1.6.4 BV kinematics, CA programming

```
(* C is simulation axis *)

%L SUB_1
N570 G261
N575          A15
N580  G01 G90 X50
N590          V50
N600          X0
N610          V0
N620          X-50
N630          V[-50]
N640          V0
N650          X0
N620 G260
M29

%t_tube
V.G.KIN[90].PARAM[0] = 1000000
V.G.KIN[90].PARAM[1] = 0
V.G.KIN[90].PARAM[2] = 0
V.G.KIN[90].PARAM[3] = 0
V.G.KIN[90].PARAM[4] = 0
V.G.KIN[90].PARAM[5] = 0
V.G.KIN[90].PARAM[6] = 0
V.G.KIN[90].PARAM[7] = 0
V.G.KIN[90].PARAM[8] = 0
V.G.KIN[90].PARAM[9] = 0
V.G.KIN[90].PARAM[10] = 0
V.G.KIN[90].PARAM[11] = 0
V.G.KIN[90].PARAM[12] = 10  (* Kinematic 9: A-U  10: B-V *)
V.G.KIN[90].PARAM[13] = 1   (* Progr. orientation 0: same as Kin 1: CA *)
V.G.KIN[90].PARAM[14] = 0
V.G.KIN[90].PARAM[15] = 0
V.G.KIN[90].PARAM[16] = 0
V.G.KIN[90].PARAM[17] = 0

N05 #SLOPE [TYPE=STEP]
N10 #SET AX[X,1,0][Y,2,1][Z,3,2][C,4,3][A,8,4][V,7,5]

N20 G01 X0 Y0 Z150 C0 A0 V0 F2000
N30 #CONTOUR MODE[DEV PATH_DEV 0.1 TRACK_DEV 1]

N40 #CYL ORI LATERAL[AX1=X AX2=V RADIUS=25]
N50 G01 V0 X0 Y0 Z30 C0 A0

N56 #CAXTRACK ON[AX=C ANGLIMIT 1]
N60 LL SUB_1
N70 #CAXTRACK OFF

N80 #CYL OFF

M30
```

3.4.2 Polygonal tube, profiled tube

Machining with 5-axis head

The Kinematic 93 [▸ 132] is provided for profiled tube machining with 5-axis heads. It is activated implicitly when tube machining is selected. Its configuration is described in the section "Polygonal tube, profiled tube, (5/6-axis) [▸ 132]".

5-axis heads supported

The Kinematic 93 [▸ 132] also supports all 5-axis heads described in the section "Round tube, lateral surface [▸ 75]".

> One restriction is that the tube axis must always be parallel to the X axis. This explains why the command #CYL ORI PROFILE [...] has no options to specify the axes.

3.4.2.1 Programming #CYL ORI PROFILE [..]

> The kinematic parameters in ID 93 [▸ 132] must be set for this machining type.

Syntax for selecting and parameterising, active as of the next motion block:

#CYL ORI PROFILE [EDGES<*expr*> **ROUNDING**<*expr*> **LENGTH1**<*expr*> [**LENGTH2**<*expr*>] [**VEL**<*expr*>] [**ACC**<*expr*>] **]** (modal)

EDGES<*expr*>	Number of edges (corners) of the profiled tube, positive integer The minimum number of corners on the profile is limited to 3 and the maximum number to 16.
ROUNDING<*expr*>	Edge rounding radius (corner radius), [mm, inch].
LENGTH1<*expr*>	Side length for symmetrical tubes or first side length for rectangular tubes, [mm, inch]
LENGTH2<*expr*>	Second side length for rectangular tubes, [mm, inch]
VEL<*expr*>	Path velocity on edge rounding [mm/min]
ACC<*expr*>	Path acceleration on edge rounding [mm/min²]

Syntax for deselection:

#CYL OFF (modal)

#CYL ORI PROFILE [..]

```
(Symmetrical square profile with 100 mm edge length)
(and 10 mm edge rounding radius)
N10 #CYL ORI PROFILE [EDGES=4 ROUNDING=10 LENGTH1=100]
...

(Rectangular tube with edge lengths of 100 mm)
(and 80 mm and 15 mm edge rounding radius)
N10 #CYL ORI PROFILE [EDGES=4 ROUNDING=15 LENGTH1=100 LENGTH2=80]
...

(Reduced path dynamics on the profile rounding)
N10 #CYL ORI PROFILE [EDGES=4 ... LENGTH2=50 ACC=1000000]
```

3.4.2.2 Program example with AB tool head configuration

This configuration contains 6 real axes.

```
N010 ; configuration of AB orientation head
N020 V.G.KIN[93].PARAM[0] = 0 ; Z offset to the tool fixing point
N030 V.G.KIN[93].PARAM[1] = 10000 ; X offset to the tool fixing point
N040 V.G.KIN[93].PARAM[2] = 20000 ; Y offset to the tool fixing point
N050 V.G.KIN[93].PARAM[3] = 30000 ; X offset rotation point A axis - rotation point B axis
N060 V.G.KIN[93].PARAM[4] = 31415 ; Y offset rotation point A axis - rotation point B axis
N070 V.G.KIN[93].PARAM[5] = 27181 ; Z offset rotation point A axis - rotation point B axis
N080 V.G.KIN[93].PARAM[6] = -1234 ; X offset zero point - rotation point A axis
N090 V.G.KIN[93].PARAM[7] = 17 ; Y offset zero point - rotation point A axis
N100 V.G.KIN[93].PARAM[8] = 100 ; Z offset zero point - rotation point A axis
N110 V.G.KIN[93].PARAM[11] = 1000 ; angle offset U/V axis
N120 V.G.KIN[93].PARAM[12] = 0 ; 0 = AB head
N130 V.G.KIN[93].PARAM[13] = 0 ; 0 = PCS programming same as head
N140 V.G.KIN[93].PARAM[14] = 0 ; rotation direction AM positive
N150 V.G.KIN[93].PARAM[15] = 0 ; rotation direction BM positive
N160 V.G.KIN[93].PARAM[16] = 200 ; angle offset AM
N170 V.G.KIN[93].PARAM[17] = 100 ; angle offset BM
N200 ; configuration of profile tube
N230 V.G.KIN[93].PARAM[23] = 513 ; Z offset rotary axis U to machine zero point
N240 V.G.KIN[93].PARAM[24] = 1000 ; X offset rotary axis U to machine zero point
N250 V.G.KIN[93].PARAM[25] = -5000 ; Y offset rotary axis U to machine zero point
N260
N270 ; sort axes
N280 #SET AX [X, 1, 0][Y, 2, 1][Z, 3, 2][A, 4, 3][B, 5, 4][U, 6, 5]
N290
N300 ; move to zero
N310 G00 G90 X0 Y0 Z0 A0 B0 U0
N320
N330 ; select kinematic 93
N340 #KIN ID[93]
N350
```

```
N360 ; start processing
N370 G01 X500 Y0 Z50 A0 B0 F2000
N380 #CYL ORI PROFILE [EDGES = 4 ROUNDING = 10 LENGTH1 = 50]
N390 G01 X0 U0 Z30 A0 B0 F2000
N400 G01 G90 U50 F2000
N410 B15
N420 X40
N430 B0 A-15
N440 G01 U-40
N450 B-15 A0
N460 G01 X-40
N470 A15 B0
N480 G01 U40
N490 B15 A0
N500 G01 X0
N510 G01 G90 U20 F2000
N520 #CYL OFF
N530
N540 ; end program
N550 M30
```

3.4.2.3 Program example with BV configuration:

This configuration contains 5 real axes. The A axis included is a virtual simulation axis.

```
%L SUB_GEOM
N570 G261
N575          B=15 F200
N580  G01 G90 X50 F5000
N590          G91 U100
N600          G90 X0
N610          G91 U-100
N620          G90 X-100
N630          G91 U-100
N640          G91 U100
N650          G90 X0
N660          G90 B=0
N620 G260
M29

%t_edge_prof_5ax_BV.nc
N9  ;
N10  V.G.KIN[93].PARAM[0]  = 1000000
N11  V.G.KIN[93].PARAM[1]  = 0
N12  V.G.KIN[93].PARAM[2]  = 0
N13  V.G.KIN[93].PARAM[3]  = 0
N14  V.G.KIN[93].PARAM[4]  = 0
N15  V.G.KIN[93].PARAM[5]  = 0
N16  V.G.KIN[93].PARAM[6]  = 0
N17  V.G.KIN[93].PARAM[7]  = -942000
N18  V.G.KIN[93].PARAM[8]  = 0
N21  V.G.KIN[93].PARAM[11]  = 0
N22  V.G.KIN[93].PARAM[12] = 10  (* 10: B WZ, V *)
N23  V.G.KIN[93].PARAM[13]  = 0
N24  V.G.KIN[93].PARAM[14]  = 0
N25  V.G.KIN[93].PARAM[15]  = 0
N26  V.G.KIN[93].PARAM[16]  = 0
N27  V.G.KIN[93].PARAM[17]  = 0
N33  V.G.KIN[93].PARAM[23]  = 0
N34  V.G.KIN[93].PARAM[24]  = 0
N35  V.G.KIN[93].PARAM[25]  = 0

N10 #SET SLOPE PROFIL[1]
N20 G00 X0 Y0 Z250
N30 #CONTOUR MODE[DEV PATH_DEV 0.1 TRACK_DEV 1]

N40 #SET AX[X,1,0][Y,2,1][Z,3,2][A,4,3][B,5,4][U,6,5]
N50 G00 X0 Y94.2 Z250 A0 B0 U0
N60 #CYL ORI PROFILE[EDGES=4 ROUNDING=5 LENGTH1=50 LENGTH2=50]
(* Profile circumference approx. 231.41592 mm *)

N70 LL SUB_GEOM

N90 #CYL OFF
M30
```

3.5 Parameter

Parameterisation

The workpiece parameters are defined in the NC program. The following parameters are offset values of the kinematic structure, parameters for the rotary axis and optionally applicable M/H codes.

3.5.1 Overview

3.5.1.1 Channel parameters

The following kinematic parameters must be assigned function-specific for machining variants.

ID	Parameter	Description
P-CHAN-00094	kinematik[i].param[j]	<spezifische Kinematikparameter>

The following parameters are optional for profiled tube machining. The M/H numbers are defined for output at the rounding transition of the profiled tube.

ID	Parameter	Description
P-CHAN-00249	tube_profile.techno_nr_rnd_on	M/H number, entering edge rounding
P-CHAN-00250	tube_profile.techno_nr_rnd_off	M/H number, leaving edge rounding
P-CHAN-00251	tube_profile.techno_type	0 = M, 1 = H

3.5.1.2 Axis parameters

The U rotary axis must be set by the following parameters.

