DOCUMENTATION ISG-kernel

Functional description
Smoothing process

Short description:
FCT-D3

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Preface

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Personnel qualifications

This description is solely intended for skilled technicians who were trained in control, automation and drive systems and who are familiar with the applicable standards, the relevant documentation and the machining application.

It is absolutely vital to refer to this documentation, the instructions below and the explanations to carry out installation and commissioning work. Skilled technicians are under the obligation to use the documentation duly published for every installation and commissioning operation.

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Further information

The links below (German/DE)

https://www.isg-stuttgart.de/produkte/softwareprodukte/isg-kernel/dokumente-und-downloads

or (English/EN)

https://www.isg-stuttgart.de/en/products/softwareproducts/isg-kernel/documents-and-downloads

contain further information on messages generated in the NC kernel, PLC libraries, tools, etc. in addition to the latest documentation (PDF or as HTML online help).

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1 Overview

Task

NC programs describe tool motions using linear blocks and arcs. Smoothing methods are required to enable these contours to be traversed without stopping. Depending on the application and hardware, various options are available, each with suitable generators for feed rate profiles. In addition, axis command values can be filtered symmetrically [FCT-C37] and FIR filter [▸ 51].

Notice

Parts of these functionalities are additional options that require a license.

Possible applications

- Contour mode methods which smooth each corner are ideal for programs with long motion blocks. This is often referred to as polynomial contouring [▸ 11].
- HSC methods are suitable for free-form surfaces that contain several short blocks since they machine the entire contour. The surface option represents an excellent, robust method.
- The B spline method [▸ 43] places fewer requirements on the hardware and is suitable for programs with uniform linear blocks.

Parameterisation

- With all smoothing methods, the deviation between a smoothed and a programmed contour is limited by the parameter PATH_DEV. TRACK_DEV can also be specified for tracking axes.
- The higher HSC methods are expansions that require a license and can be enabled at controller start-up [P-CHAN-00605].
- The CIR_MODE option and the channel parameter P-CHAN-00239 are required to smooth transitions with arcs. If a kinematic is used, it may be useful to activate the automatic segmentation of NC programs.

Programming

Smoothing methods can be configured and selected using the following commands:

- #CONTOUR MODE [PATH_DEV=..], select with G261 and deselect with G260
- #HSC ON [SURFACE PATH_DEV=] and #HSC OFF
- #SLOPE [TYPE= TRAPEZ, STEP or HSC]

References

- [PROG] G functions \ Path conditions and
- [PROG] Additional options \ Jerk-limiting slope and Surface [▸ 38]

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 Smoothing methods

Introduction

A programmed contour smoothed within specific tolerances to allow it to move as quickly and uniformly as possible even over corners without stopping.

Notice

In general, it is advisable to program the smoothing methods using as many decimal places as possible.

This increases the accuracy of the internal calculations and thus the quality of the smoothing methods.

There are various processes available for contouring:

Contour mode: Polynomial contouring is ideal for simple contours with few long linear and circular blocks. This is selected by using **G61/G261** and deselected with **G260**, for example. This method is described in section G functions [PROG].

It is preferable to use the two **HSC** methods Surface and B spline when there are several short linear blocks:

Surface: The highly rugged SURFACE method [▸ 38] is particularly suited to free-form surface machining. It achieves the best results in the event of disruptions in the programmed contour and blocks which have very different lengths. By contrast, this places greater requirements on the hardware.

B spline method: The B spline method [▸ 43] can also be used to trim a contour or for very regularly spaced control points. It requires less high-performance hardware.

The two methods Surface or B spline should be supplemented by the options CIR_MODE [▸ 38] and the channel parameter P-CHAN-00239 [▸ 75] in order to additionally smooth circular blocks in HSC programs. If NC programs contain many short blocks, it is advisable to use the HSC profile generator #SLOPE[TYPE=HSC] [▸ 47].

Filter: Besides smoothing a programmed contour, it may be useful to filter axis command values symmetrically. The corresponding functions are described in the function descriptions [FCT-C37] FIR filter.

Apart from these recommended standard methods, there are a number of other methods such as interpolation with the Akima spline [PROG], the direct programming of B spline control points [PROG] and older HSC functions with OP1 and OP2 [PROG].

Name of function (* = requires license)	**Its suitability**	**Advantages**	**Disadvantages**
Contour mode:	For simple contours with few long blocks.	Greater path velocities at block transitions..	Restricted smoothing effect for short NC blocks.
Surface methods*	For contours with several short blocks.	Very rugged against program generation errors (CAM).	Increased hardware requirements.
B spline method*	Trimming a contour or very regularly spaced blocks.	Lower hardware requirements compared to Surface.	If programmed unfavourably, slower path motion.
Filter programming*	Filter axis command values symmetrically.	Additional contour smoothing with steadier axis motions.	Additional contour deviation.

No longer recommended:			
Name of function (* = requires license)	**Its suitability**	**Advantages**	**Disadvantages**
Akima spline	Interpolates specified interpolation points.	Runs precisely through the programmed points.	Generally requires a denser and exactly calculated specification of points.
B spline interpolation	Simulates a spline interface.	Full control of the path travelled by the CNC machine.	Monitors no tolerances.
HSC functions with OP1 and OP2*	Rigid machines	Low hardware requirements	Relatively strong excitation of machine structure.

3 Description of the various smoothing methods

CAD/CAM systems use an error-tolerant algorithm to scan the original surface model. The task of the NC is to follow the interpolation point path at high velocity. When CAD/CAM systems are used, the NC program is generated by scanning the original contour created by the user. Then linear and circular blocks are generated depending on the CAD/CAM system. This often results in short blocks ranging from a few mm down to 1/1000 mm.

The figure below shows an example of a linear path of a tool track:
Each interpolation point represents an NC block.

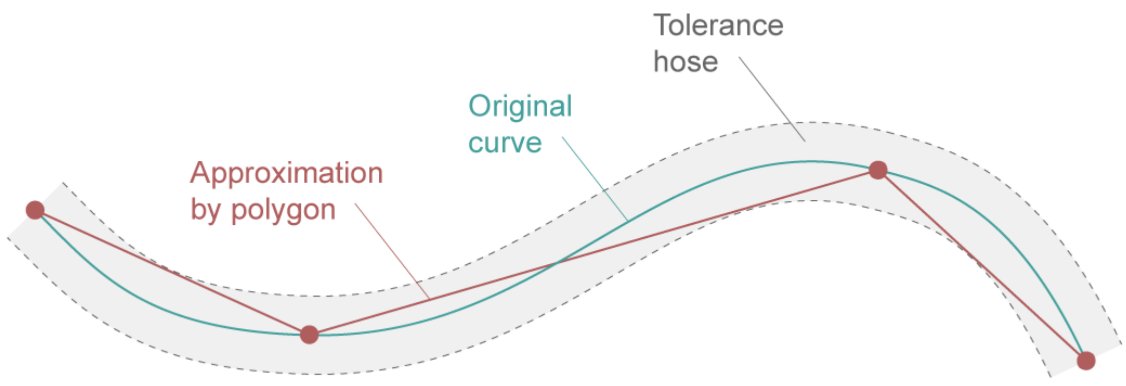


Fig. 1: Approximation of a continuous tool path by means of linear blocks within a tolerance band.

Depending on the workpiece type, the contour then describes a relatively smooth path (non-prismatic), or the contour contains corners or edges which must be reproduced or remain recognisable in the workpiece.

A sufficiently high path velocity can only be achieved if the generated NC program has a smooth path of interpolation points. Large fluctuations in block motion paths can lead to highly fluctuating feed rate profiles. This can also have a negative impact on machining results.

Irregular distributions of interpolation points are best interpolated using a highly smoothing method such as the Surface method. However, it is even better to use a suitable filter function in the CAD/CAM system since only this system contains the original contour data.

In all contour smoothing methods, the error tolerance for the main axes forming the feed group is defined in millimetres using the keyword **PATH_DEV**. If there are more than 3 axes, the tolerance of the angular axes is additionally specified in degrees using the keyword **TRACK_DEV**.

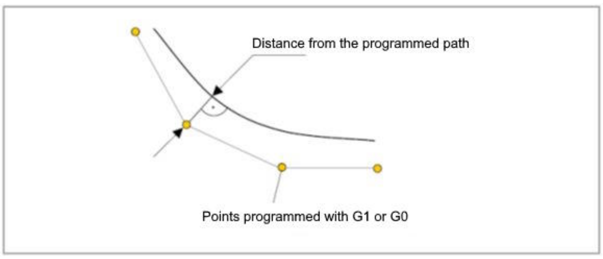


Fig. 2: Distance between the smoothed contour and the programmed path

3.1 Contour mode (for simple programs)

`Syntax:`

G61	Polynomial contouring (at block end)	non-modal

... or for polynomial contouring across several blocks:

G261	Selecting polynomial contouring (at block end)	modal
G260	Deselecting polynomial contouring	modal

3.1.1 Definition of terms

Polynomial contouring:	Curvature and direction-continuous connection of two motion blocks.
Contouring curve:	The contouring curve inserted at the corner point.
Block length:	The path length of the curve corresponding to the motion block.
Corner distance:	Distance from the start/end of the contouring curve to the programmed target point/starting point of a motion block (see figure below). The corner distance is always limited to half the block length. In a circular block, the corner distance is the arc length from the starting point of the contouring curve up to the programmed target point of the arc.

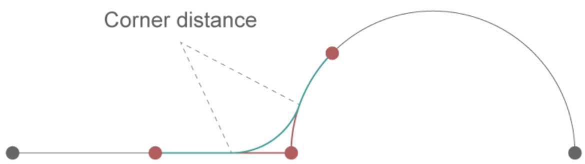


Fig. 3: Definition of corner distance

Pre-block:	Motion block before the contouring curve
Post-block:	Motion block after the contouring curve
Pre-distance:	Corner distance of the pre-block
Post-distance:	Corner distance of the post-block
Interim point:	Point at which the two partial curves of the contouring curve meet.
Corner deviation:	The distance between the programmed corner point and the interim point of the contouring curve (see figure below).

