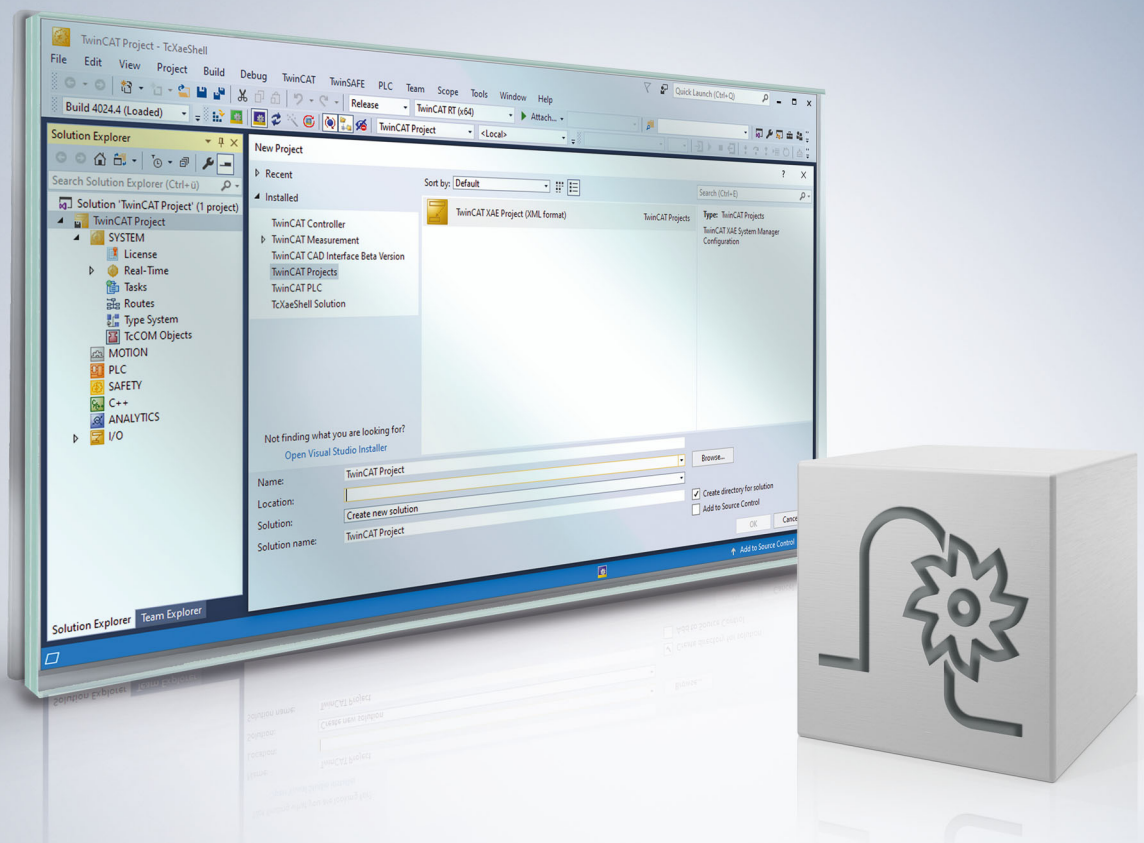
BECKHOFF New Automation Technology

Functional description | EN

TF5200 | TwinCAT 3 CNC

Online tool compensation



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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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General and safety instructions

Icons used and their meanings

This documentation uses the following icons next to the safety instruction and the associated text. Please read the (safety) instructions carefully and comply with them at all times.

Icons in explanatory text

1. 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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Task

With certain processes such as grinding, the length or the radius of the tool must be continuously corrected to compensate for wear.

Wear compensation depends on the path travelled.

Properties

Wear compensation can only be enabled with tool type 2 (grinding tool). If a different tool type is used, error message P-ERR-21391 is output.

Wear compensation can be used for 4 processing types and 3 different modes.

Parametrisation

Wear compensation is activated and deactivated from the NC program. The wear constant can be parameterised both from the NC program and using preset parameters in the tool list P-TOOL-00030. Further parameters in this context are described in the section Parameter [▶ 32].

Programming

The following NC command is provided to program online tool compensation in the NC program. Parametrisation can be programmed in advance or in combination with **#OTC ON** .

For further details on the above command, see the section Programming (#OTC ON/OFF) [▶ 9].

Mandatory note on references 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 (HTML5, CHM) but not in pdf files since pdfs do not support cross-linking.

2 Description

Task

With certain processes such as grinding, the length or the radius of the tool must be continuously corrected to compensate for wear.

Wear compensation depends on the path covered. In addition, compensation can be influenced by the PLC.

Wear compensation is activated and deactivated from the NC program. The wear constant can be parameterised both from the NC program and using preset parameters in the tool list P-TOOL-00030.

Rapid traversing blocks have no wear.

It is assumed that the entire width of the lateral surface of the grinding disc is in contact.

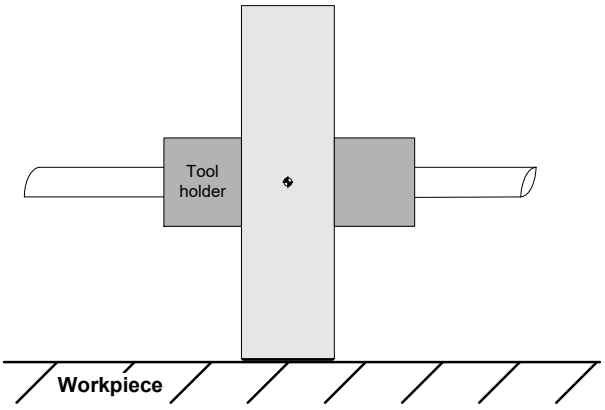


Fig. 1: Grinding a contour

Tool type

Wear compensation can only be enabled with tool type 2 (grinding tool). If a different tool type is used, error message P-ERR-21391 is output.

Processing types

Online wear compensation can be used for 4 processing types and 3 different modes.

1. Radius compensation (only in combination with active TRC) for processing contours in the plane (2.5 D)
2. Length compensation for processing surfaces (surface grinding, 2.5 D)
3. Compensation in tool direction for any orientation (5-axis)
4. Compensation in direction of surface normal (5-axis)

Modes

1. Continuous (dependent on motion path traversed)
2. Discrete (discrete wear compensation via PLC)
3. Automatic, combination of discrete and continuous

Discrete additive wear values which are assigned by the PLC are adjusted over several cycles.

2.1 Programming (#OTC ON/OFF)

The following NC command is provided to program online tool compensation in the NC program. Parametrisation can be programmed in advance or in combination with #OTC ON:

#OTC ON | **OFF** [**[RADIUS** | **LENGTH** | **TOOL_DIR** | **SURF_NORM_DIR DISC** | **CONT** | **AUTO**

WEAR_CONST=.. | **WEAR_CONST_TOOL ACC_WEIGHT**=.. **]**]

RADIUS	Radius compensation processing type
LENGTH	Length compensation processing type (**default**)
TOOL_DIR	Compensation in tool direction (5-axis) processing type
SURF_NORM_DIR	Compensation in direction of surface normal (5-axis) processing type
DISC	Discrete mode: input only via PLC, external presetting
CONT	Continuous mode: Presetting values only by calculating the motion path traversed and the wear constant, internal calculation
AUTO	Automatic mode: Adding the external presetting and internal calculation (**default**)
WEAR_CONST=..	User-specific definition of wear constant; it acts modally, this means that with #OTC ON the programmed wear constant is used and not the default wear constant defined in the current tool data. Defining the valid wear constant is optional. Unit: 0.1 µm/m
WEAR_CONST_TOOL	Switch to the default wear constant defined in the current tool data; it acts modally, this means that with #OTC ON the default wear constant (default) defined in the current tool data is used and not the user-specific definition of the wear constant.
ACC_WEIGHT=..	Acceleration weighting in percent [1;100], default: 100%

When OTC is deselected with #OTC OFF, the amount of wear (discrete and/or continuous) is included in the calculation for the current tool.

2.2 Wear compensation of tool radius

Grinding a contour

Use tool radius wear compensation (radius compensation) by preference to grind a contour at the same time as tool radius compensation.

Grinding disc wear in the direction of the disc radius can be compensated continuously or discretely.

In the radius compensation processing type, wear is only considered for active tool radius compensation (TRC).