ID	Parameter	Value	Description
P-AXIS-00015	axis mode	0x0000 0204	Axis defined as U rotary axis for lateral surface, projection and profiled tube machining.
P-AXIS-00126	moduloo	3600000	Definition of upper modulo limit
P-AXIS-00127	modulou	0	Definition of lower modulo limit

3.5.2 Description

3.5.2.1 Round tube, lateral surface (kinematic ID 15)

P-CHAN-00094	Offset parameters of the kinematics		
Description	Offsets and attributes of kinematic 15		
Parameter	kinematik[15].param[i]		
Data type	REAL64		
Data range	**HD offset**	**param[i]**	**Meaning**
	HD1	0	Z offset tool clamping point tool carrier reference point (WZBP)
	HD2	1	Rot. Angle offset of rotary axis
	HD3	2	X offset tool clamping point tool carrier reference point
	HD4	3	-
	HD5	4	Z offset of rotary axis U to machine zero point (MNP)
	HD6	5	X offset of rotary axis U to machine zero point
	-	-	-
	HD10	9	PCS modulo calculation 0: inactive, 1: active
Dimension	0.1 µm or 0.0001° (for offsets)		
Default value	0		
Remarks	Parameters are defined under the ID 15 of the kinematics offsets. If required, PCS modulo calculation can be activated by the parameter HD10 (kinematik[15].param[9]).		

The general description is contained in the channel parameter list under P-CHAN-00094

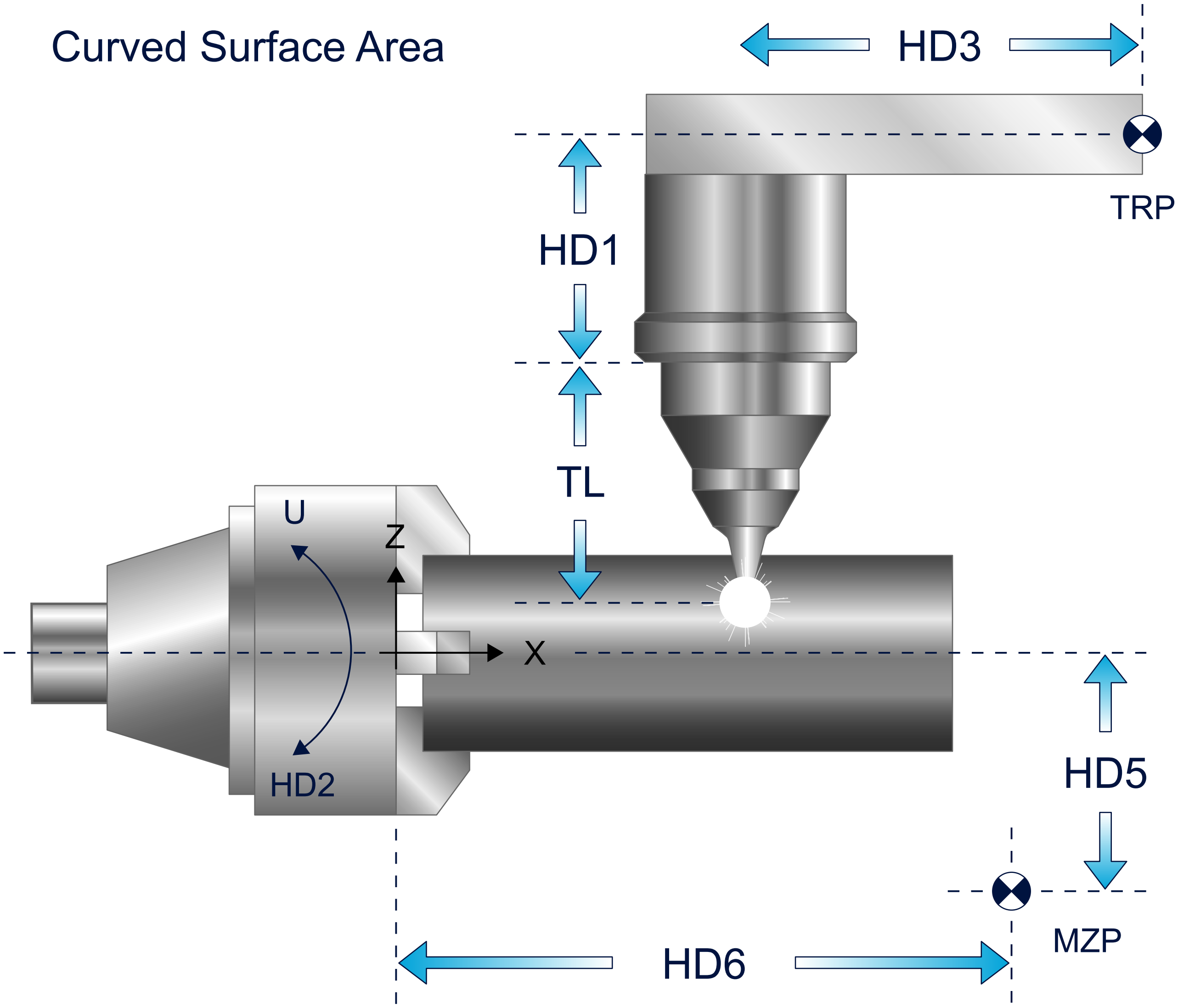


Fig. 57: Kinematic offsets for lateral surface machining

3.5.2.2 Round tube, projection (kinematic ID 78)

P-CHAN-00094	Offset parameters of the kinematic		
Description	Offsets and attributes of kinematic 78		
Parameter	kinematik[78].param[i]		
Data type	REAL64		
Data range	**HD offset**	**param[i]**	**Meaning**
	HD1	0	Z offset tool clamping point tool carrier reference point (WZBP)
	HD2	1	X offset tool clamping point tool carrier reference point
	HD3	2	Y offset tool clamping point tool carrier reference point
	HD4	3	-
	HD5	4	Z offset of rotary axis U to machine zero point (MNP)
	HD6	5	X offset of rotary axis U to machine zero point
	HD7	6	Y offset of rotary axis U to machine zero point
Dimension	0.1µm bzw. 0.0001° (bei Versätzen)		
Default value	0		
Remarks	The parameters are defined under ID 78 of the kinematic offsets. With regard to modulo calculation, the U axis is handled depending on the MDS setting in the axis.		

The general description is contained in the channel parameter list under P-CHAN-00094.

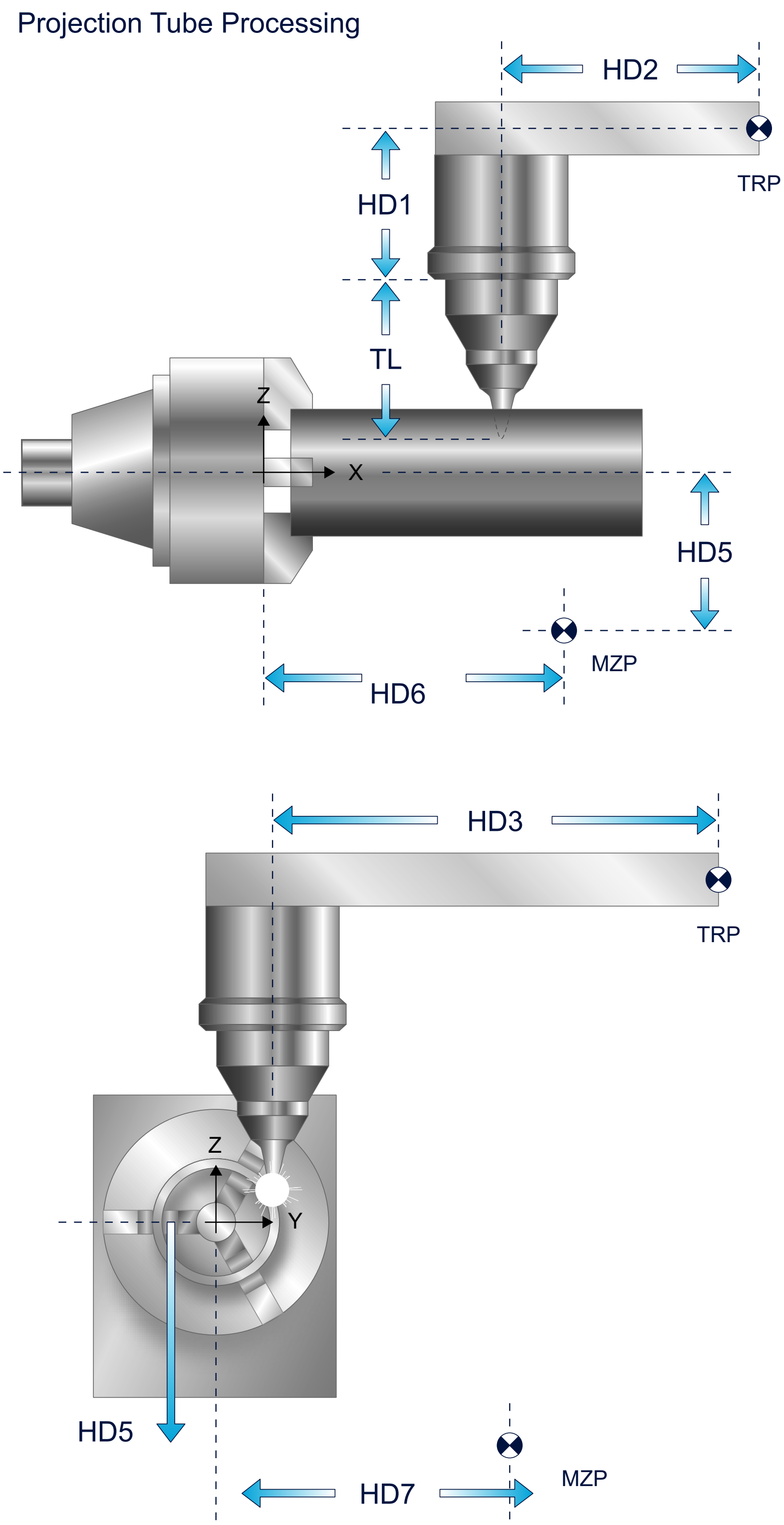


Fig. 58: Tube projection transformation kinematics offsets

3.5.2.3 Polygonal tube, profiled tube (kinematic ID 79)

P-CHAN-00094	Offset parameters of the kinematic		
Description	Offsets and attributes of kinematic 79		
Parameter	kinematik[79].param[i]		
Data type	REAL64		
Data range	**HD offset**	**param[i]**	**Meaning**
	HD1	0	Z offset tool clamping point tool carrier reference point (WZBP)
	HD2	1	X offset tool clamping point tool carrier reference point
	HD3	2	Y offset tool clamping point tool carrier reference point
	HD4	3	Z offset of rotary axis U to machine zero point (MNP)
	HD5	4	X offset of rotary axis U to machine zero point
	HD6	5	Y offset of rotary axis U to machine zero point
	HD7	6	-
	HD8	7	Workpiece clamp position
Dimension	0.1µm bzw. 0.0001° (bei Versätzen)		
Default value	0		
Remarks	The parameters are defined under ID 79 of the kinematic offsets. A modulo compensation is always executed for the U axis.		