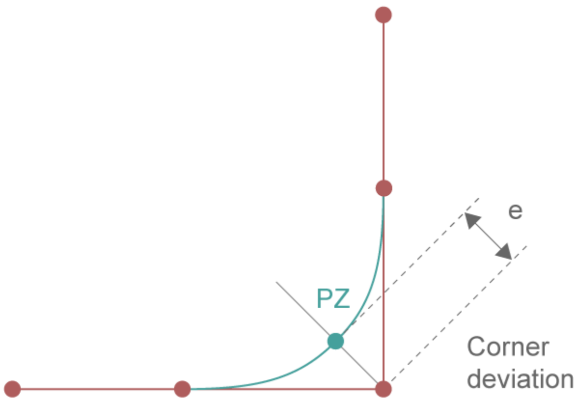


Fig. 4: Definition of corner deviation

Programing Example

Comparing the programming of G61 – G261/G260

The three NC programs all generate the identical contour shown in the figure below.

```
%poly_G61
N10  X0   Y0 G01 F1000
N20 X20 Y100
N30  G61  X40 Y100
N40  G61  X60 Y20
N50  G61  X80 Y20
N60  G61  X100 Y100
N70  X120 Y100
N80  X140 Y20
N90  X160 Y20
N100 M30
```

```
%poly_G261_1
N10  X0   Y0 G01 F1000
N20  X20  Y100
N30  G261 X40 Y100
N40  X60  Y20
N50  X80  Y20
N60  X100 Y100
N70  G260 X120 Y100
N80  X140 Y20
N90  X160 Y20
N100 M30
```

```
%poly_G261_2
N10 X0   Y0 G01 F1000
N20 X20  Y100
N25 G261
N30 X40  Y100
N40 X60  Y20
N50 X80  Y20
N60 X100 Y100
N70 X120 Y100
N75 G260
N80 X140 Y20
```

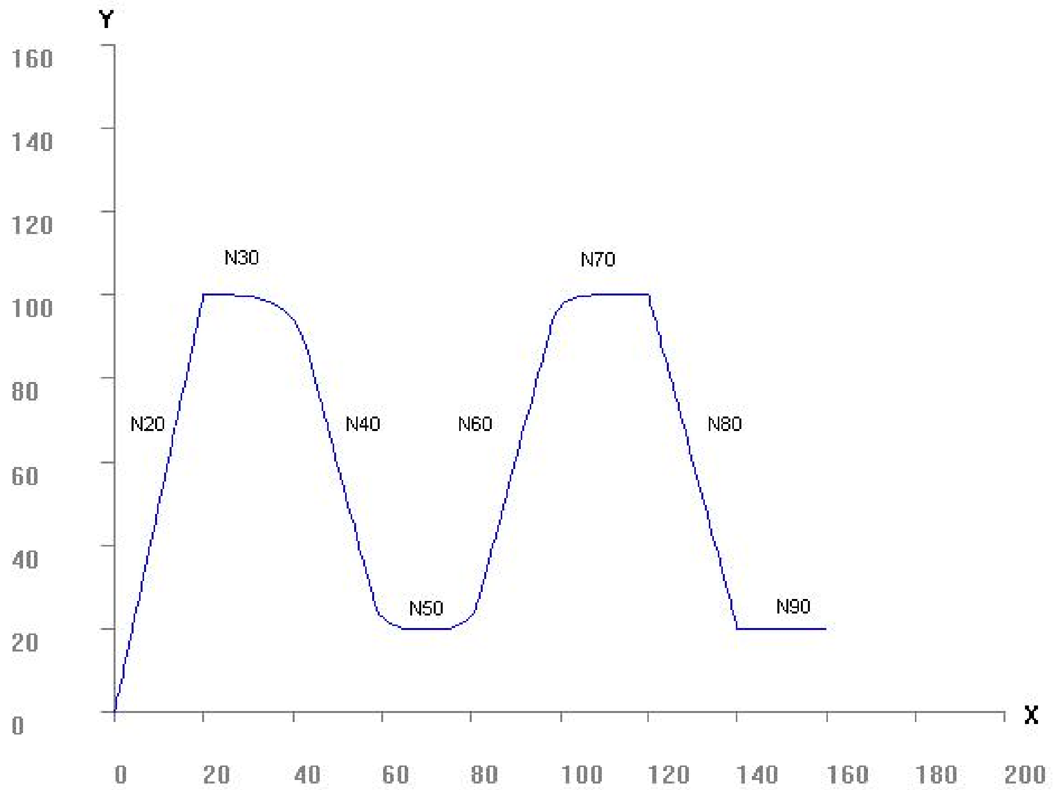


Fig. 5: Contour for programming G61 – G261/G260

3.1.2 General properties of contour mode

The process of polynomial contouring is calculated from the geometrical path contour of the main axes in space. The given conditions, e.g. corner deviation or percentage path velocity, result in a position on the original contour from which the contour can be changed or replaced by a contouring curve (polynomial). This means that the starting or target point of the contouring curve which is known on the original path curve.

Using the determined starting and target points of the polynomial of the main axes calculated using the conditions, it is also possible to specify the position of the tracking axes at which their original contour can be replaced by a polynomial.

With tracking axes, as with main axes, a curvature and direction-continuous polynomial is inserted between the corner distances of the pre-block and post-block, taking into consideration the max. acceleration of these axes. However, the originally specified corner deviation refers only to the deviation of the main axis in space so that, if required, an additional limit value can be specified for the maximum deviation of the tracking axes. Any theoretical excess of this deviation by the tracking axis causes a reduction in the contouring curve (reduction in corner distance).

Polynomial contouring is automatically suppressed depending on the transition between the pre-block and post-block if:

- The transition of all axes is mirrored tangentially or directly.
- The transition of the main axes is tangential and no maximum deviation (value = 0) was specified for the tracking axes.
- After programming G61, program end is reached without post-block.

Maximum corner distance, minimum residual block length

In addition, the following restrictions apply in order to generate smooth transitions.

- The corner distance may assume a maximum of 50% of the original block length. If the corner distance selected is greater, the distance of the pre-block and post-block is limited accordingly. If the corner distance at block start and block end is 50% of the original block length, the block is skipped completely.
- When parameterising the contouring function, the minimum residual block length can be set between 0% and 100%. This corresponds to a variable maximum corner distance from 50% to 0%. At every program start, the minimal residual block length is first set to 0% (block can be completely contoured). If the minimum residual block length is specified as 10%, for example, the corner distances of this block can be maximum (100% - 10%) / 2 = 45% of the original block length.
- In circular blocks the maximum corner distance (distance travelled on circle) is limited so that the angle covered does not exceed 90°.

3.1.2.1 Relevant block length

If the programmed relevant block length, which is defined by **RELEVANT_PATH** is less than the defined minimum length of 32 µm, the block is limited to this minimum length.

In addition, the contour can include very short compensation blocks which are inserted by a programming system (CAD/CAM) or by tool radius compensation. After compensation the block retains a continuous path.

A minimum block length can be defined in order to avoid abortion of contouring by these short blocks: Shorter blocks are skipped during active contouring, i.e. contouring is considered in the following block.

Here, a limit for the motion path of the main axes in space as well as a limit can be specified for the motion path of the tracking axes. The block is skipped completely only when both the motion path of the main axes and the motion path of the individual tracking axes are below the specified limit. Polynomial contouring combines the pre-block and the post-block in direction and curvature-continuous function. The initial blocks need not be adjacent (contour need not be continuous).

If a block is skipped, the maximum corner deviation of the main axes and tracking axes can only be approximated. This means, it is assumed that the deviation of the contouring can be ignored in the skipped blocks.

Programing Example

Relevant block length

```
#CONTOUR MODE [DEV, PATH_DEV 5, RELEVANT_PATH 2]
N03 G01 X0 Y0 Z0 C0 F4
N907090 G04 X0.1
N04 X5 G261
N05 Y1
N09 X10 Y3 G260
N907091 Y0
```

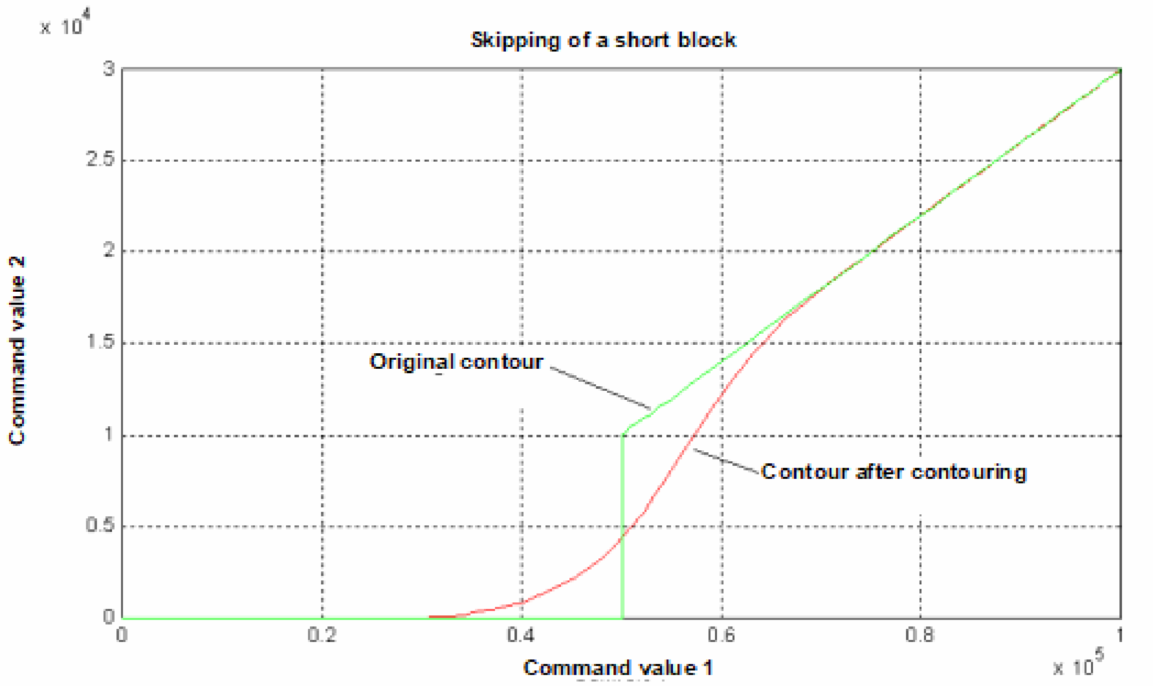


Fig. 6: Example of skipping a short block N05 when contouring

Special case 1: Sequence of multiple short blocks behind the block transition

If multiple sequential blocks (N20, N30, N40) are shorter than the minimum motion path specified, the blocks are skipped provided the distance to the target point from the last relevant end point (N10) is shorter than the specified minimum motion path. If the target point of the skipped block is outside this envelope curve, the block (N40) is used to calculate the contouring curve even if it is shorter than the specified minimum length. This method permits a slight deviation from the original contour even if multiple sequential blocks are skipped.