The figure below shows the tool radius wear:

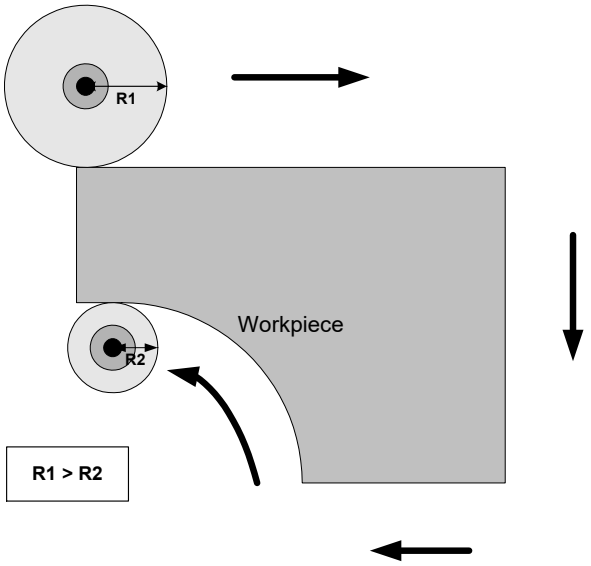


Fig. 2: Wear compensation of tool radius

The start-up movement in relation to the equidistant path after selecting TRC (G41/G42) is considered without wear.

Motion after deselecting TRC (G40) is also without wear.

General #OTC programming example

```
N10 F10000
N20 D1                  (Data set selection for grinding wheel)
N30 G0 X0 Y0 Z0
N40 #OTC[RADIUS, AUTO] (define OTC processing type + mode)
N50 #OTC ON             (select OTC)
N60 G41 G01 X50         (select TRC, wear-free movement)
N70 X1000
N80 G40 X50             (deselect TRC with path motion to reduce TRC)
N90 #OTC OFF            (deselect OTC)
N100 G00 X50
N199 M30
```

OTC with discrete compensation

```
%wr_quad_disc.nc
N20 G17G90
N22 D1 G25              (Linear transition block)
N40 G1 X0Y0Z0 F600

N50 #OTC ON[RADIUS DISC]
N55 G42
N60 G1 X2
N70 G1 X102
N80 G26 Y100            (Circular transition block)

N90 X2
N95 Y0

N100 G40 G1 X0
N110 #OTC OFF

N99999 M30
```

Legend:

Green:	Path contour with active TRC without OTC offset
Black:	Path contour with negative value for OTC radius offset
Red:	Path contour with positive value for OTC radius offset

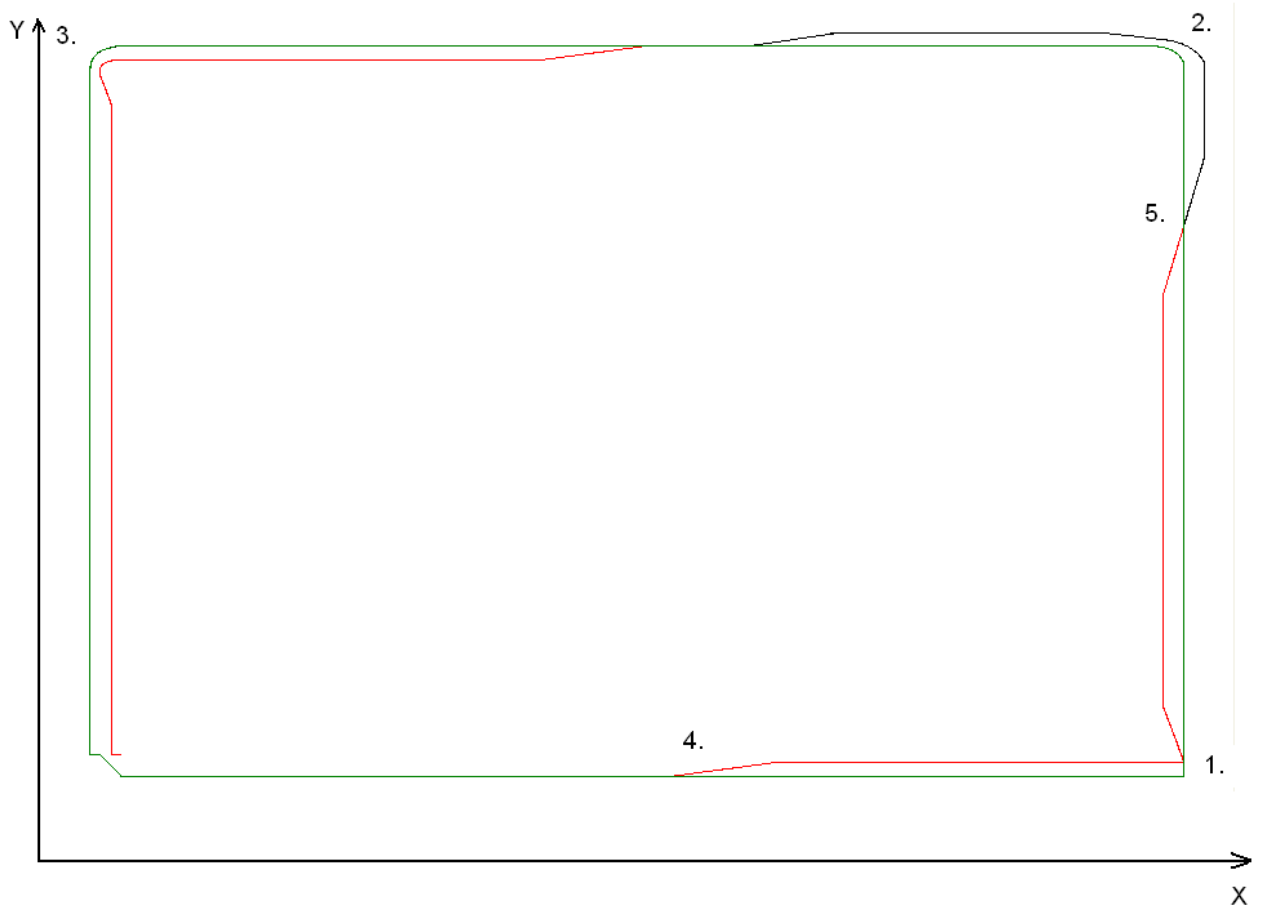


Fig. 3: Contour of the NC program wr_quad_disc.nc

Explanation to the figure above (the discrete OTC offset applied is 2 mm)

1. In this corner of the contour, G25 is active. The contour is not continuous. The predefined OTC offset is applied to another axis over several cycles.
2. The TRC inserts a circular transition because of G26. But the OTC offset is so large that the increase in offset is unable to keep up with the continuous change in the contour.
3. The OTC offset lags behind considerably.
4. Increase the OTC offset
5. Decrease the positive OTC offset and increase the negative OTC offset

The tool radius is influenced by the PLC.

Condition: After the OTCRadiusOffset control unit is active, the OTC radius offset can then be programmed accordingly for the build currently in use. This value is then added to each cycle perpendicular to the programmed contour.

PLC example code

```
(* Enable the OTC control unit for first channel *)
gpCh[0]^.bahn_mc_control.otc_radius_offset.enable_w := TRUE;

(* write radius offset in the first channel *)
gpCh[0]^.bahn_mc_control.otc_radius_offset.command_w := OTC_Offset;
```

PLC example code for CNC Build as of V2.11.20cxx:

where channel_idx = [1.. HLI_SYS_CHNMAX]

```
(* Enable the OTC control unit for first channel *)
pMC[1]^.addr^.MCControlBahn_Data.MCControlSGN32Unit_OTCRadiusOffset.X_Enable := TRUE;

(* write radius offset in the first channel *)
pMC[1]^.addr^.MCControlBahn_Data.MCControlSGN32Unit_OTCRadiusOffset.D_Command := OTC_Offset;
```

A continuous contour path is recommended because changing the orientation of the predefined offset is not applied to the axis all at once but is distributed over several cycles.

On selection, the commands G41/G42 and #OTC ON can be swapped. On deselection, the sequence G40 before #OTC OFF must be maintained. The TRC modes G138/G139 make a path motion between the two commands **absolutely** necessary.
If error 90050 is output, the path motion does not exist when deselected with G138/G139.