The general description is contained in the channel parameter list under P-CHAN-00094.

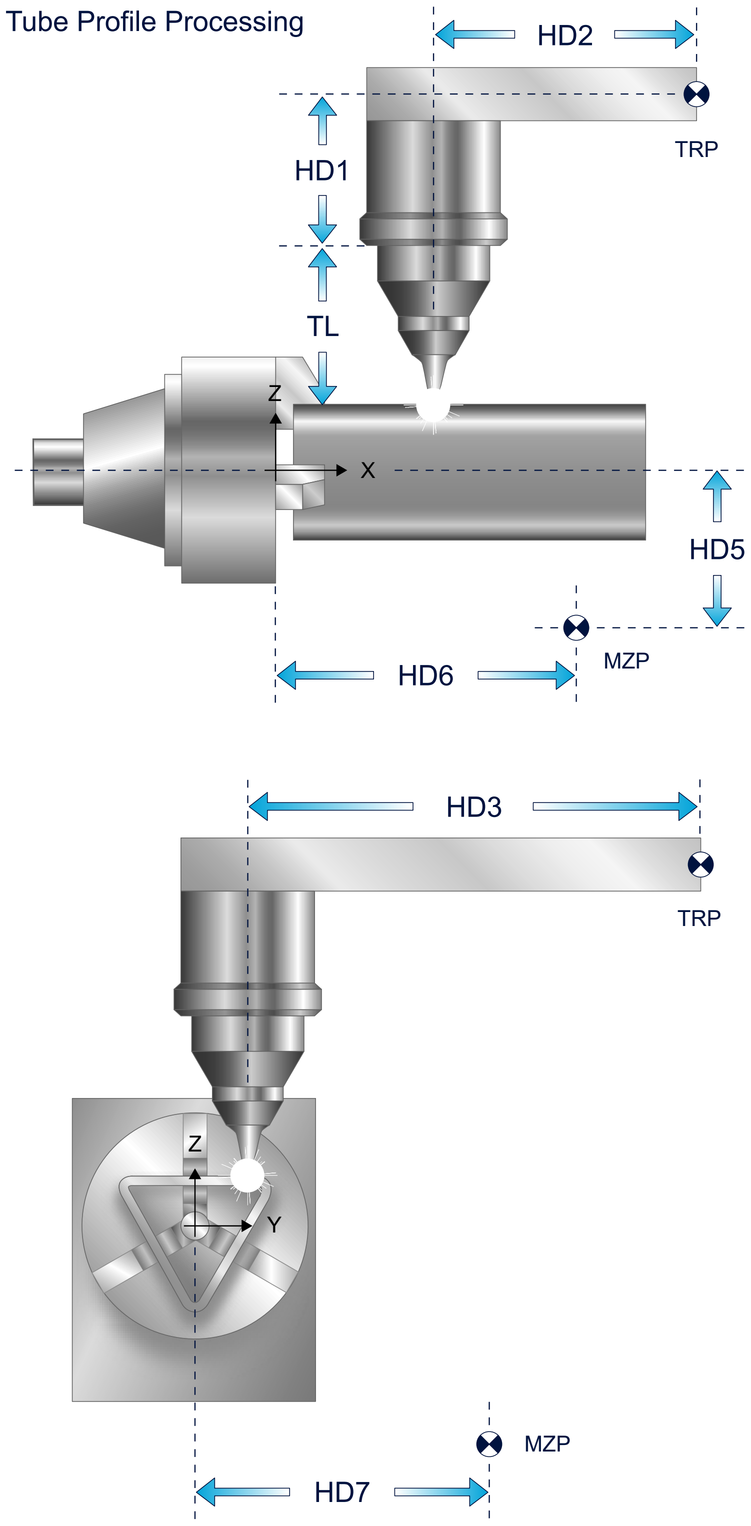


Fig. 59: Profiled tube transformation kinematics offsets

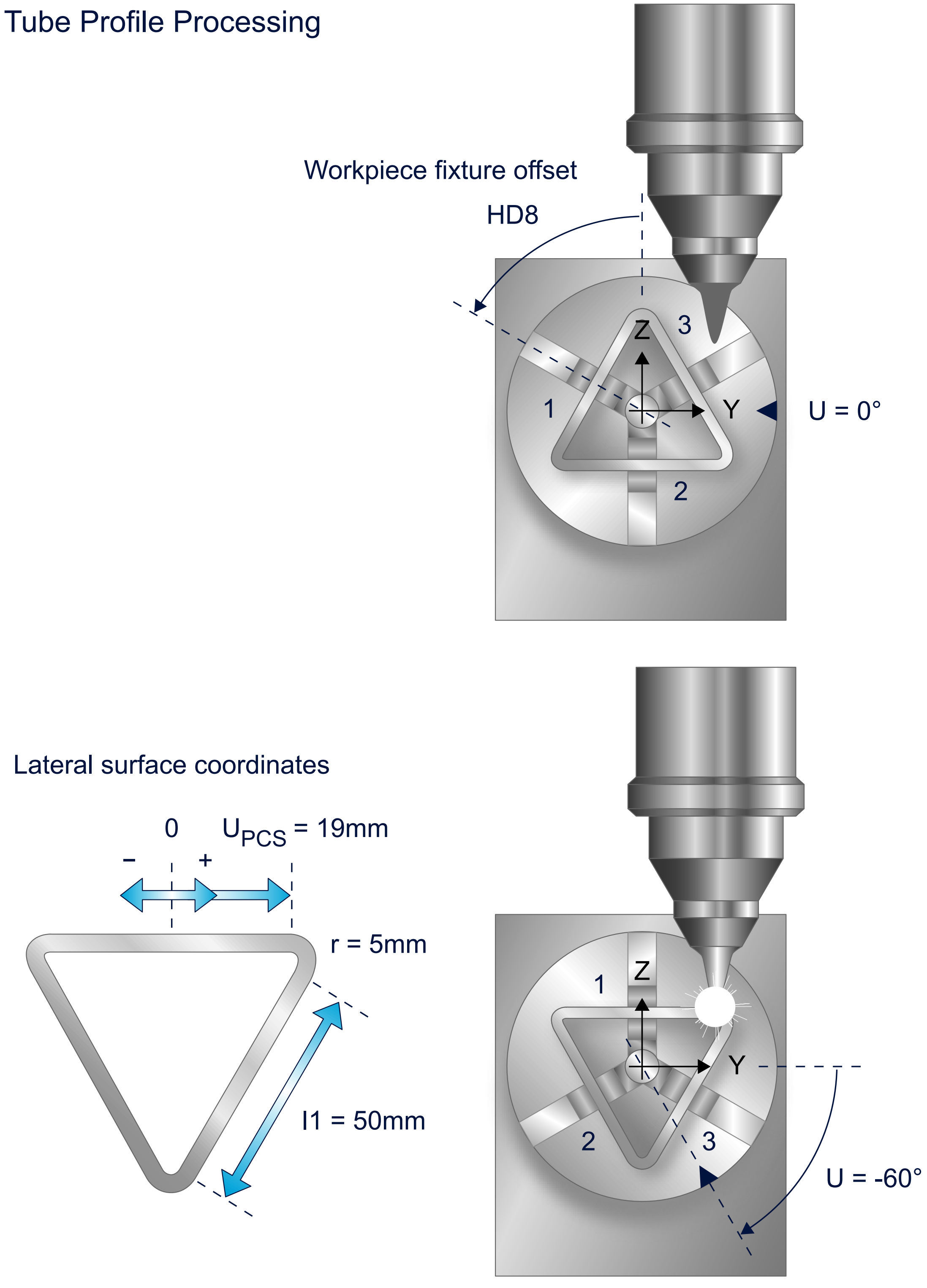


Fig. 60: Offset for workpiece clamp position

When the rotary workpiece axis is at zero position, the clamped workpiece is not in the requested base orientation where the tool axis is perpendicular to the profile cut. The kinematic parameter HD8 considers the clamp position of the profiled tube. In this case, the workpiece must be oriented above the rotary axis so that a plane surface of the profile is perpendicular to the tool. In the current example the U axis is moved to -60°; the required offset setting is then +60°.

The lateral surface system results as shown in the figure above after the transformation is selected according to following parameters #CYL[EDGES=3 ROUNDING=5 LENGTH1=50]. The zero point of the lateral surface system is located in the middle of the lateral surface plane 1; the PCS start position of the TCP is U_{PCS} = +19 mm.