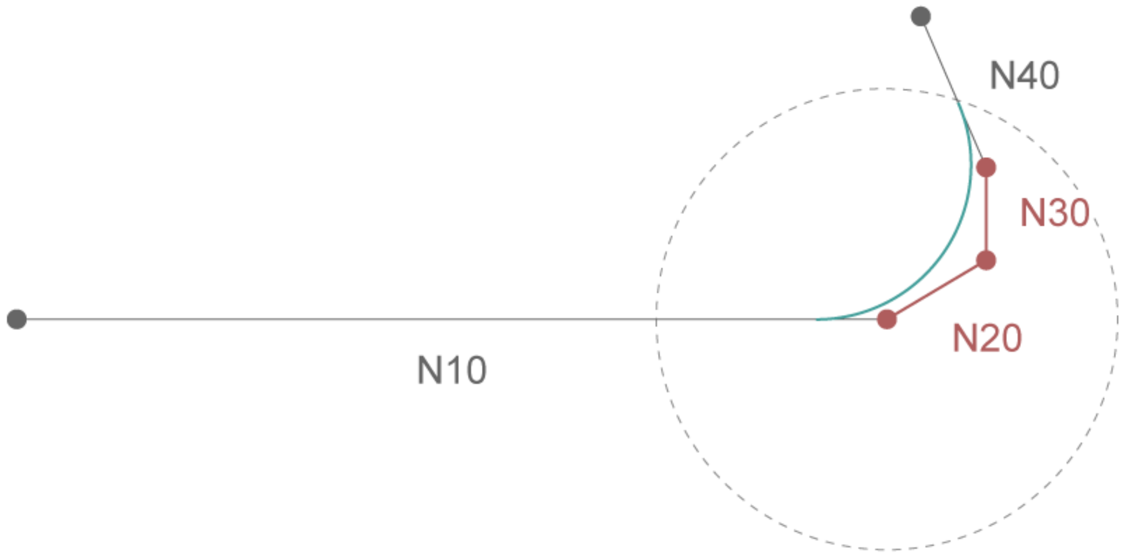


Fig. 7: Some single blocks (N20, N30 and N40) are too short but the target point is outside the minimum block length.

Special case 2: Sequence of multiple short blocks behind the block transition, last block is extremely short

As an exception, the block N40 itself may be shorter than the minimum system-specific length (about 16 µm) required for contouring. In this case, the last end point and the new target point are connected by a linear block. This new linear block N20´ is then used to calculate the contouring curve.

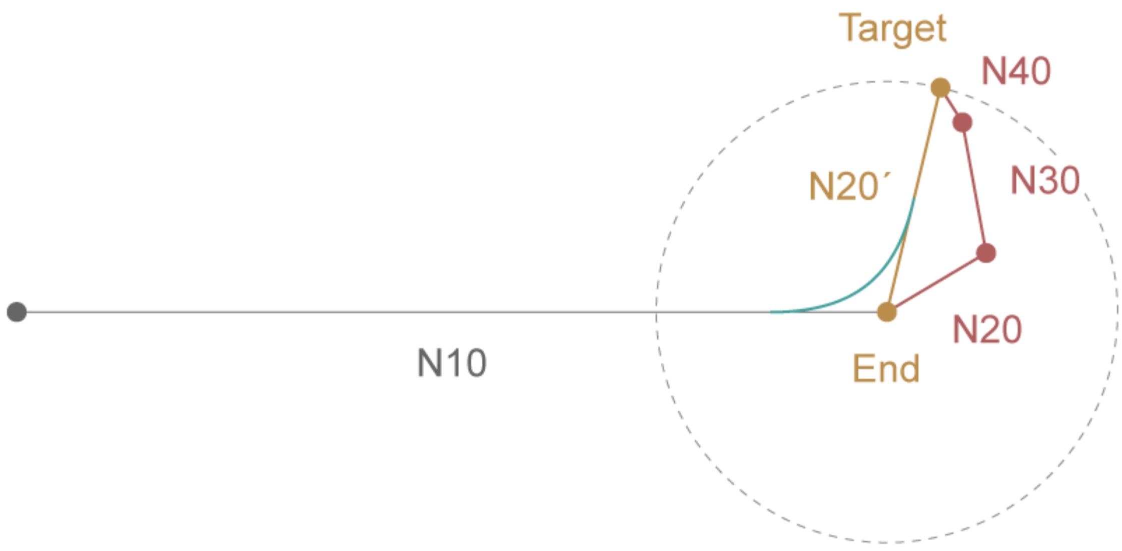


Fig. 8: Single blocks (N20, N30 and N40) are too short but the sum of all blocks exceeds the minimum system-specific block length.

Special case 3: Short blocks before the block transition

If the blocks at the beginning of contouring (before block transition) are already shorter than the minimum system-specific length, the blocks are skipped. The blocks are skipped until the distance between the last valid point and the current target point exceeds the minimum block length. If this is the case, the last end point and the current target point is connected by a linear block N10’. This linear block then is used as the start block for contouring.

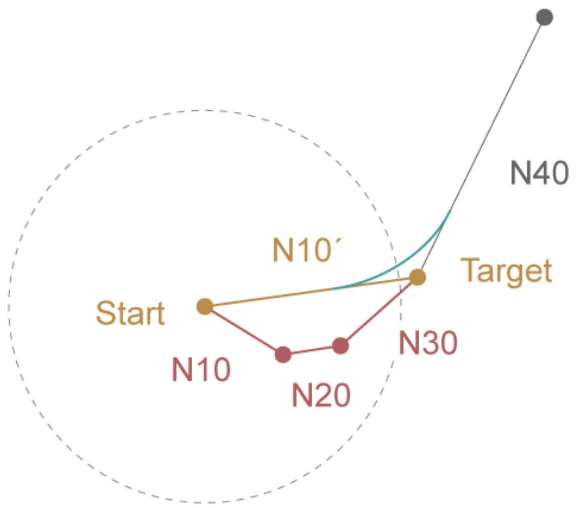


Fig. 9: Multiple blocks (N10, N20 and N30) are too short but the sum of all blocks exceeds the minimum system-specific block length.

Special case 4: Deselect contouring or changing parameterisation

If contouring is deselected when blocks are skipped or the basic conditions for contouring are changed, the current contouring may only be continued up until they are deselected or parameters are changed. After this function, contouring may be continued using the new parameters.

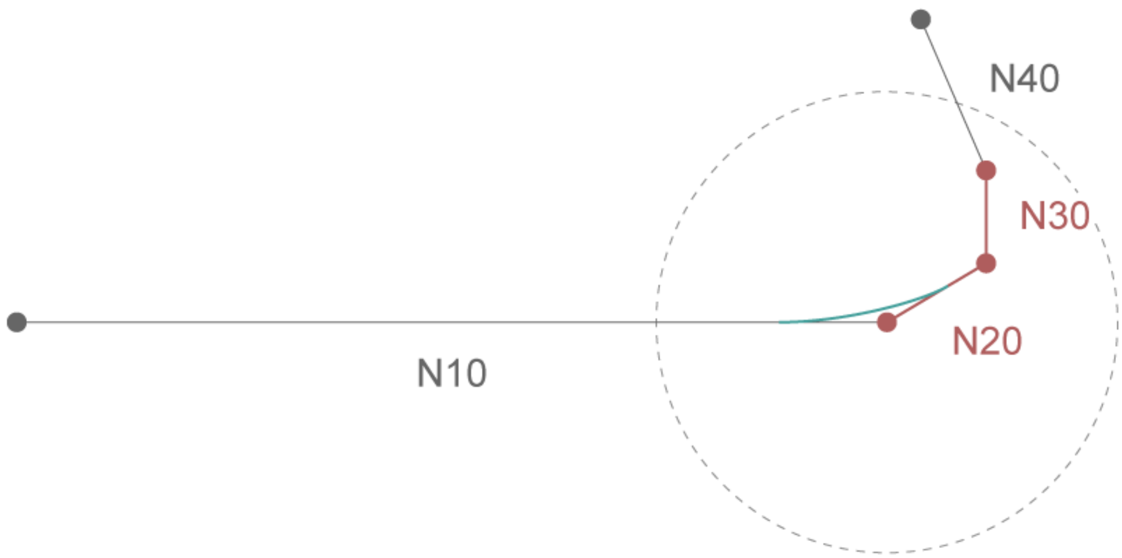


Fig. 10: Some single blocks (N20, N30 and N40) are too short but contouring is deselected as of block N20.