The functionality of the RADIUS type is shown by the example of the G17 plane:

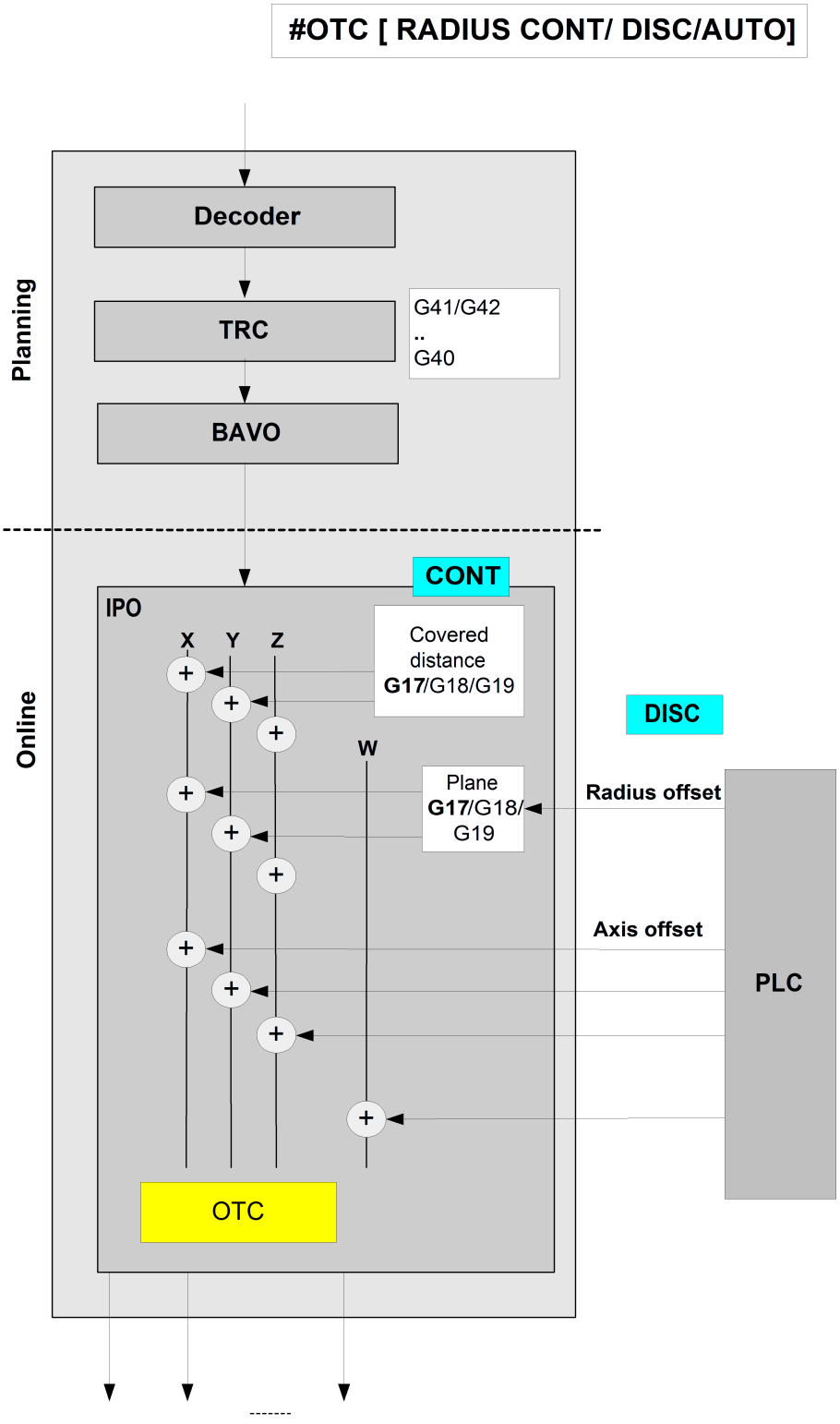


Fig. 4: Description of RADIUS function

2.3 Wear compensation of tool length

Grinding a surface

When the tool length is compensated (length compensation), wear is compensated in the direction of the 3rd main axis. This can take place both continuously and discretely. This procedure is used in particular for processing surfaces (surface grinding).

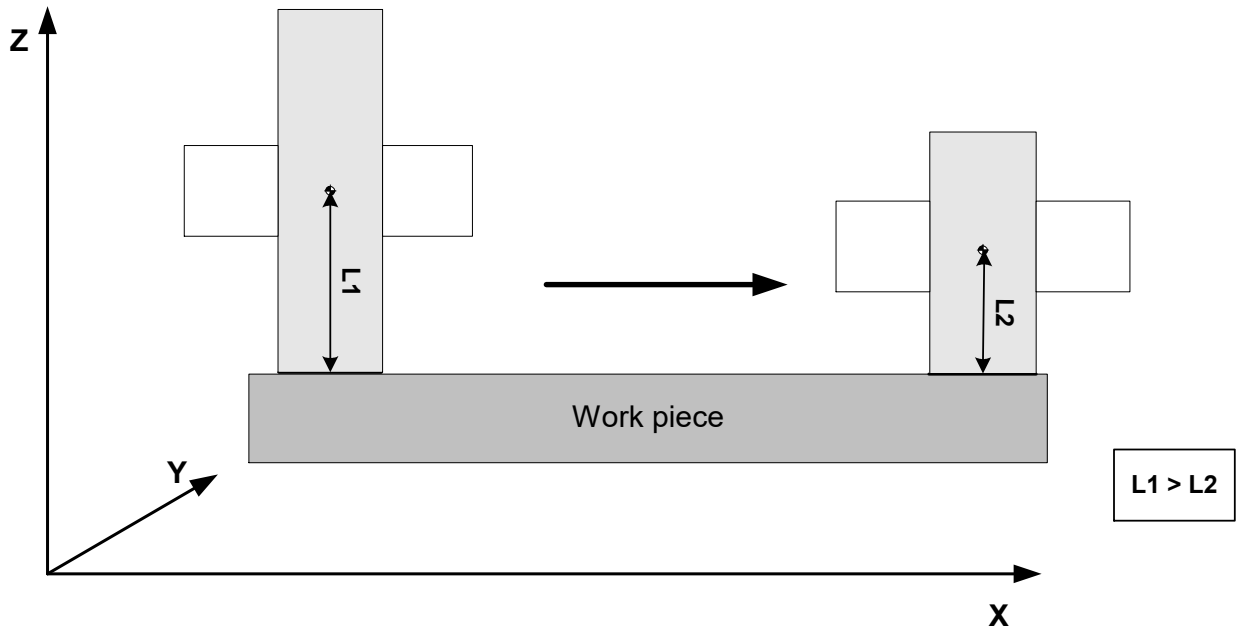


Fig. 5: Wear compensation of tool length

Tool length wear

```
...
N30 D1                (Select record for grinding disc)
N40 G00 X0 Y0 Z0
N50 #OTC ON [LENGTH]   (Select OTC)
N60 G1 X1000 F10000
N70 #OTC OFF          (Deselect OTC)
...
```

Distributing continuous wear on 2 main axes depends on the inclination of the grinding disc as described in section Inclined grinding disc [▶ 18].

The LENGTH operation mode is shown in the figure below:

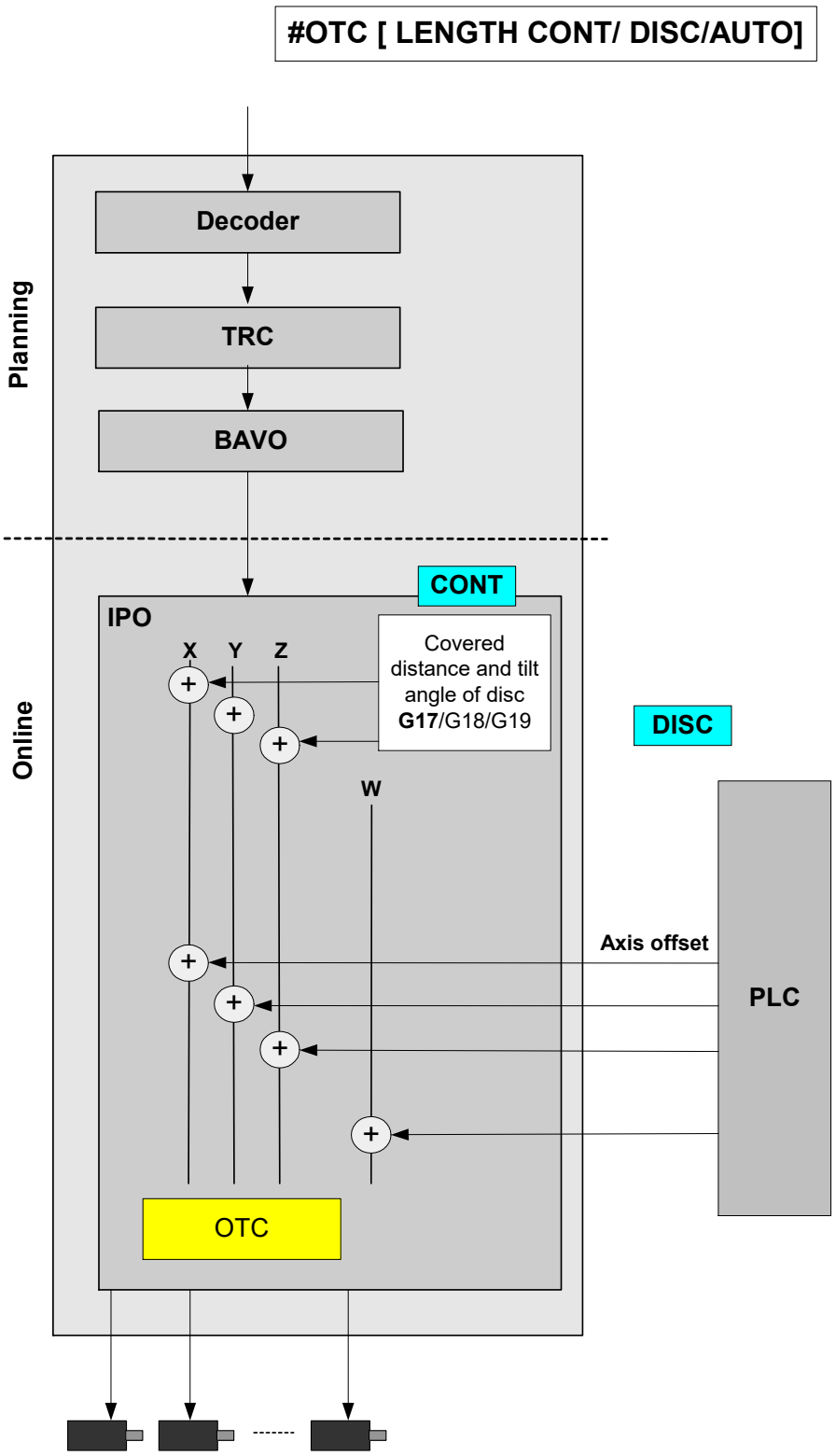


Fig. 6: Description of LENGTH function

2.3.1 Inclined grinding disc

Inclined grinding

The incline of the grinding disc is only entered in the tool list (P-TOOL-00138) to grind inclined surfaces. Here the complete lateral surface of the grinding disc is also in contact.

The figure below shows the orientation of the tilt angle using the example of the G17 plane:

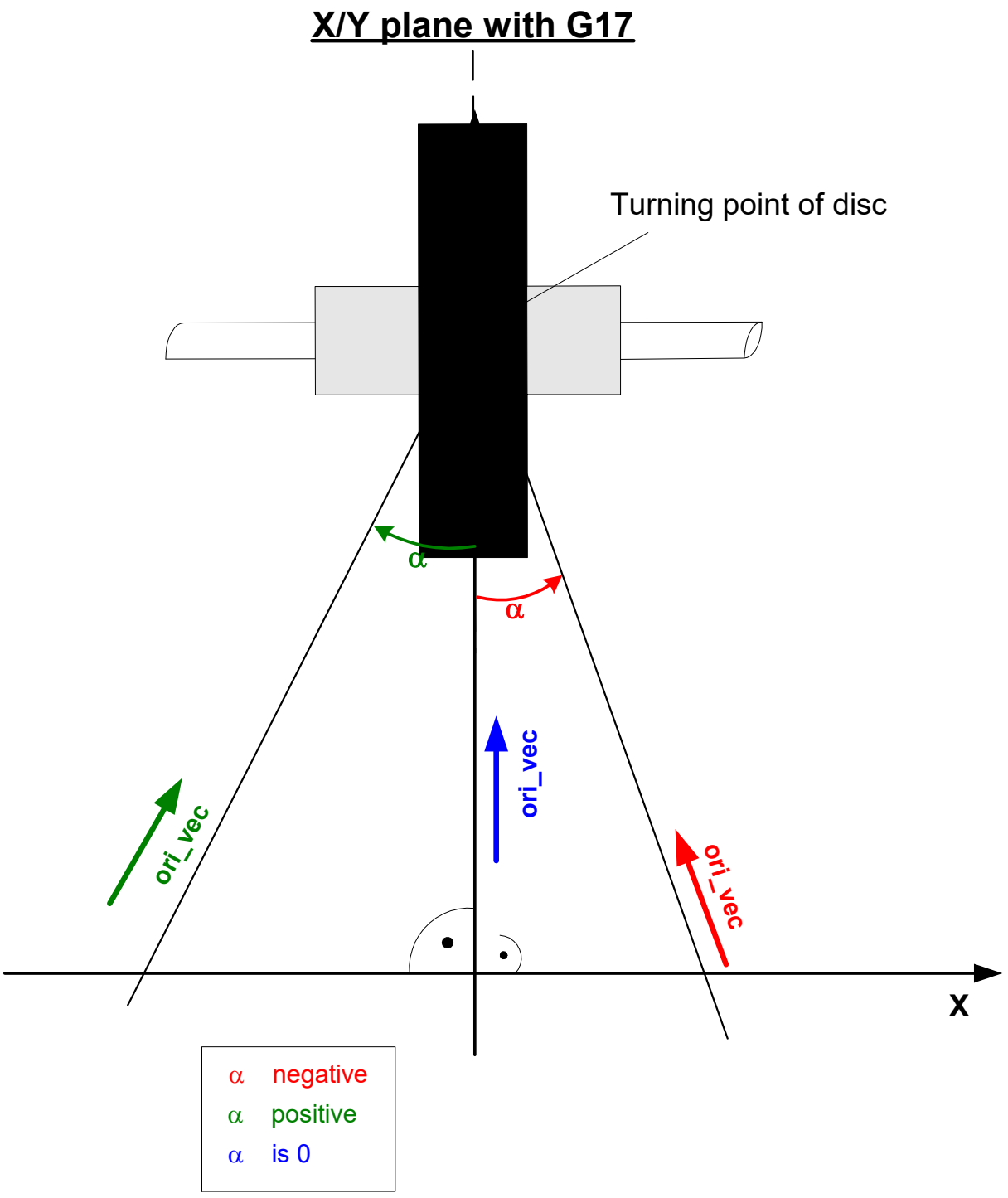


Fig. 7: Inclined grinding disc

Tool orientation is determined by the disc tilt angle. This tool orientation can then be used to apply the resulting wear proportionately to the main axes.

In the figure above, wear is included in the calculation of the X and Z axes.

2.4 Wear compensation in tool direction

Grinding a surface

This compensation type is used to compensate for wear in the tool direction. This can take place both continuously and discretely.