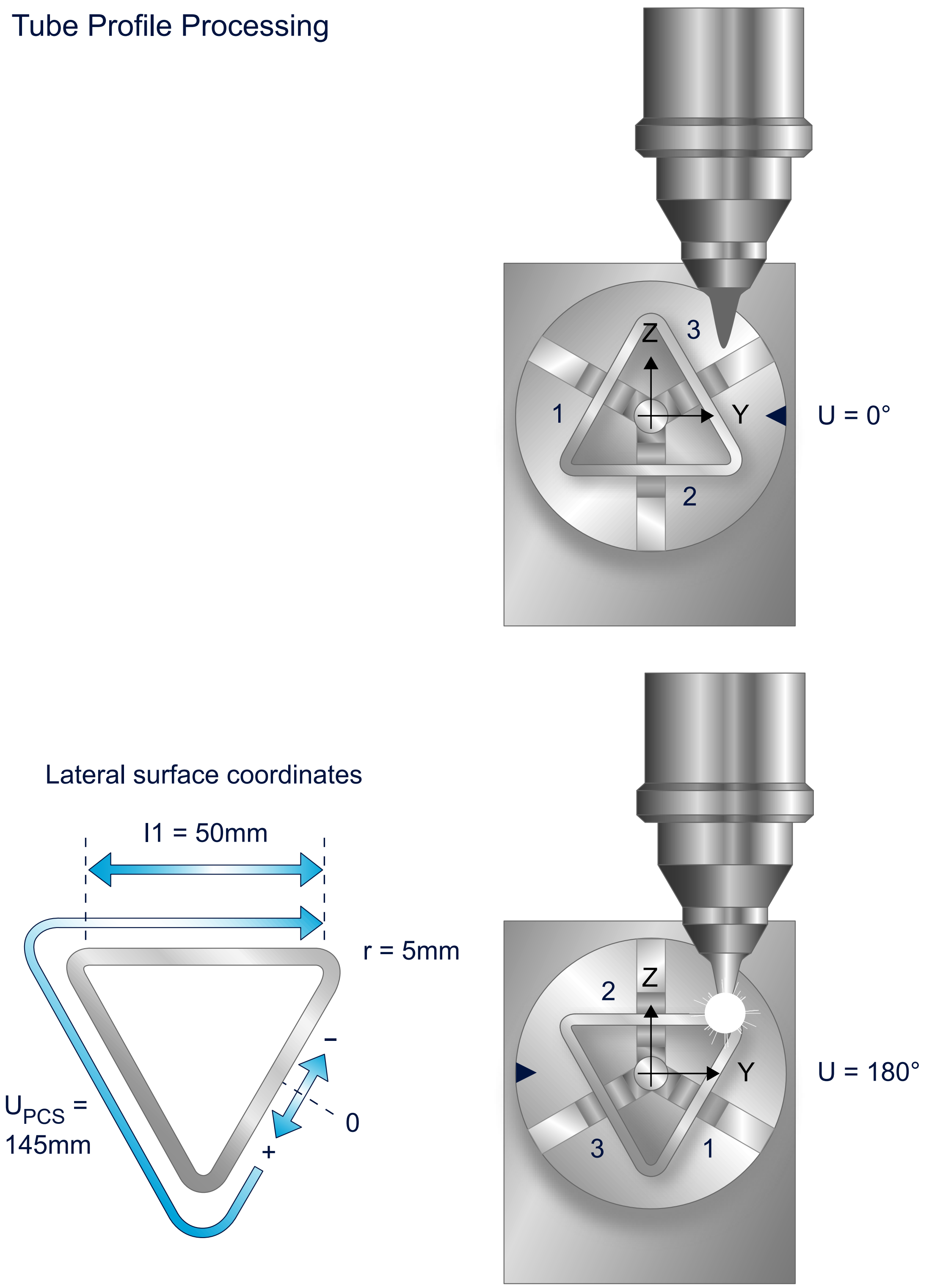


Fig. 61: Selecting on the plane lateral surface

In the following case the transformation should be activated on the lateral surface 2. The clamping position and kinematic parameter HD8 correspond to the above example. The U axis is positioned at 180° before the transformation is selected so that the tool is perpendicular to the required plane surface.

The lateral surface system then results as shown in the above figure after transformation is selected according to the following parameters #CYL[EDGES=3 ROUNDING=5 LENGTH1=50]. The zero point of the lateral surface system is located in the middle of lateral plane 1; in the lateral surface system, it is located at the start position U_{PCS}=145 mm.

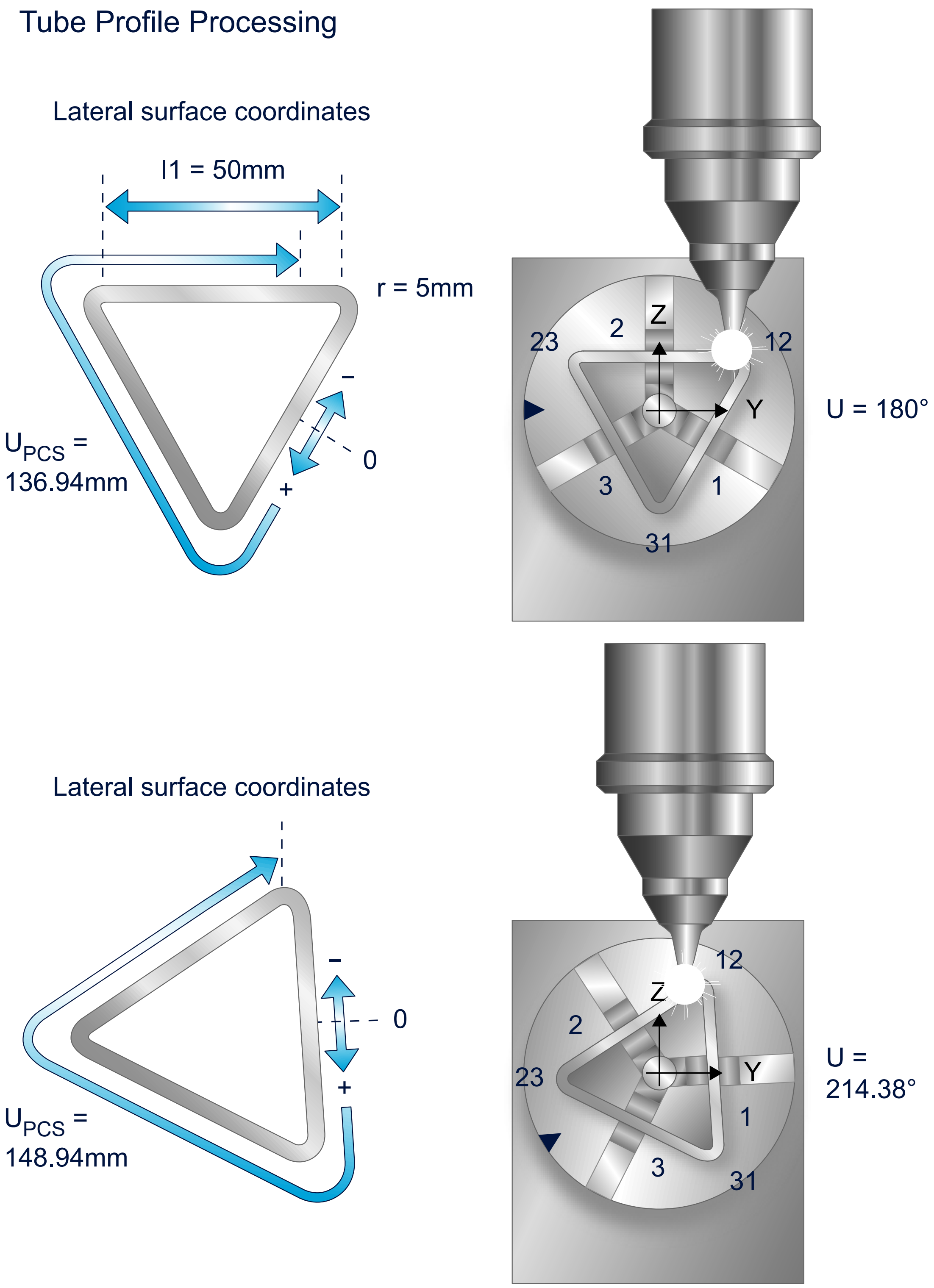


Fig. 62: Selecting on profile rounding

In this case the transformation should be activated on the profile rounding 12. The clamping position and kinematic parameter HD8 correspond to the above example. The lateral surface system after transformation is selected results as shown in above figure. The system is located at the start position U_{PCS}=136.94 mm. The approach to the profile rounding at position U_{PCS}=148.94 mm is executed by positioning with the command #PTP ON.

Polygonal tube, profiled tube (kinematic ID 79)

```
N30 ...
N40 G0 G90 X0 Y=20 U=0 Z50
N50 #CYL [EDGES=3, ROUNDING=5, LENGTH1=50]
N60 #PTP ON
N70 G0 G90 U148.94 Z40
N80 #PTP OFF
N90 Z0
N100 G01 U150 X5
...
```

3.5.2.3.1 M / H Steuercodes

The M/H functions described below can be used for process control on the profile rounding.

Variable name	Type	Permitted range	Dimension
tube_profile.techno_nr_rnd_on	SGN16	-1 ... [M/H_FKT_ANZ-1] Default: -1 (not used	---
tube_profile.techno_nr_rnd_off	SGN16	-1 ... [M/H_FKT_ANZ-1] Default: -1 (not used	---
tube_profile.techno_type	SGN16	0 : M numbers 1 : H numbers	----

Wert M/H_FKT_ANZ	Meaning
application-specific	Maximum number of M/H functions

NOTICE

To activate the function, the M/H numbers of the two parameters must be >= 0.

M/H numbers may not already be assigned by an application in P-CHAN-00041 (m_synch[...]) or P-CHAN-00027 (h_synch[...].

Excerpt from the channel parameter list:

```
# Definition of M/H functions for profiled tube rounding technology
# ===============================================================
:
tube_profile.techno_type              1       Use of H numbers
tube_profile.techno_nr_rnd_on       300       H number, entering a rounding
tube_profile.techno_nr_rnd_off      400       H number, exiting a rounding
#
```

3.5.2.4 Round tube, lateral surface (5/6-axis) (kinematic ID 90)

3.5.2.4.1 Parameters for AB orientation head

P-CHAN-00094	Offset parameters of the kinematic		
Description	Offsets and attributes of kinematic 90		
Parameter	kinematik[90].param[i]		
Data type	REAL64		
Data range	**HD offset**	**param[i]**	**Meaning**
	HD1	0	Z axis offset to the tool fixing point
	HD2	1	X axis offset to the tool fixing point
	HD3	2	Y axis offset to the tool fixing point
	HD4	3	X axis offset rotation point A axis - rotation point B axis
	HD5	4	Y axis offset rotation point A axis - rotation point B axis
	HD6	5	Z axis offset rotation point A axis - rotation point B axis
	HD7	6	X axis offset zero point - rotation point A axis
	HD8	7	Y axis offset zero point - rotation point A axis
	HD9	8	Z axis offset zero point - rotation point A axis
	HD10	9	n.a.
	HD11	10	n.a.
	HD12	11	Angle offset U/V axis
	HD13	12	Orientation head, sequence of rotary axes: 0: AB, 1: BA
	HD14	13	PCS angle programming 0: same as orientation head, 1: CA
	HD15	14	Rotation direction AM, 0: math. positive, 1: math. negative
	HD16	15	Rotation direction BM, 0: math. positive, 1: math. negative
	HD17	16	Angle offset AM
	HD18	17	Angle offset BM
Dimension	0.1µm bzw. 0.0001° (bei Versätzen)		
Default value	0		
Remarks	The parameters are defined under ID 90 of the kinematic offsets.		

The general description is contained in the channel parameter list under P-CHAN-00094.