3.1.2.2 Executing additional blocks

If a command without contour information is programmed in addition to the motion blocks at block end (N10 – N20) (e.g. M function requiring acknowledgement with pre-block output and post-block synchronisation, MVS_SNS), the command may be executed before, during or after the contouring curve.

Programing Example

Executing additional blocks

```
N100 #CONTOUR MODE [DEV, PATH_DEV 4, RELEVANT_PATH 0.1, INTER_ACTION]
N110 X100 G61 M25
N120 Y100
```

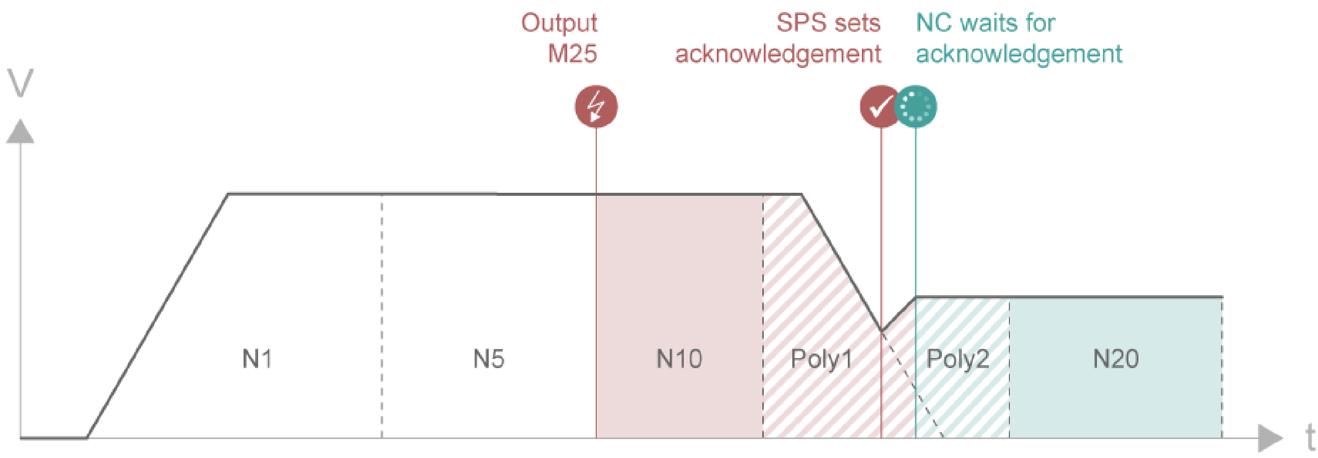


Fig. 11: Synchronisation without contour-relevant actions during contouring

```
N100 #CONTOUR MODE [DEV, PATH_DEV 4, RELEVANT_PATH 0.1, POST_ACTION]
```

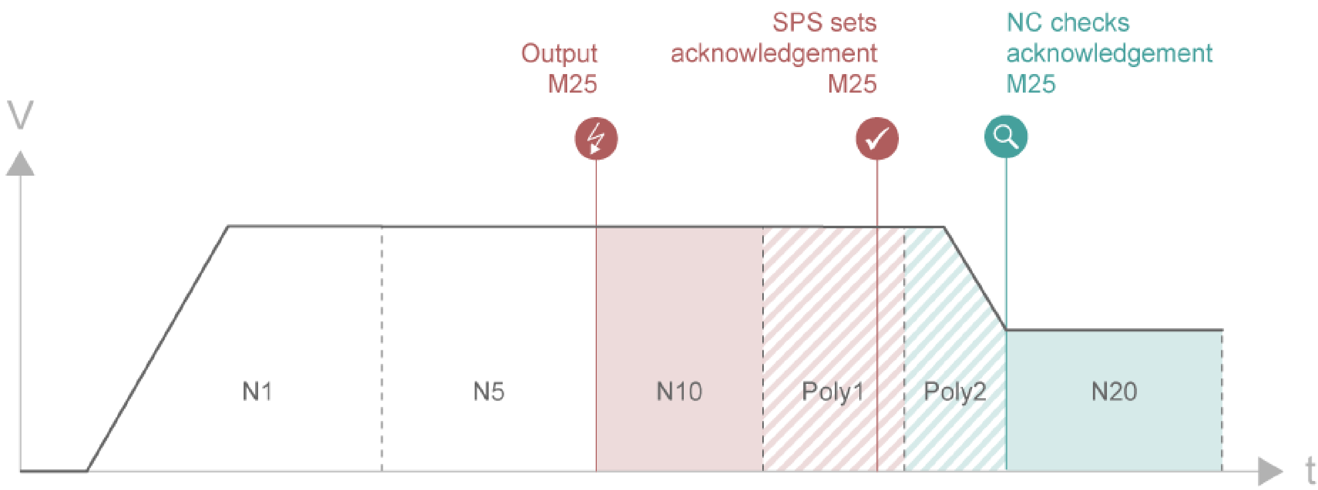


Fig. 12: Synchronisation without contour-relevant actions after contouring

There are 3 options to execute these commands:

1. Directly after pre-block (N10) and before the first contouring polynomial
2. Between first and second contouring polynomial
3. After the second contouring polynomial and before the post-block (N20)

3.1.2.3 Jerk within the polynomial

The curvature of the polynomial results in a jerk for the axes running across the path trajectory. This jerk is normally checked with the maximum dynamic parameters of the axes (P-AXIS-00199). If the jerk is too strong, path velocity is reduced accordingly. In some user-specific applications, this reduction in velocity is undesirable because of the maximum jerk. This can be defined specifically by control commands in the NC command #CONTOUR MODE. The control commands overwrite the pre-definition in the channel parameter list P-CHAN-00110 and are valid modal up to program end.

In the example below, the block transition from N6 to N7 is contoured by polynomials and this is considered by the jerk. The transition from N7 to N8 is also contoured but with no consideration for jerk on the path contour.

Programing Example

Jerk within the polynomial

```
%poly_jerk.nc
(default setting in the channel parameter list:
(check_jerk_on_poly_path)

#SLOPE[TYPE=TRAPEZ]
#CONTOUR MODE [ DEV, PATH_DEV 4, RELEVANT_PATH 0.1]
N0003 G1 X0 Y100 Z0 F4

N0004 G261
N0005 G1 G91 X100
N0006 Y-50
N0007 #CONTOUR MODE [CHECK_JERK=1]
N0008 X100
N0009 #CONTOUR MODE [CHECK_JERK=0]
N0010 Y-50
N0009 G260
N0055 M30
```

3.1.2.4 Velocity curve in the contouring section

Depending on axis parameterisation and the application, it may be necessary to influence the velocity curve in the contouring section. In the default definition, the contouring section is travelled at maximum permissible path velocity. If the axes have strongly different dynamics, this could lead to an unacceptable excitation of vibrations in the machine because path velocity is adjusted in the contouring section.

The characteristic in the contouring section can be adjusted by specific control commands in the NC command #CONTOUR MODE.

In the example below, the block transition from N6 to N7 is contoured by polynomials which are moved in the contouring section at maximum velocity, i.e. the velocity is adjusted here by different axis dynamics. The transition from N9 to N10 is also contoured but without any velocity adjustment. This leads to a constant path velocity in the contouring section.

Programing Example

Compensate velocity curve in the contouring section

The velocity curve on the right-hand side of the graph is compensated.

```
%poly_const_speed
N0003 #SLOPE[TYPE=TRAPEZ]
N0004 G1 X0 Y0 Z0 F8000
N0005 #CONTOUR MODE [CONST_VEL=0]
N0006 X100 G61
N0007 Y100
N0008 #CONTOUR MODE [CONST_VEL=1]
N0009 X0 G61
N0010 Y0
N0020 M30
```

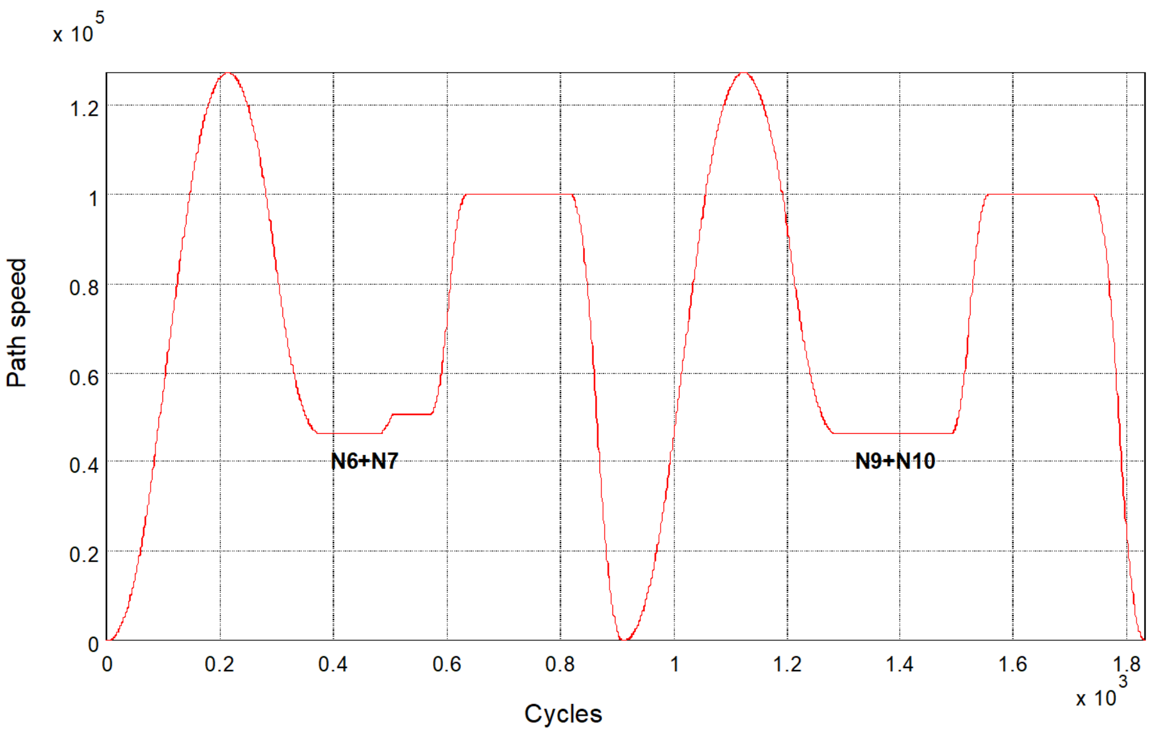


Fig. 13: Behaviour in the contouring section

3.1.3 Contour mode in the NC program

Contouring is activated by the G functions G61 (blockwise) or G261 (modal) after parameterising the corresponding contouring mode.