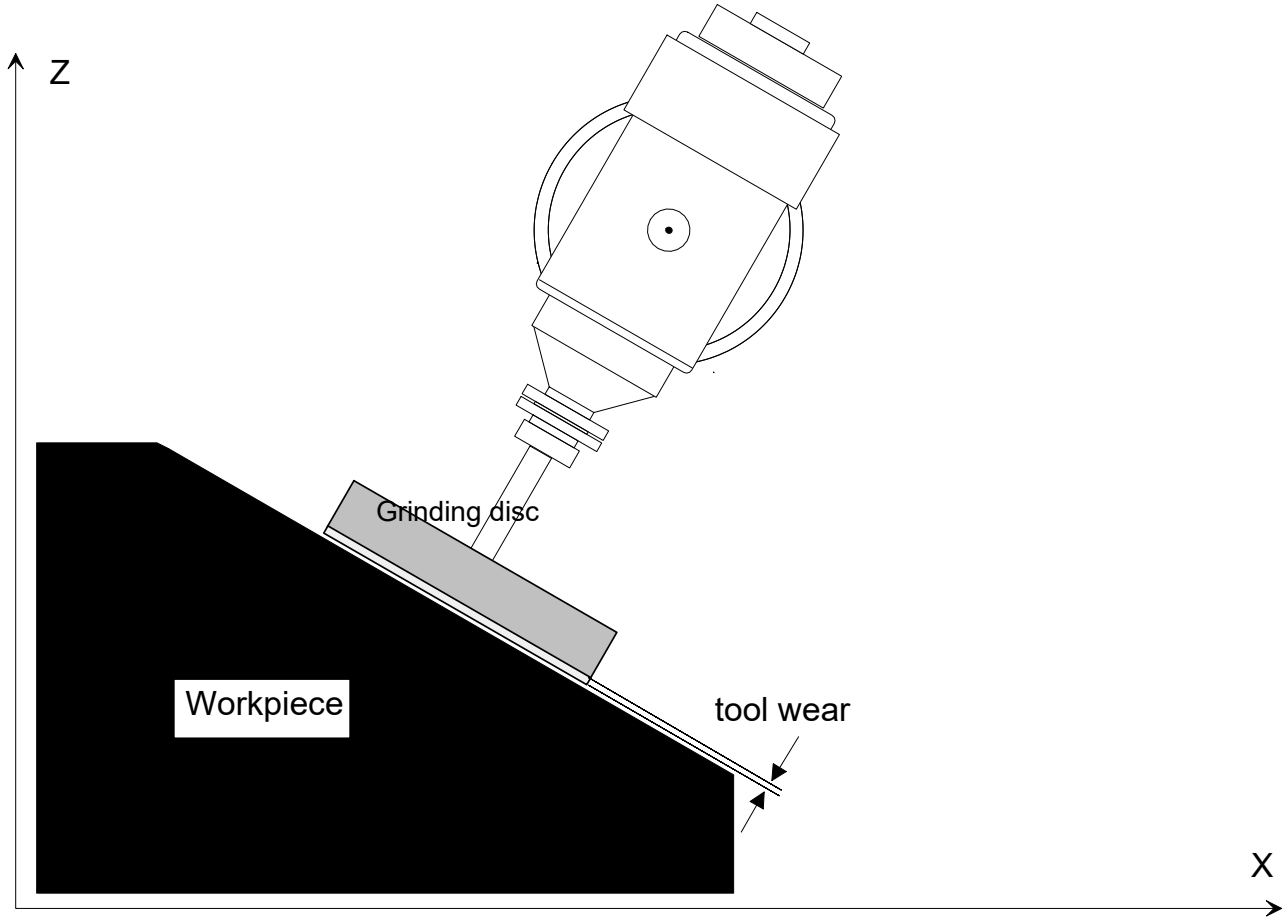


Fig. 8: Wear compensation in tool direction

OTC grinding with kinematic type 4

```
...
N30 D1                (Select record for grinding disc)
N40 G00 X0 Y0 Z300 B0
N50 #KIN ID[4]
N50 #TRAFO ON
N60 G00 B45
N70 G01 X100 Z50 F1000
N80 #OTC ON [TOOL_DIR, DISC]                (Select OTC)
N90 $FOR P1=0, 20, 1
N100 G91 G01 X10 Z-10 F2000
N110         X-10 Z10
N120 $ENDFOR
N120 #OTC OFF                               (deselect OTC)
N130 #TRAFO OFF
...
```

Programming kinematic parameters

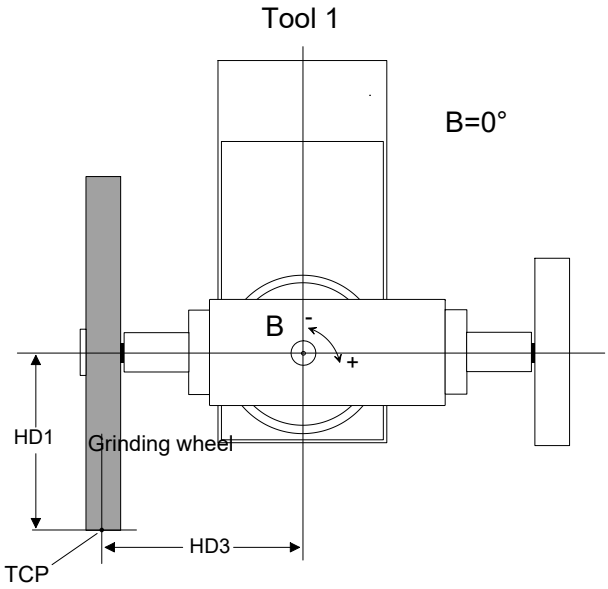


Fig. 9: Grinding disc setting B=0

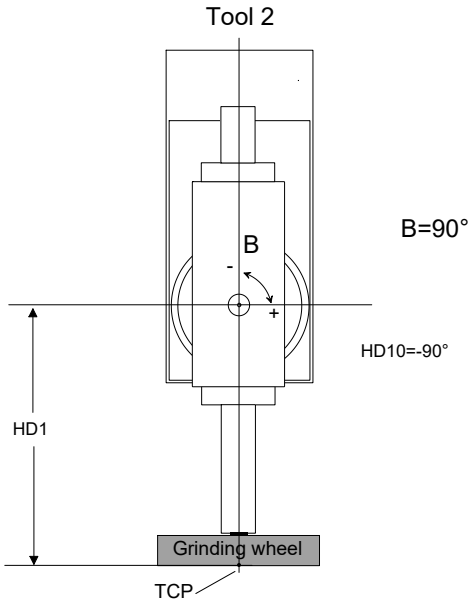


Fig. 10: Grinding disc setting B=90

The figure below shows the function of TOOL_DIR:

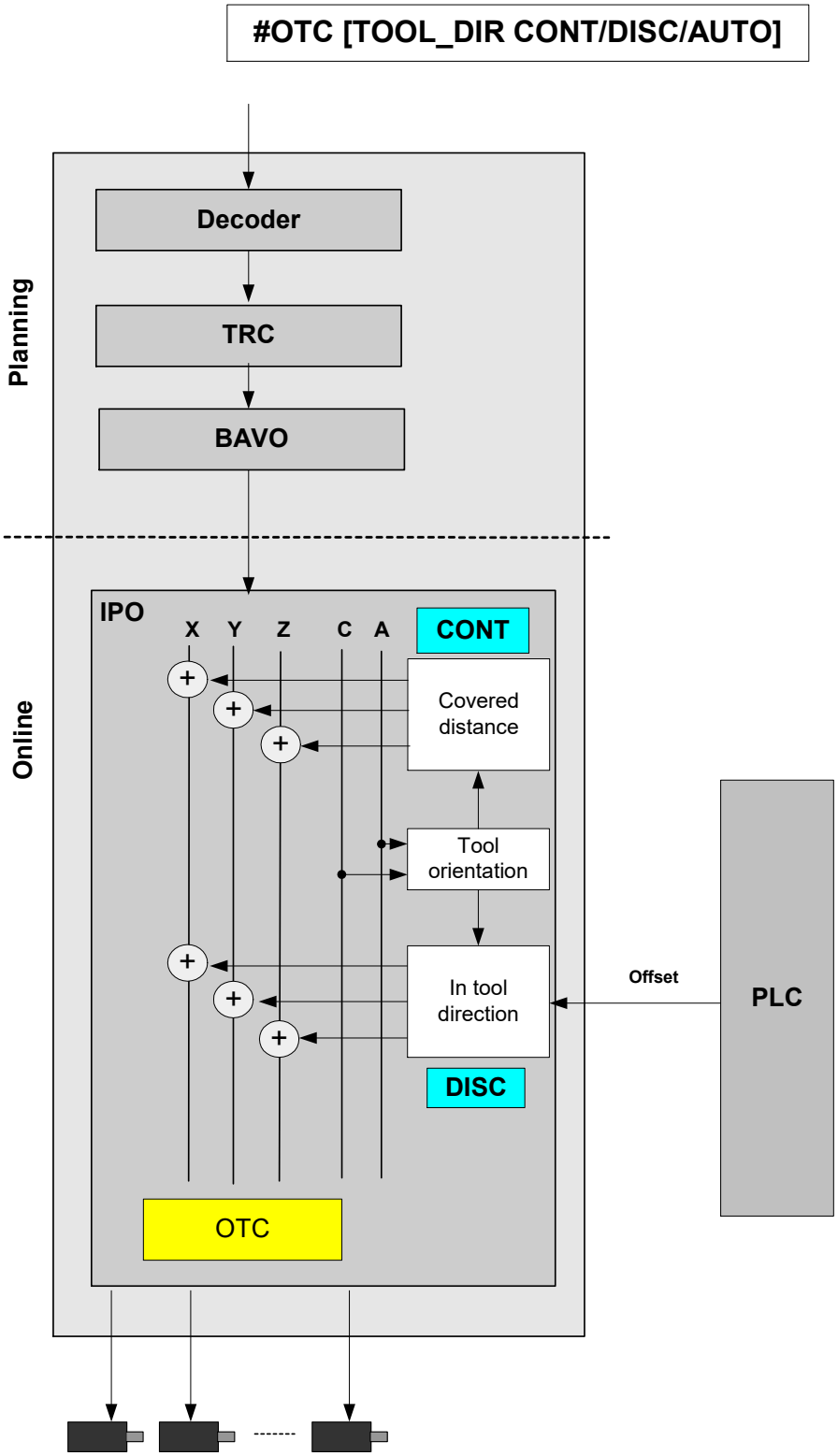


Fig. 11: Description of TOOL_DIR function

2.5 Wear compensation in direction of surface normal

Grinding a surface

This compensation type compensates for wear in surface normal direction. The surface normal direction is calculated in the CNC based on the tool direction vector and the path tangent vector.