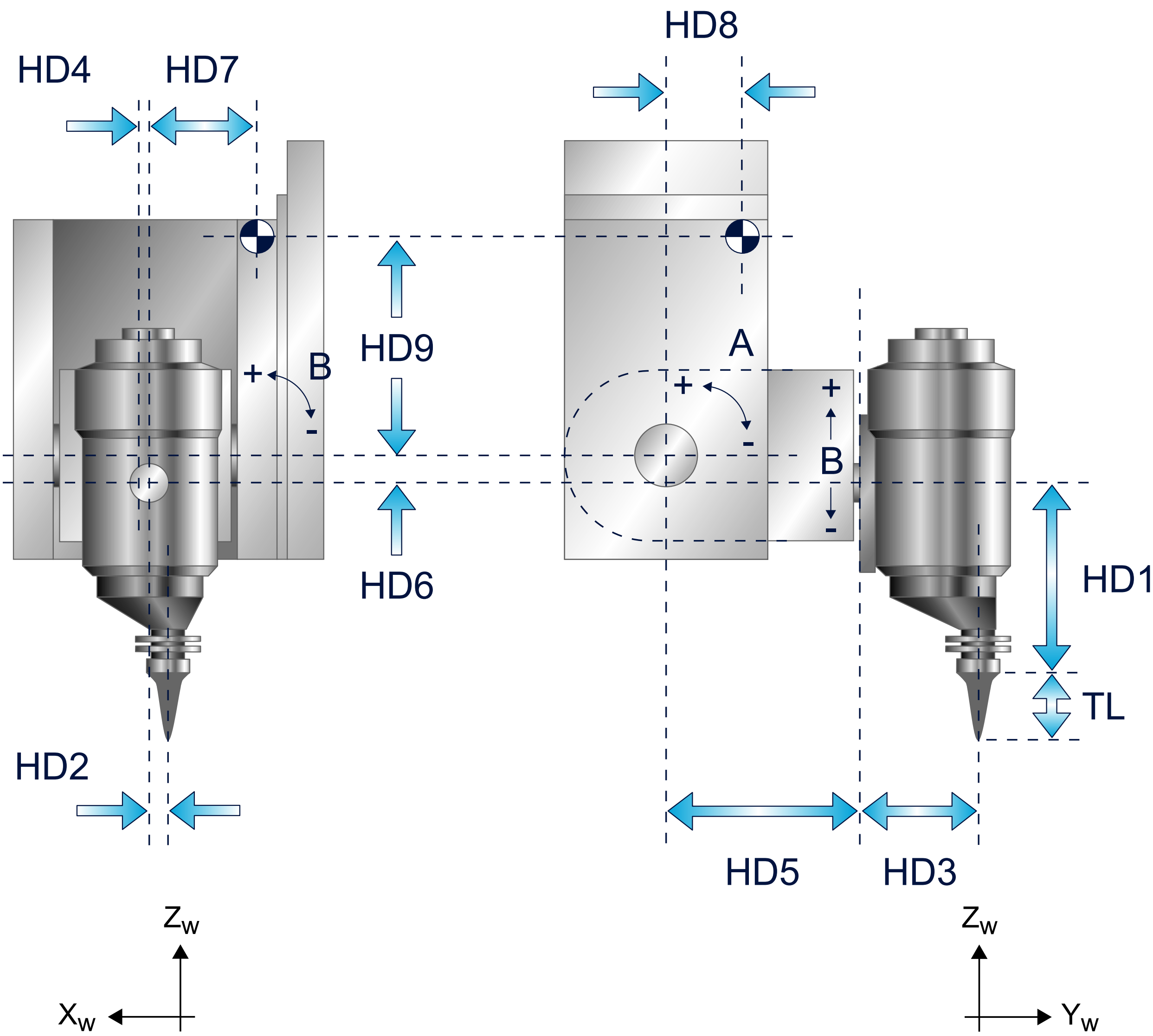


Fig. 63: Parameters of AB tool head

3.5.2.4.2 Parameters for BA orientation head

P-CHAN-00094	Offset parameters of the kinematic		
Description	Offsets and attributes of kinematic 90		
Parameter	kinematik[90].param[i]		
Data type	REAL64		
Data range	**HD offset**	**param[i]**	**Meaning**
	HD1	0	Z axis offset to the tool fixing point
	HD2	1	X axis offset to the tool fixing point
	HD3	2	Y axis offset to the tool fixing point
	HD4	3	X axis offset rotation point B axis - rotation point A axis
	HD5	4	Y axis offset rotation point B axis - rotation point A axis
	HD6	5	Z axis offset rotation point B axis - rotation point A axis
	HD7	6	X axis offset zero point - rotation point B axis
	HD8	7	Y axis offset zero point - rotation point B axis
	HD9	8	Z axis offset zero point - rotation point B axis
	HD10	9	n.a.
	HD11	10	n.a.
	HD12	11	Angle offset U/V axis
	HD13	12	Orientation head, sequence of rotary axes: 0: AB, 1: BA
	HD14	13	PCS angle Programming 0: same as orientation head, 1: CA
	HD15	14	Rotation direction AM, 0: math. positive, 1: math. negative
	HD16	15	Rotation direction BM, 0: math. positive, 1: math. negative
	HD17	16	Angle offset AM
	HD18	17	Angle offset BM
Dimension	0.1µm bzw. 0.0001° (bei Versätzen)		
Default value	0		
Remarks	The parameters are defined under ID 90 of the kinematic offsets.		

The general description is contained in the channel parameter list under P-CHAN-00094.

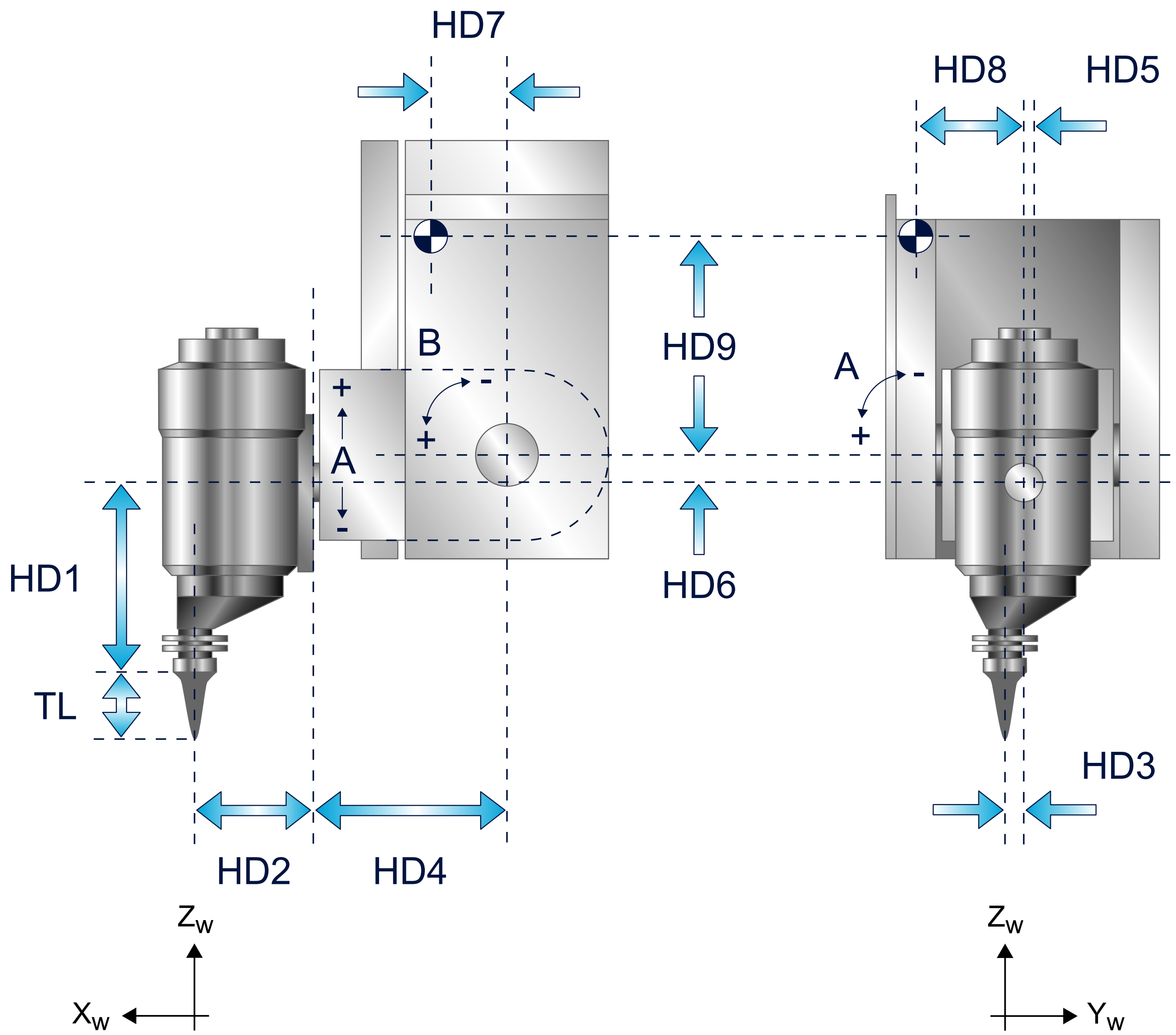


Fig. 64: Parameters for BA orientation head

3.5.2.4.3 Parameters for CA orientation head

<table>
<tr><td>P-CHAN-00094</td><td colspan="3">Offset parameters of the kinematic</td></tr>
<tr><td>Description</td><td colspan="3">Offsets and attributes of kinematic 90</td></tr>
<tr><td>Parameter</td><td colspan="3">kinematik[90].param[i]</td></tr>
<tr><td>Data type</td><td colspan="3">REAL64</td></tr>
<tr><td rowspan="19">Data range</td><td>HD offset</td><td>param[i]</td><td>Meaning</td></tr>
<tr><td>HD1</td><td>0</td><td>Z axis offset to the tool fixing point</td></tr>
<tr><td>HD2</td><td>1</td><td>X axis offset to the tool fixing point</td></tr>
<tr><td>HD3</td><td>2</td><td>Y axis offset to the tool fixing point</td></tr>
<tr><td>HD4</td><td>3</td><td>X axis offset rotation point C axis - rotation point A axis</td></tr>
<tr><td>HD5</td><td>4</td><td>Y axis offset rotation point C axis - rotation point A axis</td></tr>
<tr><td>HD6</td><td>5</td><td>Z axis offset rotation point C axis - rotation point A axis</td></tr>
<tr><td>HD7</td><td>6</td><td>X offset reference point – rotation point C axis</td></tr>
<tr><td>HD8</td><td>7</td><td>Y offset reference point – rotation point C axis</td></tr>
<tr><td>HD9</td><td>8</td><td>Z offset reference point – rotation point C axis</td></tr>
<tr><td>HD10</td><td>9</td><td>n.a.</td></tr>
<tr><td>HD11</td><td>10</td><td>n.a.</td></tr>
<tr><td>HD12</td><td>11</td><td>Angle offset U/V axis</td></tr>
<tr><td>HD13</td><td>12</td><td>Orientation head, sequence of rotary axes: 2: CA, 4:CB</td></tr>
<tr><td>HD14</td><td>13</td><td>-</td></tr>
<tr><td>HD15</td><td>14</td><td>Rotation direction CM, 0: math. positive, 1: math. negative</td></tr>
<tr><td>HD16</td><td>15</td><td>Rotation direction AM, 0: math. positive, 1: math. negative</td></tr>
<tr><td>HD17</td><td>16</td><td>Angle offset CM</td></tr>
<tr><td>HD18</td><td>17</td><td>Angle offset AM</td></tr>
<tr><td>Dimension</td><td colspan="3">0.1µm bzw. 0.0001° (bei Versätzen)</td></tr>
<tr><td>Default value</td><td colspan="3">0</td></tr>
<tr><td>Remarks</td><td colspan="3">The parameters are defined under ID 90 of the kinematic offsets.</td></tr>
</table>

The general description is contained in the channel parameter list under P-CHAN-00094.