Programing Example

Activating contour modes in the NC program

```
%Contour_on_off
N10 G90 G01 X0 Y0 Z0 A0 C0 F60
N20 #CONTOUR MODE ON [DEV PATH_DEV=1.0]     ;Parameterise and
                                            ;activate (= G261)
N30 X100
N40 Y100
N50 X0
N60 Y0
N70 #CONTOUR MODE OFF                       ;Deactivate (= G260)
N80 M30
```

Parameterise contour modes in the NC program

Before the actual enabling of polynomial contouring (G61/G261), the individual options are parameterised by the NC command **#CONTOUR MODE**.

Depending on the contour mode, specific keywords are provided for parameterisation. The command has the following syntax structure:

#CONTOUR MODE [*<contour_mode>* *<parameter>* *<action>*]

<contour_mode>	DEV	Contouring with corner deviation (default)
	DIST	Contouring with corner distance
	POS	Contour with interim point
	DIST_SOFT	Dynamic optimised contouring
	DIST_MASTER	Dynamic optimised contouring with master axis
	PTP	Dynamically optimised contouring of the complete contour

<Parameter>	PATH_DEV TRACK_DEV ...	**Caution:** The parameters for deviations and tolerances must always be specified in [mm, inch] or [°]. When specifying in [inch], please refer to the note in P-CHAN-00439.

<action>	PRE_ACTION	Execute M/H actions at the start of the contouring curve.
	INTER_ACTION	Execute M/H actions at the centre of the contouring curve.
	POST_ACTION	M/H actions after the contouring curve.

3.1.3.1 Contouring with corner deviation

Notice

Default parameterisation of this contouring type becomes effective after program start.

Corner distances used to shorten motion blocks are automatically determined after purely geometric considerations to prevent a user-specified corner deviation from being exceeded.

Corner distances are limited depending on the specified minimum residual block length. However, both distances are limited symmetrically. In this case, the programmed path velocity has no influence on the contouring curve.

It is better to use the parameter RELEVANT_PATH to obtain optimised contouring. It is recommended to adopt the maximum corner deviation value PATH_DEV.

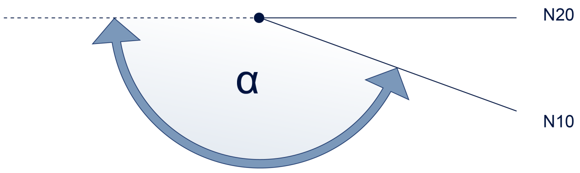
`Syntax of parameterisation:`

#CONTOUR MODE [DEV [PATH_DEV=..] [**RELEVANT_PATH**=..] [**TRACK_DEV**=..] [**RELEVANT_TRACK**=..] [**REMAIN_PART**=..] [<*action*>] [**CHECK_JERK**=..] [**MAX_ANGLE**=..] [**CONST_VEL**=..] **]**

DEV	Contour with maximum corner deviation
PATH_DEV=..	Maximum deviation of programmed contour in [mm, inch]* Default value: 1 mm * when P-CHAN-00439 is active
RELEVANT_PATH=..	Minimum path length of relevant post-blocks in [mm, inch *]. Default value: 0 mm * when P-CHAN-00439 is active
TRACK_DEV=..	Maximum deviation of tracking axes in [°] Default value: 0 °
RELEVANT_TRACK=..	Minimum path of tracking axis for relevant post-blocks in [°] Default value: 0 °
REMAIN_PART=..	Distance to go in [0%-100%] of original block Default value: 0%
<action>	Identifier for time of execution of additional actions (M/H): PRE_ACTION: Actions **before** contouring curve. INTER_ACTION: Actions **in** contouring curve (default). POST_ACTION: Actions **after** contouring curve.
CHECK_JERK=..	Jerk monitoring caused by curvature of the polynomial (cf. P-CHAN-00110) with: 0: Without jerk monitoring (default). 1: Jerk monitoring based on the geometric ramp time (P-AXIS-00199). This may reduce path velocity. 2: Jerk monitoring based on ramp times P-AXIS-00195 up to P-AXIS-00198 of the non-linear velocity profile.

MAX_ANGLE=.. Maximum contour knee angle in [°] for transitions between two linear blocks up to which contouring is active.

Default value: 178° (i.e. the entire contour is contoured)



CONST_VEL=.. Constant path velocity in the contouring section where:

0: Without constant path velocity (default).

1: At constant path velocity.

Programing Example

Contouring with corner deviation

```
...
N100 #CONTOUR MODE [DEV PATH_DEV=5]
N110 G01 X100 G61
N120 G01 Y100
...
```

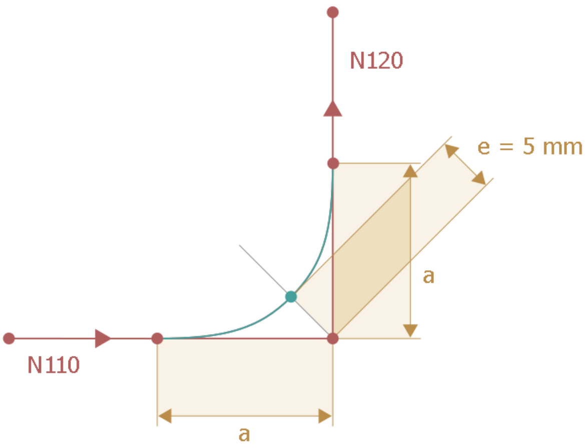


Fig. 14: Contouring with corner deviation

3.1.3.2 Corner distance contouring

If the point from which the original contour may be left is known, the user can explicitly specify the corner distances of the pre-blocks and post-blocks by which the adjacent motion blocks are to be shortened.

The corner distances are limited if they do not exceed the minimum residual block length .

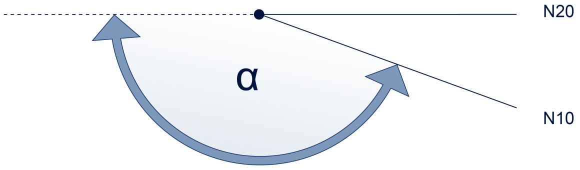
If the corner distances a and b are specified as identical, the other corner distance is symmetrically limited if one corner distance is limited to the minimum remaining block length.

If the corner distances a and b are specified as different, only the distance which is too long is reduced if limited. With asymmetrical path lengths, this can lead to a "degenerated" contour but this may sometimes be desirable.

Syntax of parameterisation:

#CONTOUR MODE [DIST [**PRE_DIST**=..] [**POST_DIST**=..] [**RELEVANT_PATH**=..]
[**RELEVANT_TRACK**=..] [**TRACK_DEV**=..] [**REMAIN_PART**=..]
[<*action*>] [**CHECK_JERK**=..] [**MAX_ANGLE**=..] [**CONST_VEL**=..] **]**

DIST	Contouring with corner distance specified
PRE_DIST=..	Corner distance in [mm, inch*] after which there is a deviation from the original contour. Default value: 1 mm *when P-CHAN-00439 is active
POST_DIST=..	Corner distance in [mm, inch*] after which there is a return to the original contour. Default value: 1 mm *when P-CHAN-00439 is active
RELEVANT_PATH=..	Minimum path length of relevant post-blocks in [mm, inch *] Default value: 0 mm
RELEVANT_TRACK=..	Minimum path length of tracking axis for relevant post-blocks in [°]. Default value: 0 °
TRACK_DEV=..	Maximum deviation of tracking axes in [°] Default value: 0 °
REMAIN_PART=..	Distance to go in [0%-100%] of original block Default value: 0%
<action>	Identifier for time of execution of additional actions (M/H): PRE_ACTION: Actions **before** contouring curve. INTER_ACTION: Actions **in** contouring curve (default). POST_ACTION: Actions **after** contouring curve.
CHECK_JERK=..	Jerk monitoring caused by curvature of the polynomial (cf. P-CHAN-00110) with: 0: Without jerk monitoring (default). 1: Jerk monitoring based on the geometric ramp time (P-AXIS-00199). This may reduce path velocity. 2: Jerk monitoring based on ramp times P-AXIS-00195 up to P-AXIS-00198 of the non-linear velocity profile
MAX_ANGLE=..	Maximum contour knee angle in [°] for transitions between two linear blocks up to which contouring is active. Default value: 178° (i.e. the entire contour is contoured)



CONST_VEL=.. Constant path velocity in the contouring section with:
0: Without constant path velocity (default).
1: At constant path velocity.