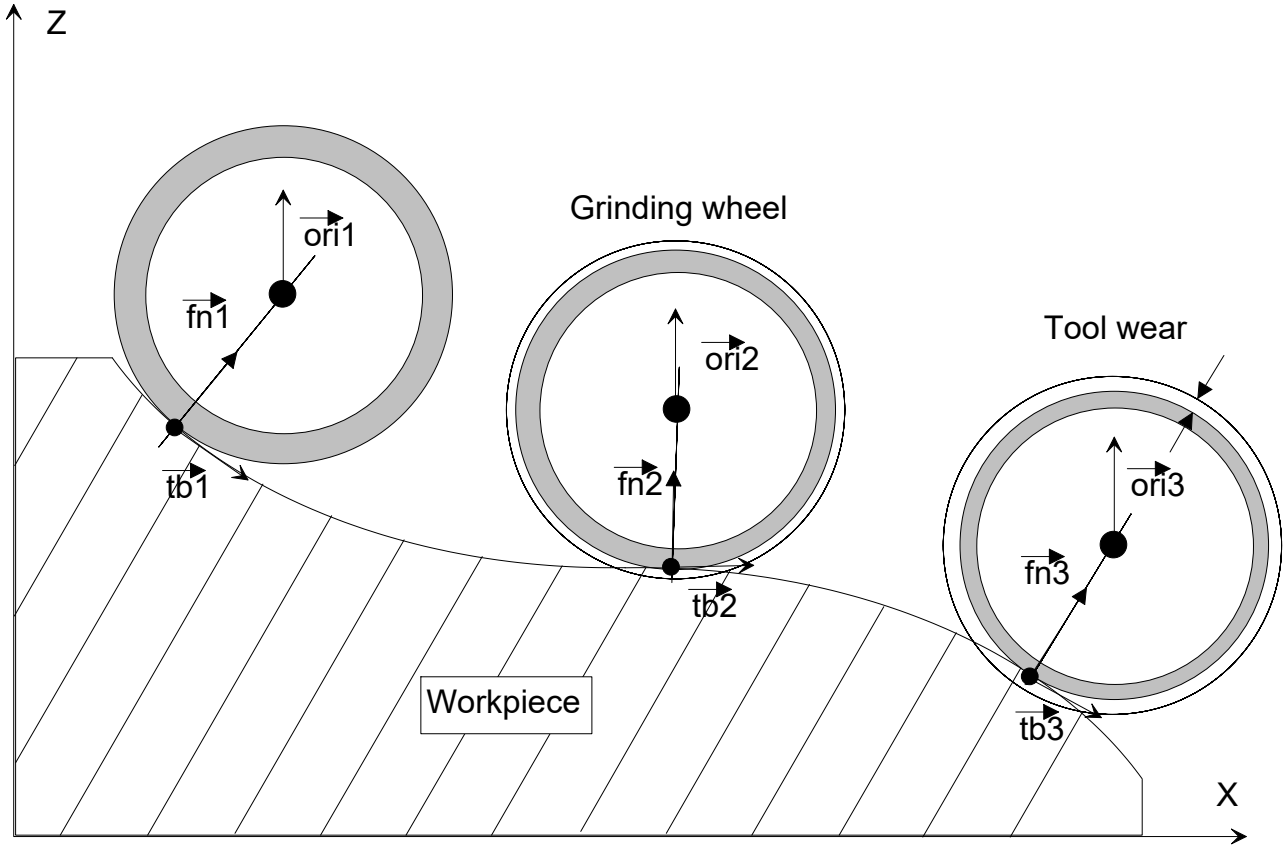


Fig. 12: Wear in surface normal direction

OTC grinding with kinematic type 4

```
N30 D1 (Select record for grinding disc)
N40 G00 X0 Y0 Z300 B0
N50 #KIN ID[4]
N50 #TRAFO ON
N60 G00 B0
N70 G01 X100 Z50 F1000
N80 #OTC ON [SURF_NORM_DIR, DISC] (Select OTC)
N85 #HSC ON[BSPLINE PATH_DEV 5 MERGE = 0]
N90 $FOR P1=0, 5, 1
N100 G91 G01 X3 Z-3 F2000
N110 X2 Z-2
N120 X5 Z-2
N130 X5 Z-1
N140 X5
N150 X5 Z-1
N160 X5 Z-2
N170 X2 Z-2
N180 X3 Z-3
N190 X-3 Z3 F2000
N200 X-2 Z2
N210 X-5 Z2
N220 X-5 Z1
N230 X-5
N240 X-5 Z1
N250 X-5 Z2
N260 X-2 Z2
N270 X-3 Z3
N280 $ENDFOR
N290 #HSC OFF
N300 #OTC OFF (Deselect OTC)
N310 #TRAFO OFF
M30
```