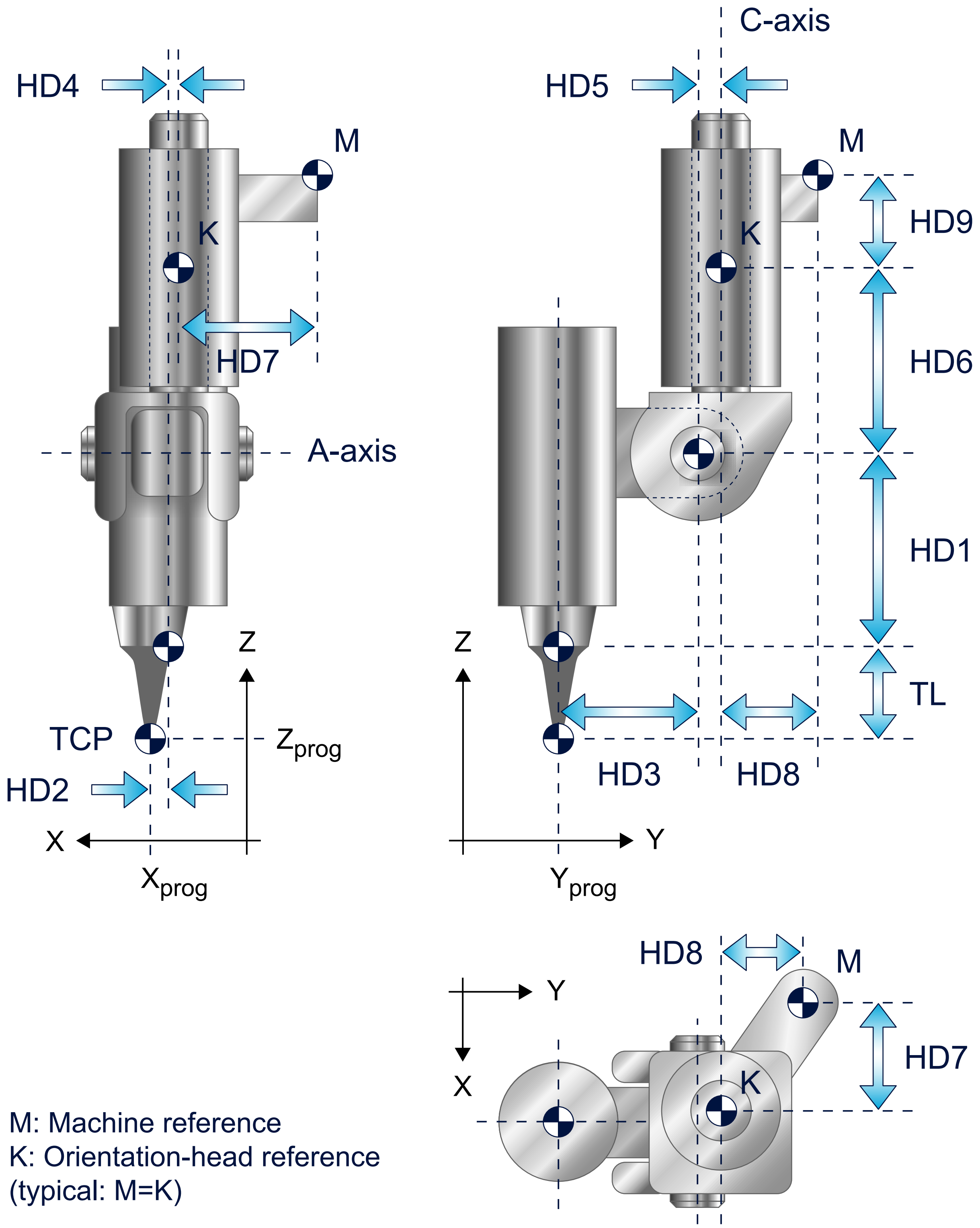


Fig. 65: Parameters for CA orientation head

3.5.2.4.4 Parameters for CB orientation head

P-CHAN-00094	Offset parameters of the kinematic	
Description	Offsets and attributes of kinematic 90		
Parameter	kinematik[90].param[i]		
Data type	REAL64		
Data range	**HD offset**	**param[i]**	**Meaning**
	HD1	0	Z axis offset to the tool fixing point
	HD2	1	X axis offset to the tool fixing point
	HD3	2	Y axis offset to the tool fixing point
	HD4	3	X axis offset rotation point C axis - rotation point B axis
	HD5	4	Y axis offset rotation point C axis - rotation point B axis
	HD6	5	Z axis offset rotation point C axis - rotation point B axis
	HD7	6	X axis offset zero point - rotation point B axis
	HD8	7	Y axis offset zero point - rotation point B axis
	HD9	8	Z axis offset zero point - rotation point B axis
	HD10	9	n.a.
	HD11	10	n.a.
	HD12	11	Angle offset U/V axis
	HD13	12	Orientation head, sequence of rotary axes: 2: CA, 4:CB
	HD14	13	-
	HD15	14	Rotation direction CM, 0: math. positive, 1: math. negative
	HD16	15	Rotation direction BM, 0: math. positive, 1: math. negative
	HD17	16	Angle offset CM
	HD18	17	Angle offset BM
Dimension	0.1µm bzw. 0.0001° (bei Versätzen)		
Default value	0		
Remarks	The parameters are defined under ID 90 of the kinematic offsets.		

The general description is contained in the channel parameter list under P-CHAN-00094.

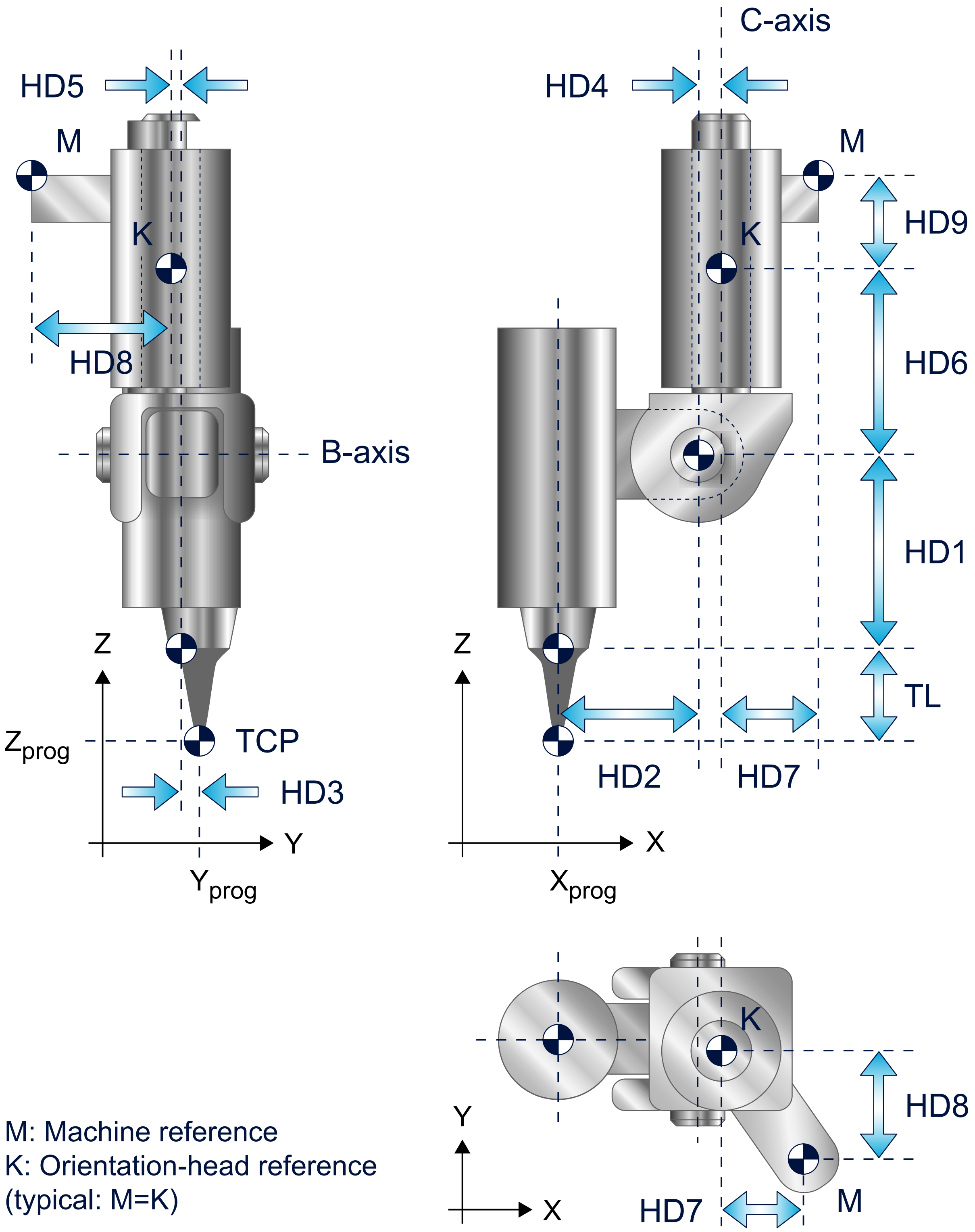


Fig. 66: Parameters for CB orientation head

3.5.2.4.5 Parameters for CA cardanic orientation head

P-CHAN-00094	Offset parameters of the kinematic		
Description	Offsets and attributes of kinematic 90		
Parameter	kinematik[90].param[i]		
Data type	REAL64		
Data range	**HD offset**	**param[i]**	**Meaning**
	HD1	0	n.a.
	HD2	1	n.a.
	HD3	2	Head angle
	HD4	3	n.a.
	HD5	4	n.a.
	HD6	5	Orientation C axis head; required if head has a 180° offset in zero position. 0: Default, 1: 180 degree offset
	HD7	6	X offset reference point – rotation point C axis
	HD8	7	Y offset reference point – rotation point C axis
	HD9	8	Z offset reference point – rotation point C axis
	HD10	9	n.a.
	HD11	10	n.a.
	HD12	11	Angle offset U/V axis
	HD13	12	Orientation head, sequence of rotary axes: CA cardan
	HD14	13	n.a.
	HD15	14	X offset to tool holding device
	HD16	15	Y offset to tool holding device
	HD17	16	Z offset to tool holding device
	HD18	17	X offset A axis to C axis
	HD19	18	Y offset A axis to C axis
	HD20	19	Z offset A axis to C axis
Dimension	0.1µm bzw. 0.0001° (bei Versätzen)		
Default value	0		
Remarks	The parameters are defined under ID 90 of the kinematic offsets.		