Programing Example

Contouring with corner distance

```
...
N100 #CONTOUR MODE [DIST PRE_DIST=10 POST_DIST=5]
N110 G01 X100 G61
N120 G01 Y100
...
```

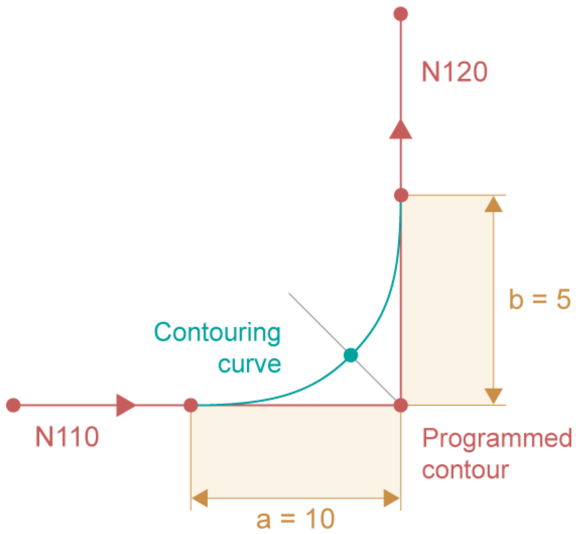


Fig. 15: Corner distance contouring

3.1.3.3 Contour with interim point

Here, the user specifies not only the corner distances but also an interim point P at which the two polynomial curves are adjacent to each other (expert mode). This mode permits the retention of the programmed contour and fully utilises the dynamics by specifying the corner distance zero. In other words, the corner distances need not be symmetrical here.

```
Syntax of parameterisation:
```

#CONTOUR MODE [POS [**PRE_DIST**=..] [**POST_DIST**=..] [**X**..] **[Y**..] [**Z**..] [<*action*>]
[**CHECK_JERK**=..] [**CONST_VEL**=..] **]**

POS	Contour by specifying the interim point
PRE_DIST=..	Corner distance in [mm, inch*] after which there is a deviation from the original contour. The value 0 mm is possible here. Default value: 1 mm *when P-CHAN-00439 is active
POST_DIST=..	Corner distance in [mm, inch*] after which there is a return to the original contour. The value 0 mm is possible here. Default value: 1 mm *when P-CHAN-00439 is active
X..	Position of interim point in the first main axis in [mm, inch]
Y..	Position of interim point in the second main axis in [mm, inch]
Z..	Position of interim point in the third main axis in [mm, inch]
<action>	Identifier for time of execution of additional actions (M/H): PRE_ACTION: Actions **before** contouring curve. INTER_ACTION: Actions **during** the contouring curve (default). POST_ACTION: Actions **after** contouring curve.
CHECK_JERK=..	Jerk monitoring caused by curvature of the polynomial (cf. P-CHAN-00110) with: 0: Without jerk monitoring (default). 1: Jerk monitoring based on the geometric ramp time (P-AXIS-00199). This may reduce path velocity 2: Jerk monitoring based on ramp times P-AXIS-00195 up to P-AXIS-00198 of the non-linear velocity profile
CONST_VEL=..	Constant path velocity in the contouring section with: 0: Without constant path velocity (default). 1: At constant path velocity.

Programing Example

Contour with interim point

```
...
N100 #CONTOUR MODE [POS PRE_DIST=2 POST_DIST=3 X110 Y-10 Z0]
N110 G01 X100 G61
N120 G01 Y100
...
```

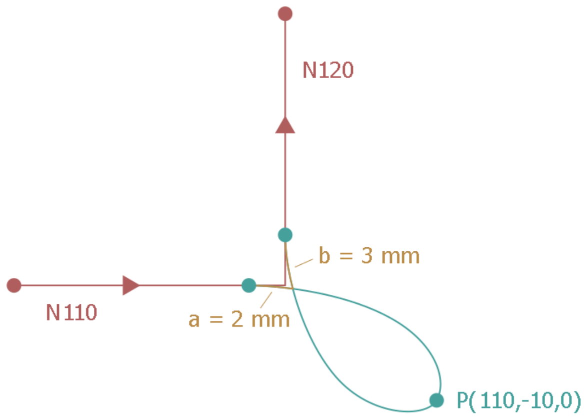


Fig. 16: Contour with interim point

3.1.3.4 Dynamic optimised contouring

Contouring types with corner deviation and interim point define the contouring curve by a direction- and curvature-continuous connection between two motion blocks. This contouring curve referred to the axes may result in a fluctuation in acceleration.

When the possible dynamic data is considered with reference to the axes (acceleration, jerk), the contouring curve is defined at **uniform acceleration** (minimum jerk) of the two axes. By utilising maximum axis acceleration, the **duration** of the contouring curve is reduced.

`Syntax of parameterisation:`

#CONTOUR MODE [DIST_SOFT [**PATH_DIST**=..] [**TRACK_DIST**=..] [**ACC_MAX**=..] [**ACC_MIN**=..]
[**RAMP_TIME**=..] [**DIST_WEIGHT**=..] **]**

DIST_SOFT	Dynamic optimised contouring
PATH_DIST=..	Corner distance of pre-block and post-block (symmetrical) in [mm, inch *] after which a deviation from the original contour is allowed. The definition refers to the motion path of the feed axes. Default value: 1 mm Monitoring off: -1 mm *when P-CHAN-00439 is active
TRACK_DIST=..	Corner distance to pre-block and post-block in [°] after which non-feed axes (tracking axes) may deviate from the original contour. Default value: Value is adopted automatically from PATH_DIST provided this value was not explicitly specified (since program start). Monitoring off: -1 °
ACC_MAX=..	Percentage in [0%-100%] of maximum axis acceleration (machine data) which may be used by the contouring curve. Default value: 100%
ACC_MIN=..	Percentage in [0%-100%] of maximum axis acceleration (machine data) which should be used by the contouring curve. If the specified corner distance (see PATH_DIST) is not maintained, the acceleration is increased to maximum value (ACC_MAX). Default value: 50%
RAMP_TIME=..	Percentage weighting of the ramp time in [0%-10000%]. Default value: 100%
DIST_WEIGHT=..	Influences the split of contoured linear blocks in [0%-100%]: In the 0% pre-definition, all blocks are halved; at 100%, the split ratio corresponds to the lengths of adjacent blocks. This value can be used to combine the two methods by percentage. Default value: 0%

Restrictions:

- If a circular block is used for contouring, the contouring curve is calculated with corner distance without dynamic optimisation.
- The calculation uses only one ramp time (maximum value of the four individual ramp times).
- No processing of kinematic transformations. In this case, calculation is performed with corner distance without dynamic optimisation.
- In many cases, weighting the corner distances by the parameter DIST_WEIGHT depending on the pre-/post-blocks results in an optimised utilisation of the available block length.

When axis-specific contouring is executed, the corner distances of the pre-block and post-block are always identical (symmetrical). If the maximum corner distances are also limited on the half block motion path, a shorter contouring section and therefore a lower contouring velocity results for longer motion paths due to the shorter preceding/following motion path.

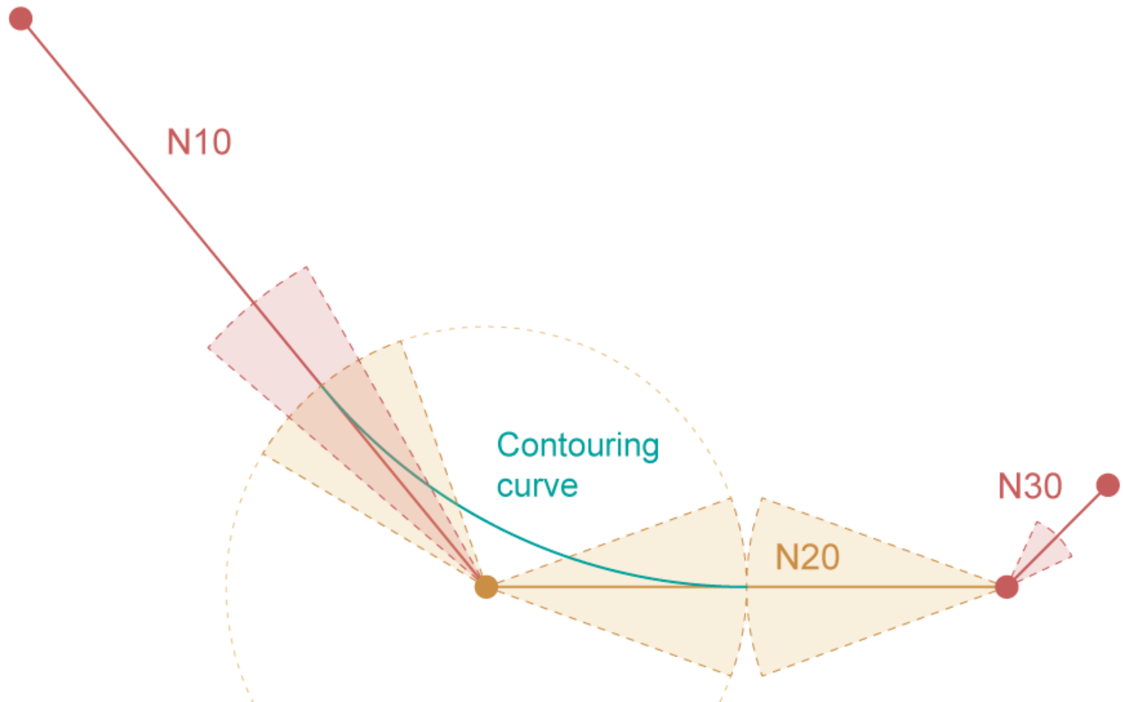


Fig. 17: Maximum corner distance of block N20 independent of the block lengths of N10 and N20 (DIST_WEIGHT = 0%)

If the length of the pre- and post-blocks are considered in the calculation of the maximum corner distances, the contouring zone can be increased.