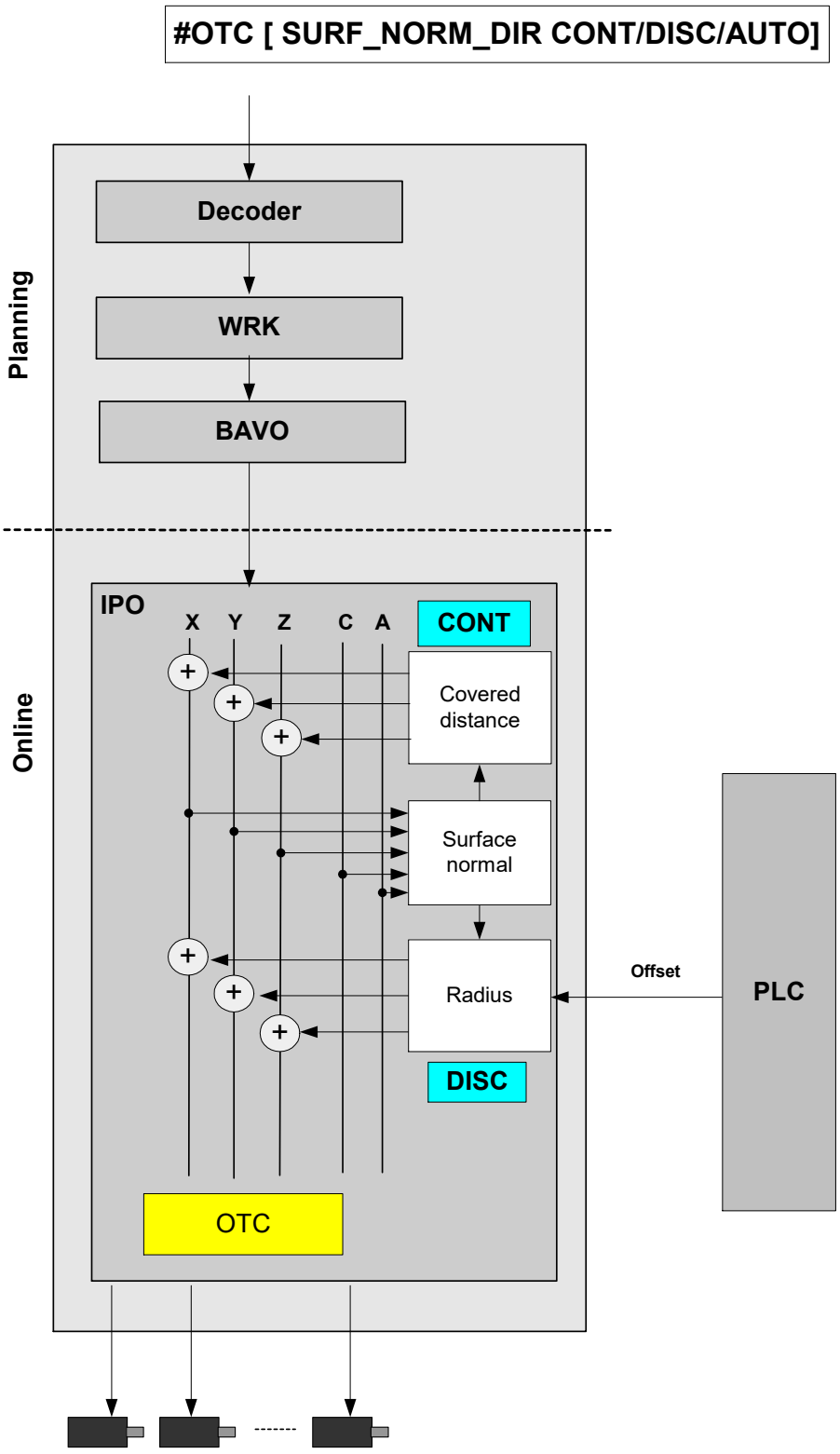


Fig. 13: Description of SURF_NORM_DIR function

2.6 Special settings in tool data

Definition of tool type and wear parameters:

```
wz[1].gueltig                       1
wz[1].typ                           2    grinding tool
wz[1].mass_einheit                  0
wz[1].laenge                        500000
wz[1].radius                        300000
wz[1].ax_versatz[0]                 0
wz[1].ax_versatz[1]                 0
wz[1].ax_versatz[2]                 0
...
# Wear constant : Unit 0.1 µm/m
wz[1].grinding_wear_const           100000
# Maximum applied discrete input via PLC, unit: 0.1µm
wz[1].grinding_max_infeed           200000
# Disc tilt angle, unit: 0.0001 degree
wz[1].grinding_disc_tilt_angle      0
```

The disc tilt angle must be entered as a function of the mechanical construction.

Unassigned data are assigned the value 0 by default.

Consequence: If the tool type is not assigned Type 2, the error P-ERR-21391 is generated when #OTC ON is programmed.

If grinding_max_infeed is not set, no discrete offset can be applied.

The following also applies: if grinding_wear_const is not set, it is not possible to calculate the continuous offset depending on the path.

2.7 HLI parameters

2.7.1 Channel-specific connection

The following channel-specific control unit is used to default wear values by the PLC in the modes – ‘Radius wear ‘ (RADIUS) or ‘Tool direction wear’ (TOOL_DIR).

See Programming (#OTC ON/OFF) [▶ 9]

The mode must be either DISC or AUTO in both modes.

Online tool compensation (OTC)	
Description	The tool radius is compensated by specifying a wear value. The wear value is specified as an offset from the planned cutting edge. It is only possible to used the control unit in the RADIUS or TOOL_DIR modes and in the DISC or AUTO mode. See NC command #OTC [▶ 9]. See also functional description [FCT-C20 [▶ 11]].
Data type	MC_CONTROL_SGN32_UNIT, see description of Control Unit
Special features	If the wear value changes, this change is distributed over several interpolation cycles to avoid sudden changes.
Access	PLC reads request_r + state_r and writes command_w + enable_w
ST Path	gpCh[*channel_idx*]^.bahn_mc_control.**otc_radius_offset**
Commanded, requested and return values	
ST Element	**.command_w** **.request_r** **.state_r**
Data type	DINT
Unit	0.1 µm
Value range	[-P-TOOL-00031, P-TOOL-00031]
Redirection	
ST Element	**.enable_w**

Adding wear in tool direction

In the third axis (axis_idx = 2) an offset value can be written in the tool direction. The PLC input of the first two axes is ignored.
All the axes in the following sequence can be influenced as usual by the PLC.

2.7.2 Axis-specific connection

Adding wear in axis direction

It is possible to use the following control unit both when the RADIUS mode is used as well as the LENGTH mode.
The mode must be either DISC or AUTO.

See Programming (#OTC ON/OFF) [▶ 9]

Adding wear in surface normal direction

When the SURF_NORM_ORI mode is used, it is possible to use automatic continuous wear compensation and influencing via the following control unit.
The mode must be either DISC or AUTO.

See Programming (#OTC ON/OFF) [▶ 9]

The surface normal is approximated based on the current tool orientation and path tangent (cf. RADIUS type). For a continuous change in direction of the surface normal vector, the contour and orientation should be steady at all times.

The PLC input of the first three axes is ignored All the axes in the following sequence can be influenced as usual by the PLC.

OTC offset	
Description	When this wear offset is set, wear in the direction of this axis can be compensated. When the SURF_NORM_ORI mode is used (wear in the direction of the surface normal), the offset value must be assigned in the third axis.
Data type	MC_CONTROL_SGN32_UNIT, see description of Control Unit
Special features	The wear offset is distributed by the CNC over several cycles.
Access	PLC reads request_r + state_r and writes command_w + enable_w
ST Path	gpAx[*axis_idx*]^.ipo_mc_control.**otc_offset**
Commanded, requested and return values	
ST Element	**.command_w** **.request_r** **.state_r**
Data type	DINT
Unit	0.1 µm
Value range	[-P-TOOL-00031, P-TOOL-00031]
Redirection	
ST Element	**.enable_w**

2.7.3 HLI parameters up to CNC Build V2.20xx

Channel-specific connection

Online tool compensation (OTC)

Description	The tool radius can be adapted by setting the wear offset depending on wear. [0,1µm] See also Wear compensation of tool radius [▶ 11]. It is only possible to used the control unit in the RADIUS or TOOL_DIR modes and in the DISC or AUTO mode. See NC command #OTC [▶ 9]. See also functional description [FCT-C20 [▶ 8]].
Data type	MCControlSGN32Unit, see description of Control Unit
Peculiarities	The wear offset is not output in a cycle in the CNC. Instead it is output over several cycles.
Access	PLC reads Request + State and writes Command + Enable
ST Path	pMC[*channel_idx*]^.addr^.MCControlBahn_Data.**MCControlSGN32Unit_OTCRadiusOffset**
Commanded, requested and return values	
ST Element	**.D_Command** **.D_Request** **.D_State**
Data type	DINT
Value range	[-P-TOOL-00031, P-TOOL-00031]
Redirection	
ST Element	**.X_Enable**

Axis-specific connection

OTC offset	
Description	When this wear offset is set, wear in the direction of this axis can be compensated. When the SURF_NORM_ORI mode is used (Wear in the direction of the surface normal), the offset value must be assigned in the third axis. Unit: 0.1µm
Data type	MCControlSGN32Unit, see description of Control Unit
Peculiarities	The wear offset is distributed by the CNC over several cycles.
Access	PLC reads Request + State and writes Command + Enable
ST Path	pAC[*axis_idx*]^.addr^.McControlIpo_Data.**MCControlSGN32Unit_OTCOffset**
Commanded, requested and return values	
ST Element	**.D_Command** **.D_Request** **.D_State**
Data type	DINT
Value range	[-P-TOOL-00031, P-TOOL-00031]
Redirection	
ST Element	**.X_Enable**
Move back manual mode offset	
Description	If manual mode is active in the channel and if the commanded axis fails to move, the axis is moved by this command so that afterwards manual mode offset is 0.
Data type	MCControlBoolUnit, see description of Control Unit
Peculiarities	A rising edge (FALSE → TRUE) at X_Command starts the process. The signal is ignored if a manual mode motion is still active or manual mode offset is already 0.
Access	PLC reads Request + State and writes Command + Enable
ST Path	pAC[*axis_idx*]^.addr^.McControlIpo_Data.**MCControlBoolUnit_ManualMvBackToStart**

Commanded, requested and return values	
ST Element	**.X_Command** **.X_Request** **.X_State**
Data type	BOOL
Value range	rising edge (FALSE → TRUE) triggers backward motion
Redirection	
ST Element	**.X_Enable**

2.8 Special V.G. variables for OTC

Reading wear values

Current tool wear can be read after processing with the following variables.