The general description is contained in the channel parameter list under P-CHAN-00094.

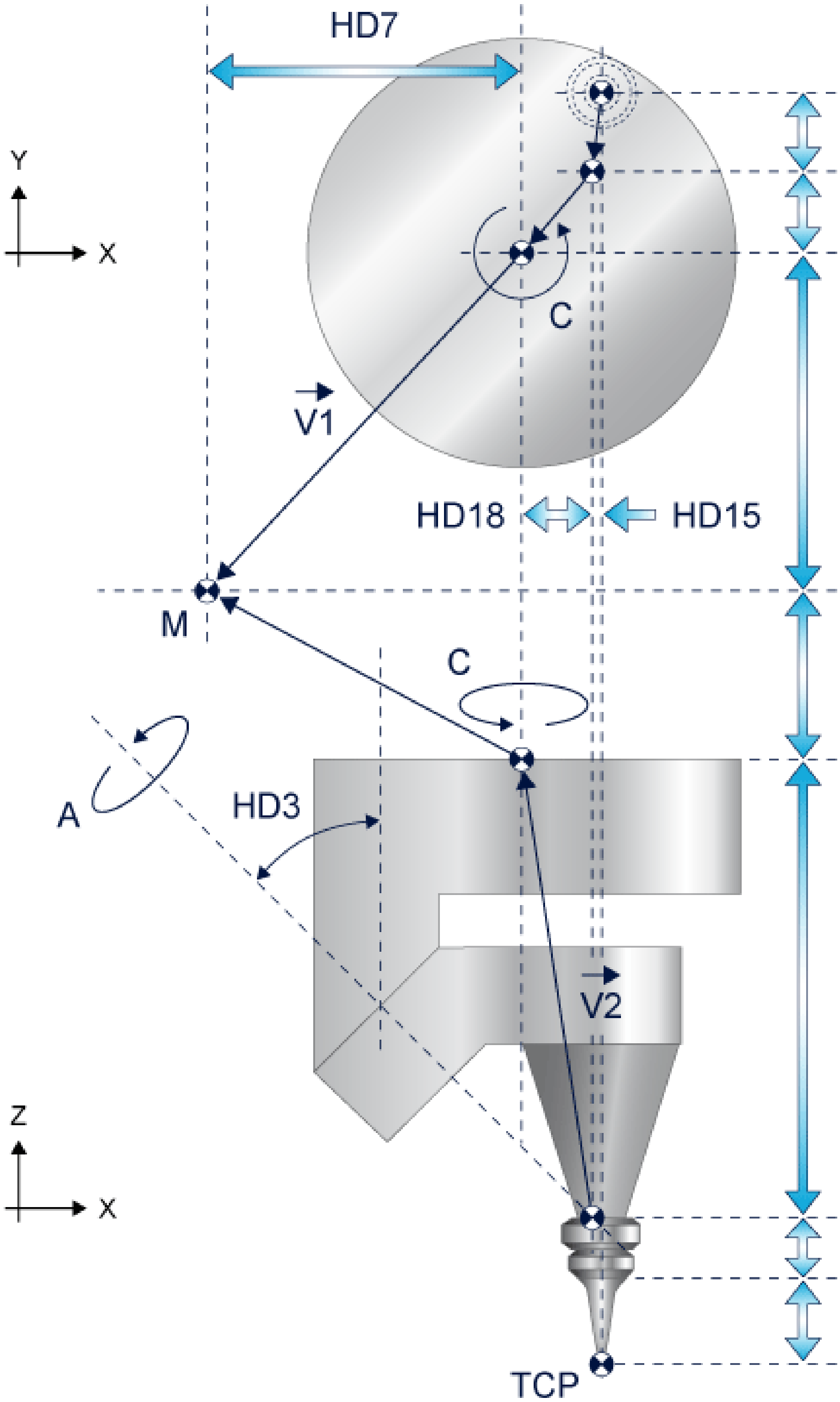


Fig. 67: Cardanic head in zero position, HD6=0

3.5.2.4.6 Parameters for AU kinematics

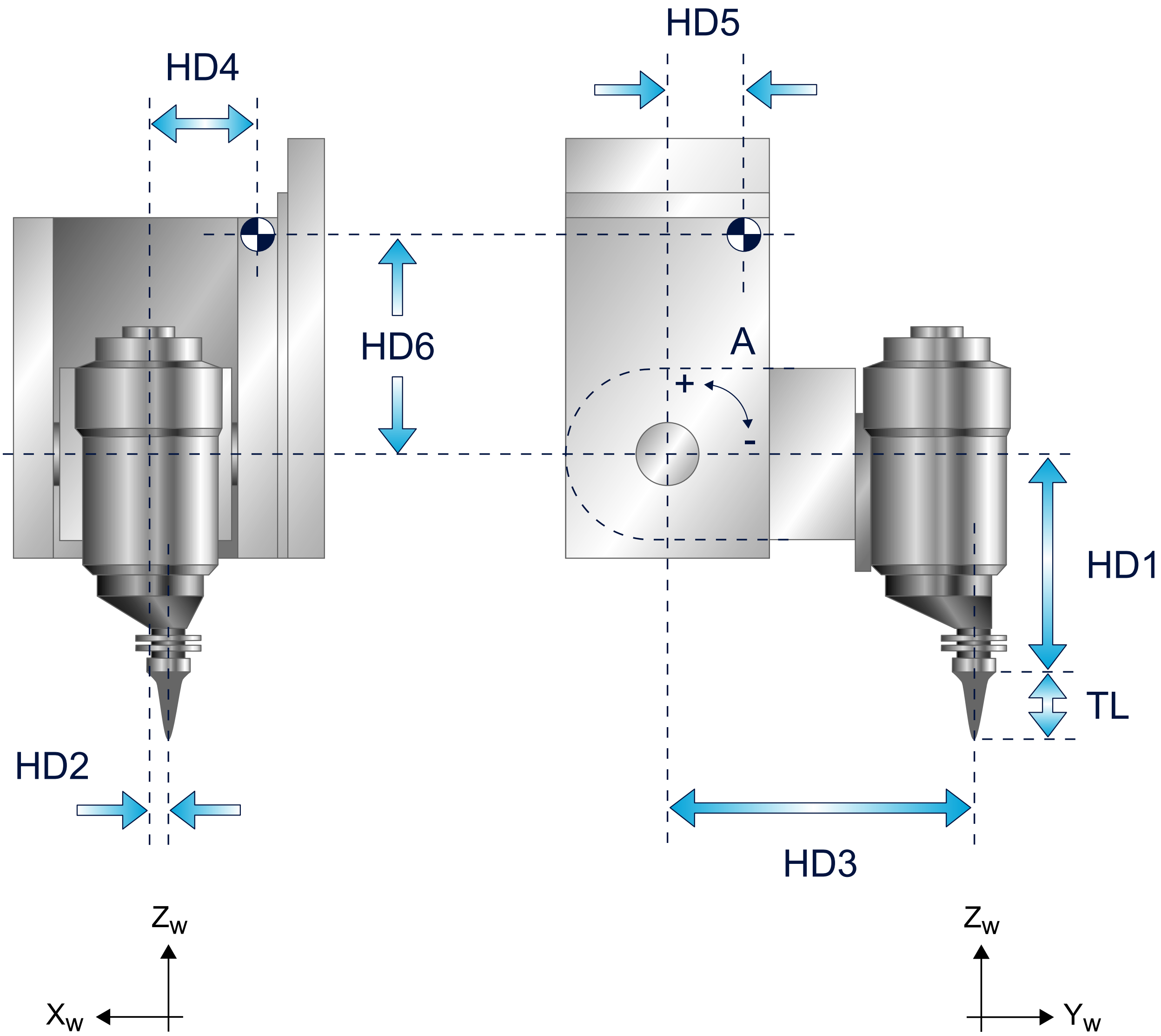


Fig. 68: Parameters of AU tool head

3.5.2.4.7 Parameters for BV kinematics

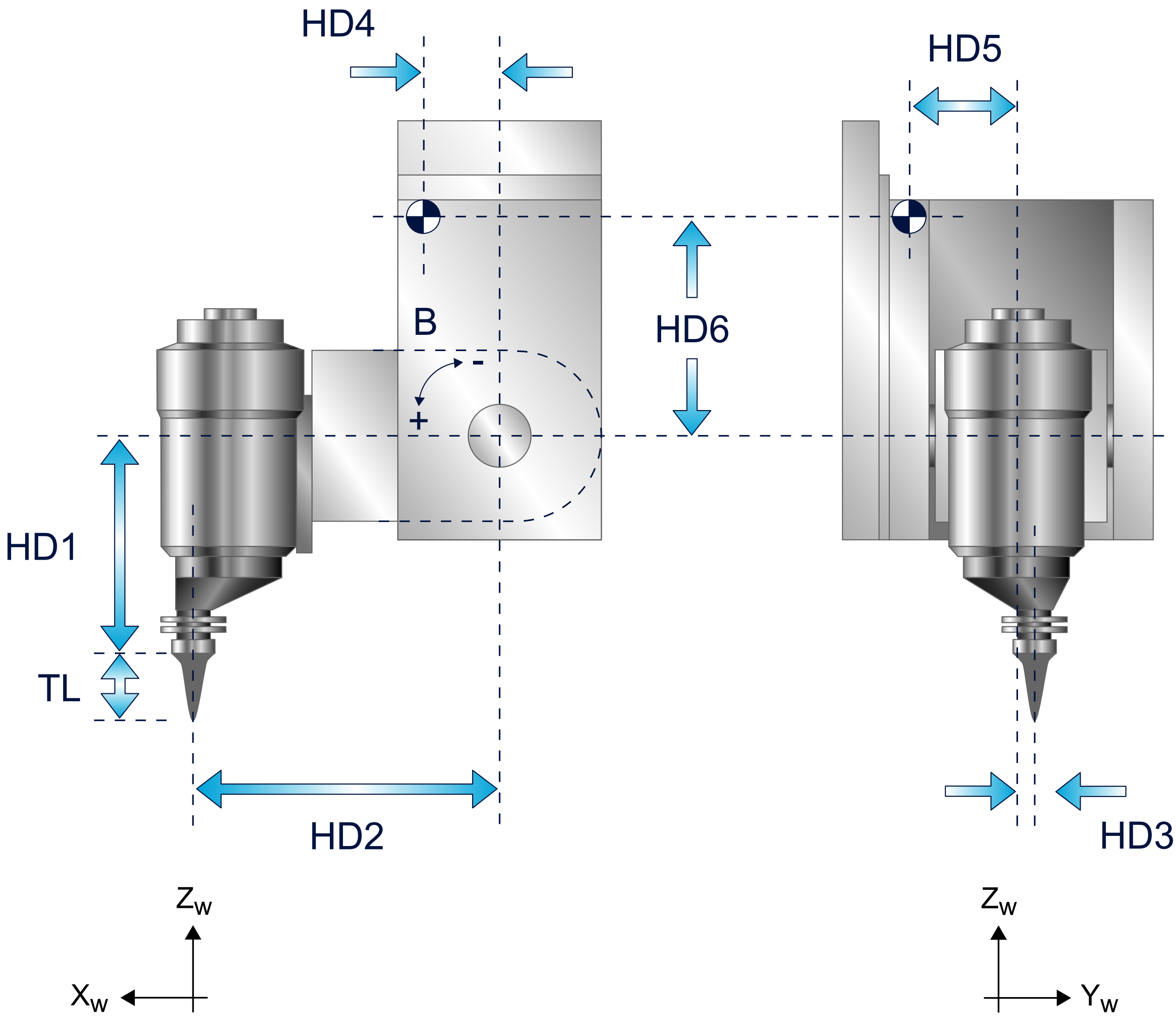


Fig. 69: Parameters of BV tool head

P-CHAN-00094	Offset parameters of the kinematic		
Parameter	kinematik[90].param[i]		
Description	Offsets and attributes		
Data type	REAL64		
Data range	**HD offset**	**param[i]**	**Meaning**
	HD1	0	Z axis offset to the tool fixing point
	HD2	1	X axis offset to the tool fixing point
	HD3	2	Y axis offset to the tool fixing point
	HD4	3	X axis offset rotation point A, B axis to origin of tool slide tool slide
	HD5	4	Y axis offset rotation point A, B - axis to origin of tool slide tool slide
	HD6	5	Z axis offset rotation point A, B - axis to origin of tool slide tool slide
	HD7	6	X offset to machine origin
	HD8	7	Y offset to machine origin
	HD9	8	Z offset to machine origin
	HD10	9	n.a.
	HD11	10	n.a.
	HD12	11	Angle offset U/V axis
	HD13	12	Machine structure: 9: A U, 10: B V
	HD14	13	PCS angle Programming 0: same as kinematic, 1: CA
	HD15	14	Rotation direction AM, 0: math. positive, 1: math. negative
	HD16	15	Rotation direction BM, 0: math. positive, 1: math. negative
	HD17	16	Angle offset AM
	HD18	17	Angle offset BM
Dimension	0.1µm bzw. 0.0001° (bei Versätzen)		
Default value	0		
Remarks	Depending on the machine structure, a simulation axis A or B must be parametrised to programme orientation.		

The general description is contained in the channel parameter list under P-CHAN-00094.

3.5.2.5 Polygonal tube, profiled tube (5/6-axis) (kinematic ID 93)

Configuration

Kinematic 93 is configured in analogy to kinematic 90 in section "Round tube, lateral surface (5/6-axis) [▸ 119]". In addition the user can specify kinematic parameters as of index 23. The parameters correspond to kinematic 79 described in section "Polygonal tube, profiled tube [▸ 113]" (i.e. Index 23 in kinematic 93 corresponds to Index 3 in kinematic 79 etc.).

As an example the configuration her is shown of an AB orientation head. Parameterisation is analogous for all other orientation heads.

Note: All offsets starting from Index 20 act as static offsets, i.e. they are not influenced by rotations within the head.

3.5.2.5.1 Parameters for AB and BV orientation head

The parameters in the AB and BV configurations only differ in the assignment of HD13.