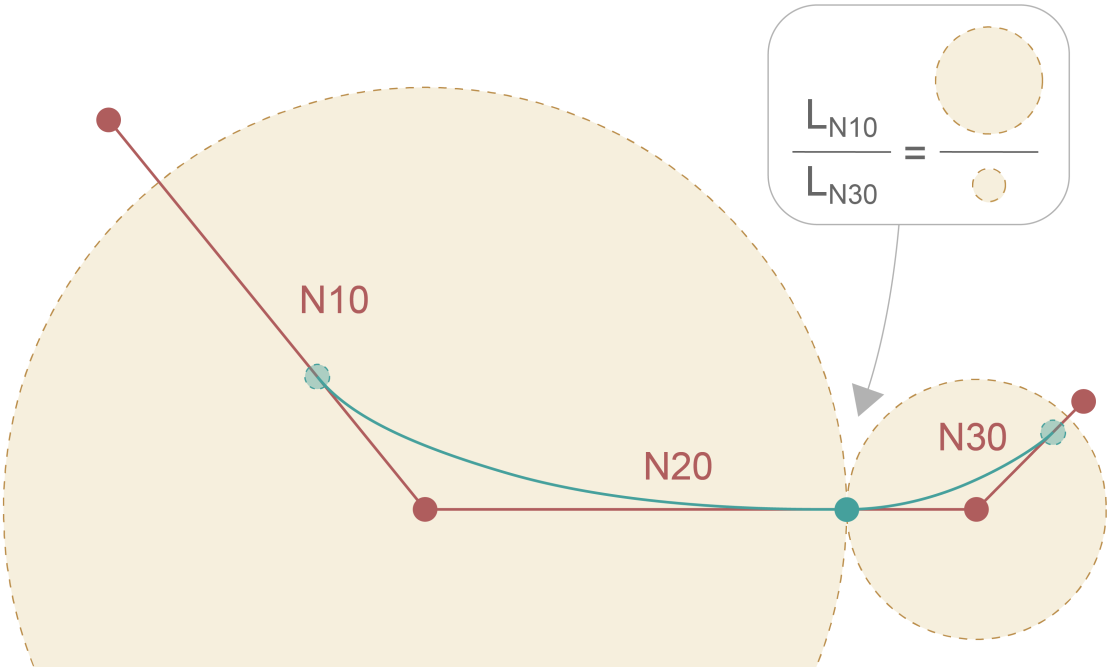


Fig. 18: Maximum corner distance of block N20 subdivided relative to the block lengths of N10 and N30 (DIST_WEIGHT = 100%)

Programing Example

Dynamic optimised contouring

Comparison of contouring of a 90° corner with the methods:

Dynamically optimised contouring (DIST_SOFT):

```
N010 #CONTOUR MODE [DIST_SOFT PATH_DIST=12]
N020 G0 X0 Y0
N030 G261
N040 G01 X80 Y0 F2.5
N050 G01 X80 Y80
N060 G260
N070 M30
```

Contouring with corner deviation (DEV):

```
N010 #CONTOUR MODE [DEV PATH_DEV=0.2]
N020 G0 X0 Y0
N030 G261
N040 G01 X80 Y0 F2.5
N050 G01 X80 Y80
N060 G260
N070 M30
```

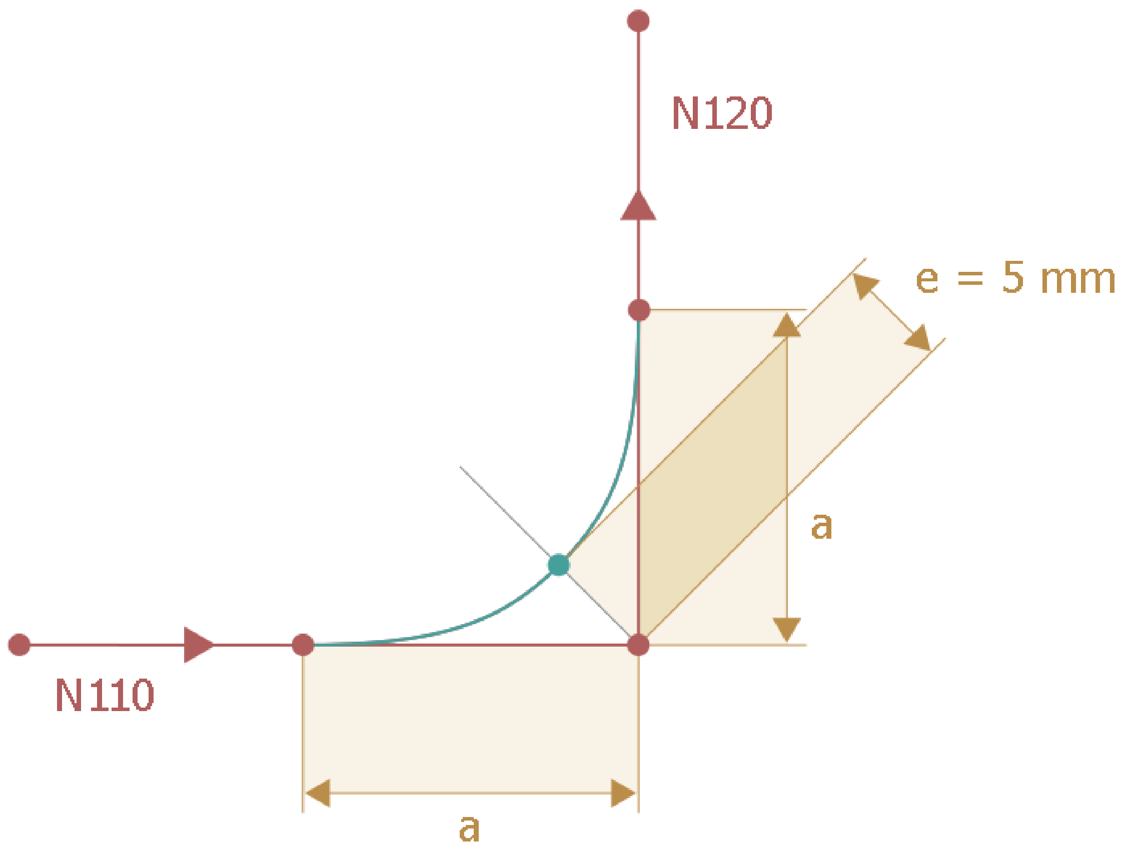


Fig. 19: Contouring with corner deviation (PATH_DEV) and corner distance (PATH_DIST).

3.1.3.5 Dynamic optimised contouring with master axis

A feed master axis is used in this variant of the dynamically optimised contouring curve. This generally results in a more favourable velocity profile.

The feed master axis is identified in the axis parameter list by an entry in P-AXIS-00015 and marked as the only feed axis in the channel parameter list (P-CHAN-00011).

Further properties and limitations correspond to the dynamically optimised contouring mode.

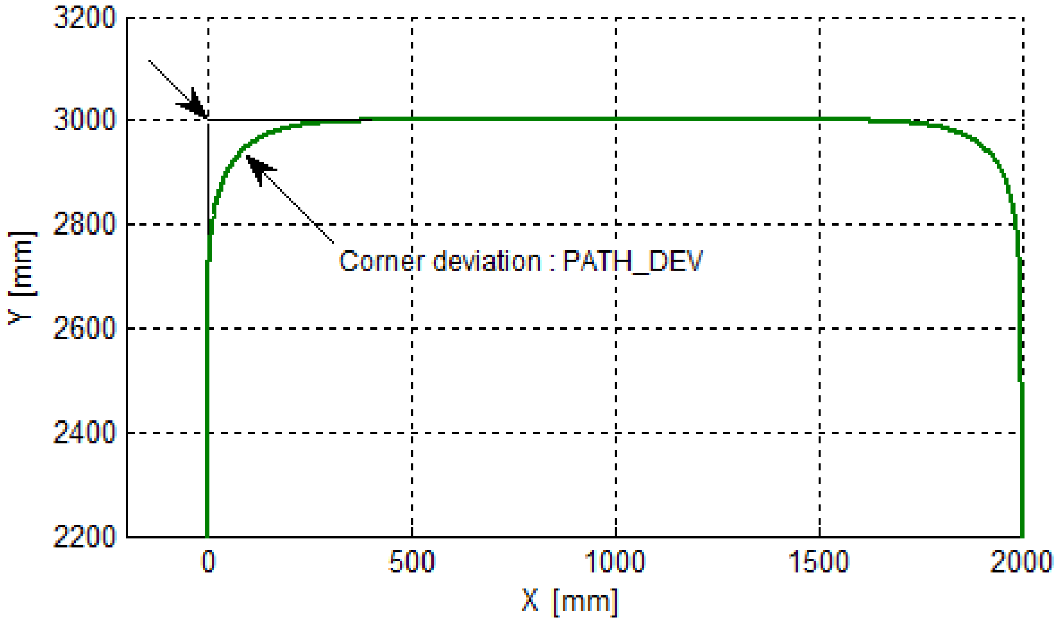
```
Syntax of parameterisation:
```

#CONTOUR MODE [DIST_MASTER [**SYM_DIST**=..] [**ACC_MAX**=..] [**ACC_MIN**=..]
[**RAMP_TIME**=..] [**DIST_WEIGHT**=..] **]**