With radius compensation processing type in [mm] or [inch]:

- Total radius wear, discrete + continuous wear

  V.G.WZ_AKT.WEAR_RADIUS

- Continuous radius wear

V.G.WZ_AKT.WEAR_RADIUS_CONT

With length compensation processing type in [mm] or [inch]:

- Wear in axis with index <idx>

  V.G.WZ_AKT.WEAR[<idx>]

or

- Wear in axis with name <axis_name>

  V.G.WZ_AKT.WEAR.<axis_name>

The current wear value is supplied after deselecting OTC. The wear value refers to the wear which occurred between selecting and deselecting OTC.

If OTC is selected and deselected repeated in the same NC program, the above variables refer to the accumulated wear.

Writing/reading wear constant

The wear constant is defined as default in the tool data. It can also be read or written in the NC program by the variable V.G.WZ_AKT.WEAR_CONST in [0.1 µm/m]:

Status query: OTC active

The OTC state can be determined in the NC program. To do this, the NC program

V.G.OTC_ACTIVE

of the Boolean type must be readable in the NC program.

NOTICE
While OTC is active, V.G.WZ_AKT wear values are not up-to-date. They are only updated after OTC (#OTC OFF) is deselected.

2.9 Connecting to external tool management

Tool data

The external tool management system must provide the following data to the CNC when a grinding tool is changed (see [FCT-C10//section Tool data]:

- Type: Tool type 2 for grinding tool
- wear_const: Wear constant
- disc_tilt_angle: Grinding disc tilt angle
- ext_discret_limit: Maximum discrete input by the PLC

When the grinding tool is replaced, the CNC informs the external tool management system of the wear:

The wear data sent includes the following:

- wear_radius, total wear consisting of discrete and continuous wear
- wear_radius_cont, continuous wear

This wear data is generated from the time when the tool is replaced. The values must be taken over by the external tool management and are used internally to recalculate the tool geometric data (radius, length).

Unassigned data are assigned the value 0 by default.

Consequence: If the tool type is not assigned Type 2, the error P-ERR-21391 is generated when #OTC ON is programmed.

If grinding_max_infeed is not set, no discrete offset can be applied.

The following also applies: if grinding_wear_const is not set, it is not possible to calculate the continuous offset depending on the path.

3 Parameter

3.1 Overview

ID	Parameter	Description
P-TOOL-00001	typ	Tool type
P-TOOL-00030	grinding_wear_const	Wear constant
P-TOOL-00031	grinding_max_infeed	Maximum discrete infeed
P-TOOL-00138	grinding_disc_tilt_angle	Grinding disc tilt angle

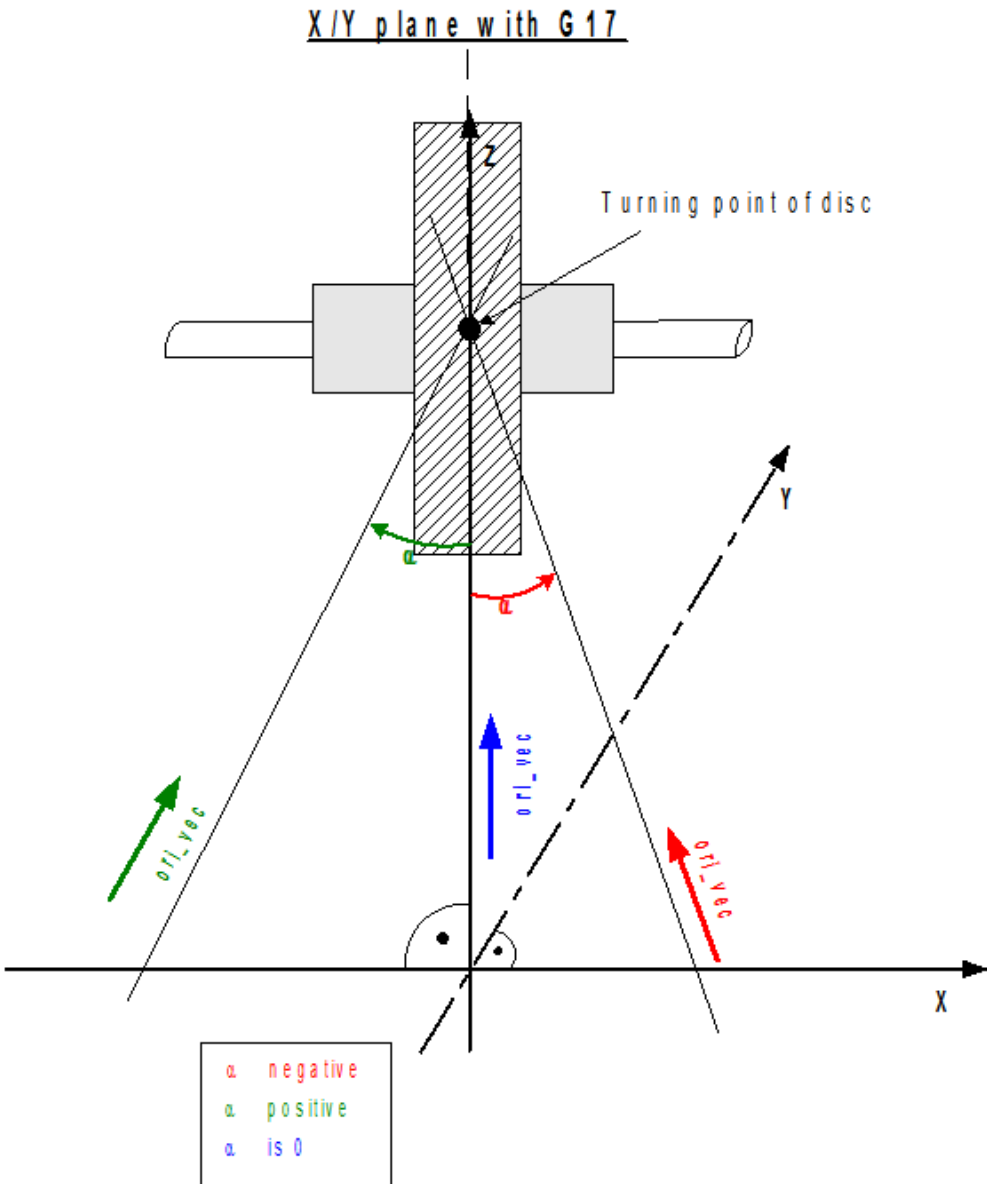
3.2 Description

P-TOOL-00001	**Differentiation between tool types**
Description	This parameter is assigned to distinguish between tool types.
Parameter	wz[i].typ
Data type	UNS16
Data range	0: Milling tool 1: Turning tool 2: Grinding tool 3: Wire (erosion)
Unit	----
Default value	0
Remarks	Parameterisation example: Tool 5 is a milling tool *wz[5]typ 0*

P-TOOL-00030	**Wear constant**
Description	The wear constant is used to calculate continuous tool wear. Alternatively, it can also be defined in the NC program (#OTC […].
Parameter	wz[i].grinding_wear_const
Data type	REAL64
Data range	0 ≤ grinding_wear_const
Dimension	0.1µm/m
Default value	0
Remarks	The wear constant should contain relatively small values. There is no special dynamic consideration based on the actual wear values.

P-TOOL-00031	**Maximum discrete infeed**
Description	The maximum discrete infeed defines the greatest relative change which is assignable by the PLC.
Parameter	wz[i].grinding_max_infeed
Data type	REAL64
Data range	MIN(SGN32) ≤ grinding_max_infeed ≤ MAX(SGN32)
Dimension	0.1µm
Default value	0
Remarks	

P-TOOL-00138	**Grinding disc tilt angle**

Description	The parameter defines the angle between the centre line of the grinding disc and the 3rd main axis for tilted grinding discs.
Parameter	wz[i].grinding_disc_tilt_angle
Data type	REAL64
Data range	-45°≤ grinding_tilt_angle ≤ 45°
Dimension	0.0001°
Default value	0
Remarks	 Grinding disc tilt angle

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Beckhoff Headquarters

Beckhoff Automation GmbH & Co. KG

Huelshorstweg 20
33415 Verl
Germany

Phone:	+49 5246 963-0
e-mail:	info@beckhoff.com
web:	www.beckhoff.com

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More Information:
www.beckhoff.com/TF5200

Beckhoff Automation GmbH & Co. KG
Hülshorstweg 20
33415 Verl
Germany
Phone: +49 5246 9630
info@beckhoff.com
www.beckhoff.com