P-CHAN-00094	Offset parameters of the kinematics		
Description	Offsets and attributes of kinematic 93		
Parameter	kinematik[93].param[i]		
Data type	REAL64		
Data range	**HD offset**	**param[i]**	**Meaning**
	HD1	0	Z axis offset to the tool fixing point
	HD2	1	X axis offset to the tool fixing point
	HD3	2	Y axis offset to the tool fixing point
	HD4	3	X axis offset rotation point A axis - rotation point B axis
	HD5	4	Y axis offset rotation point A axis - rotation point B axis
	HD6	5	Z axis offset rotation point A axis - rotation point B axis
	HD7	6	X axis offset zero point - rotation point A axis
	HD8	7	Y axis offset zero point - rotation point A axis
	HD9	8	Z axis offset zero point - rotation point A axis
	HD10	9	n.a.
	HD11	10	n.a.
	HD12	11	Angle offset U/V axis
	HD13	12	Orientation head, sequence of rotary axes: 0: AB, 1: BA
	HD14	13	PCS angle programming 0: same as orientation head, 1: CA
	HD15	14	Rotation direction AM, 0: math positive, 1: math negative
	HD16	15	Rotation direction BM, 0: math positive, 1: math negative
	HD17	16	Angle offset AM
	HD18	17	Angle offset BM
	HD19	18	n.a.
	HD20	19	n.a.
	HD21	20	n.a.
	HD22	21	n.a.
	HD23	22	n.a.
	HD24	23	Z offset of rotary axis U to machine zero point (MNP)
	HD25	24	X offset of rotary axis U to machine zero point
	HD26	25	Y offset of rotary axis U to machine zero point
	HD27	26	-
	HD28	27	Workpiece clamp position

Dimension	0.1 µm or 0.0001° (for offsets)
Default value	0
Remarks	Parameters are defined under the ID 93 of the kinematics offsets.

The general description is contained in the channel parameter list under P-CHAN-00094

3.6 Block search and profiled tube machining

Resuming path approach

Please note the following when path motion is resumed on profiled tubes with the block search function:

- The approach motion in an area with an active #CYL [EDGES..] or #CYL ORI PROFILE [EDGES=…] takes place on the **ACS plane**. To prevent any collision between tool and workpiece, position the tool at a sufficient safety height (U axis rotates without compensation motion of Z).
- The tool must be perpendicular to the profile surface and within the capture range of the profile (see figure below).
- The approach motion is executed in two steps:

1. Approach motions without Z axis (e.g. U, Y, X)
2. Approach motion of the Z axis

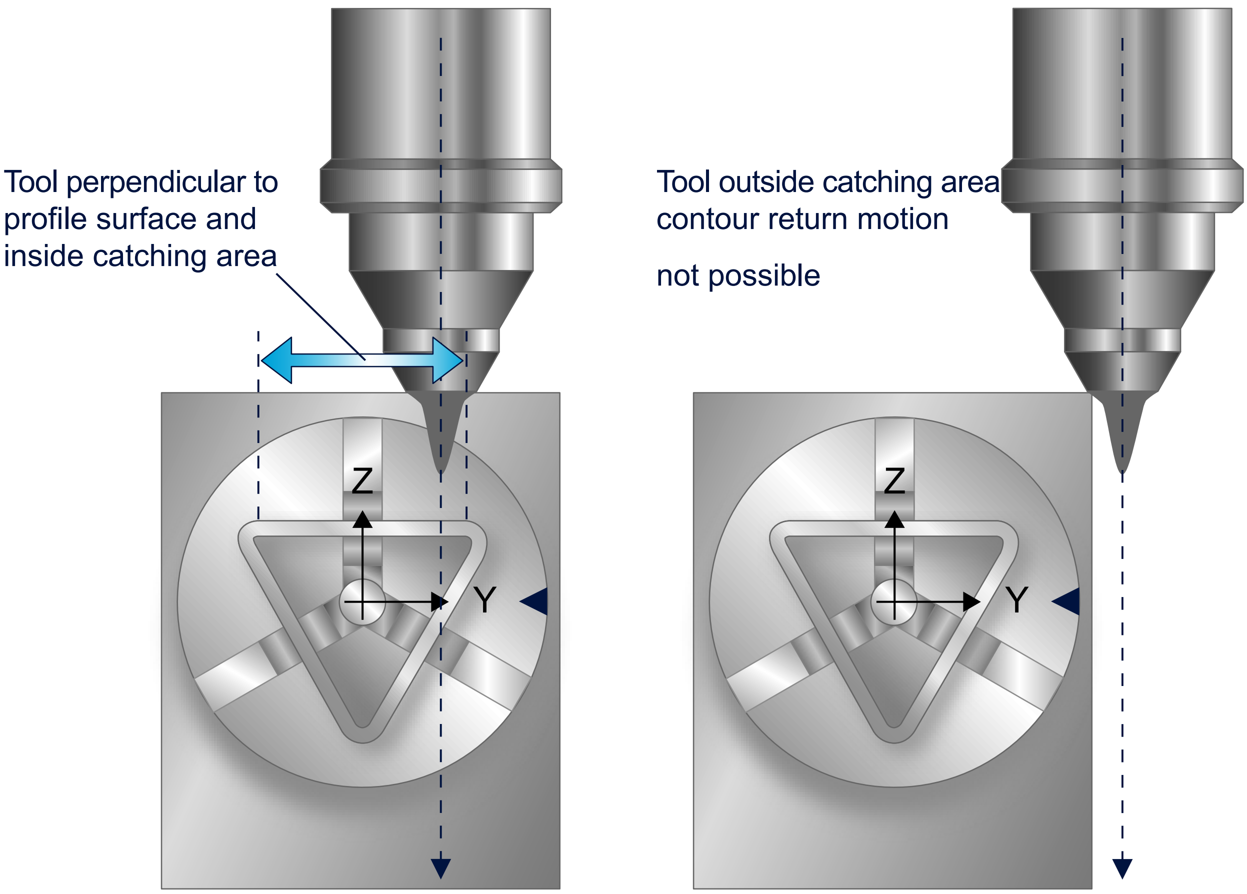


Fig. 70: Starting position for motion resumption

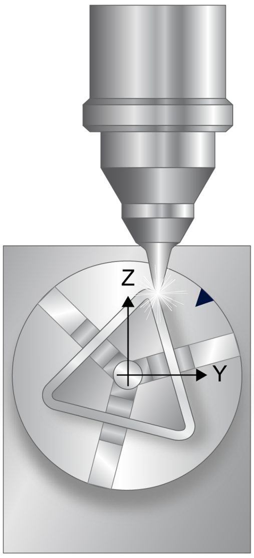


Fig. 71: Axis position after motion resumption

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