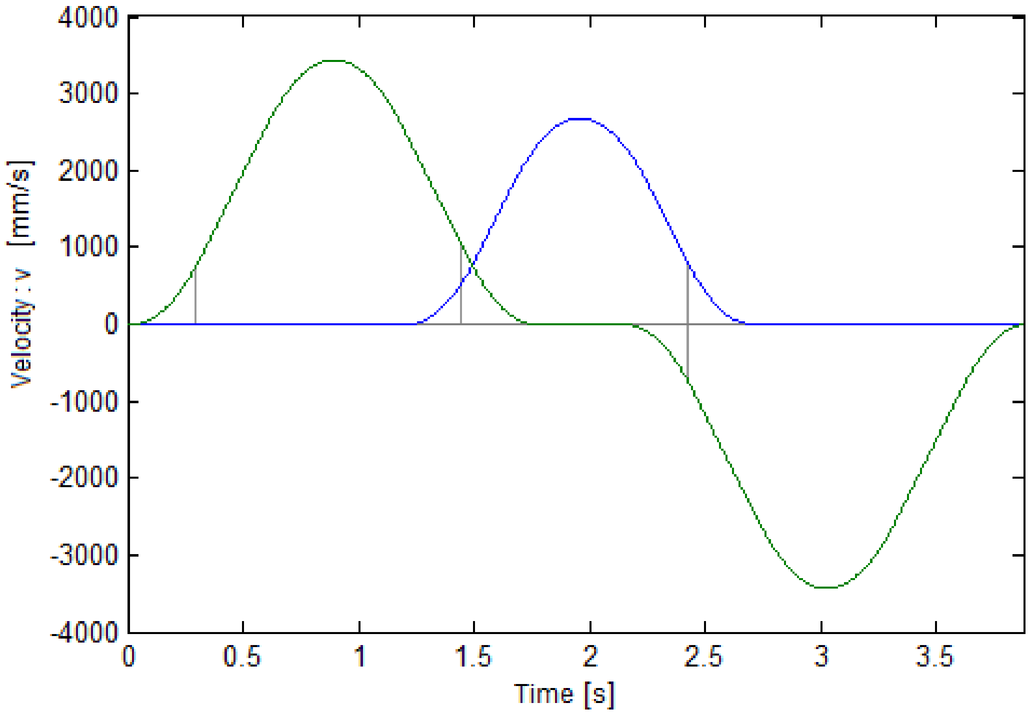
DIST_MASTER	Dynamically optimised contouring with feed master axis
SYM_DIST=..	Corner distance of pre-block and post-block (symmetrical) in [mm, inch *] after which a deviation from the original contour is allowed. Default value: 1 mm Monitoring off: -1 mm *when P-CHAN-00439 is active
ACC_MAX=..	Percentage in [0%-100%] of maximum axis acceleration (machine data) which may be used by the contouring curve. Default value: 100%
ACC_MIN=..	Percentage in [0%-100%] of maximum axis acceleration (machine data) which should be used by the contouring curve. If this specified corner distance (see SYM_DIST) is not maintained here, the acceleration is increased up to maximum value (ACC_MAX). Default value: 50%
RAMP_TIME=..	Percentage weighting of the ramp time in [0%-10000%]. Default value: 100%
DIST_WEIGHT=..	Percentage weighting of corner distances relative to the pre-/post-block in [0%-100%]. Default value: 0%

3.1.3.6 Dynamically optimised contouring of the complete contour

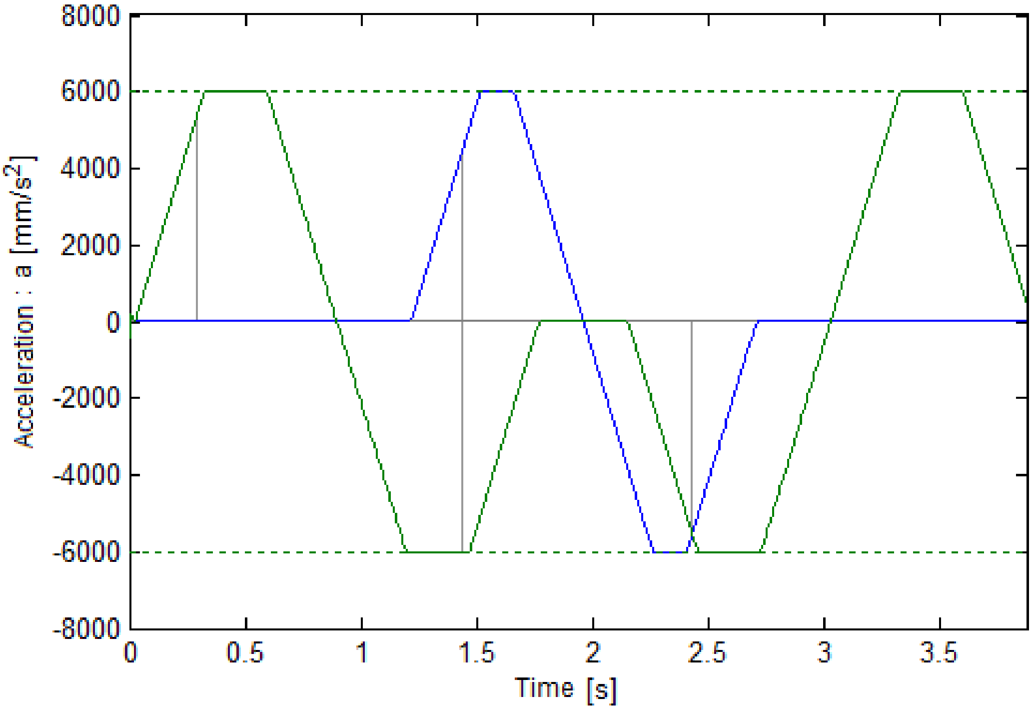
This mode is suitable for handling tasks where the feed rate need not be constant in the rounded contour. The contouring curve is selected so that at least one axis involved utilises the dynamics available. As opposed to dynamically optimised contouring (DIST_SOFT), this mode involves the entire contour. The figure below shows a typical application:



Comprehensive planning avoids unnecessary acceleration zeroes at block limits and calculates uniform velocity profiles as shown in the figure below.



Accelerations with constant jerk change to reduce further excitations. The acceleration phases are then placed in the straight sections before and after the rounded contour:



The corner deviation defines the distance of the rounded contour to the program corner point.

If the position is known at which a deviation from the original contour is permitted, the user can explicitly specify the amount of pre-block and post-block corner distances by which the adjacent motion blocks are shortened. The corner distances are limited if they do not exceed the minimum residual block length .

```
Syntax of parameterisation:
```

#CONTOUR MODE [PTP [**PATH_DEV=..**] [**PATH_DIST**=..] [**MERGE**=..] [<*action*>] **]**

PTP Axis-specific contouring with specification of corner distance [as of Build V3.1.3052.01]

PATH_DEV=.. Maximum corner deviation from the programmed contour in [mm, inch *].

Default value: 1 mm

*when P-CHAN-00439 is active

PATH_DIST=.. Corner distance of pre-block and post-block (symmetrical) in [mm, inch *] after which a deviation from the original contour is allowed. The definition refers to the motion path of the feed axes **[as of Build V3.1.3079.16].**

Default value: 1 mm

*when P-CHAN-00439 is active

MERGE=.. Merge tangential blocks **[as of V3.1.3079.16]** where:

0: Do not merge

1: Merge (default)

<action> Identifier for time of execution of additional actions (M/H) where:

PRE_ACTION: Actions **before** contouring curve.

INTER_ACTION: Actions **in** contouring curve (default).

POST_ACTION: Actions **after** contouring curve.

Attention

This mode is not suitable for:

a) Programs containing many short motion paths (see also HSC).

b) Programs with **circular blocks** since this results in the automatic deselection of the mode.

Attention

This functionality can only be used if the start-up parameter is parameterised for each channel in which the function is to be used.

Example of a setting in the start-up list:

```
configuration.channel[].path_preparation.function FCT_DEFAULT|FCT_PTP
```

Programing Example

Dynamically optimised contouring of the complete contour

```
...
N100 #CONTOUR MODE [PTP PATH_DEV=5]
N110 G01 X100 G61
N120 G01 Y100
...
```

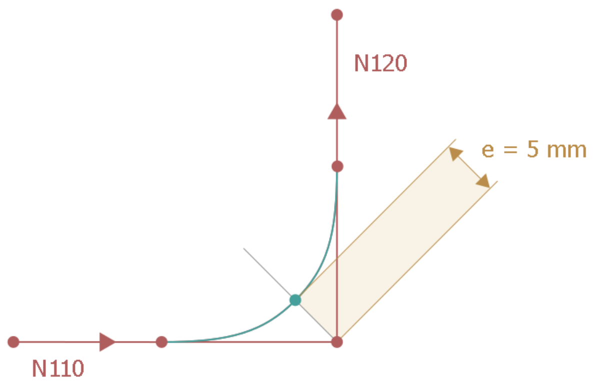


Fig. 20: Dyn. optimised contouring of the entire contour specifying corner deviation

3.1.4 Example

Programing Example

The examples below show the influence of the different output of M functions during contouring.

```
N10 X0 Y0
N20 G91 G01 F6000
N30 #CONTOUR MODE [DEV PATH_DEV=10 POST_ACTION]

N40 X100 G61 M25     (MVS_SNS)
N50 Y100 F3000
N60 X100 G61 F6000
N70 G04 X2
N80 Y100
N90 X0 Y0

N100 X100 G61
N110 Y100 M26        (MVS_SVS)

N120 G04 X1
```

Programing Example

Change the limit angle during contouring:

```
#CONTOUR MODE [DEV PATH_DEV=0.50 RELEVANT_PATH=0.1 TRACK_DEV=2 RELEV-
ANT_TRACK=0.2]
F10000

G261
N5 #CONTOUR MODE [MAX_ANGLE=3]
N10 G01 X0 Y0 Z0 G61
N15 #CONTOUR MODE [MAX_ANGLE=4]
N20 G01 X100 Y0 Z0
N25 #CONTOUR MODE [MAX_ANGLE=5]
N30 G01 X100 Y100 Z0
N35 #CONTOUR MODE [MAX_ANGLE=6]
N40 G01 X0 Y0 Z0 G61
G260
```

Result:

Contouring the N<i> block always takes place at the limit angle of the previous N<i-5> block.

Programing Example

Variation of the contour angle with constant limit angle:

```
#CONTOUR MODE [DEV PATH_DEV=0.50 RELEVANT_PATH=0.1 TRACK_DEV=2 RELEV-
ANT_TRACK=0.2]
#CONTOUR MODE [RELEVANT_TRACK=0.3]
P100 = 50
F10000

#CONTOUR MODE [MAX_ANGLE=73]
N10 G01 X-P100 Y0 Z0 C0 A0

$FOR P123 = 0, 90, 7.5
  N2 G01 X0 Y0 Z0 C0 A0 G61
  P1 = COS[P123]*P100
  P2 = SIN[P123]*P100
  NP123 XP1 YP2
  N100 G01 X-P100 Y0 Z0 C0 A0
$ENDFOR

$FOR P123 = 270, 370, 7.5
  N120 G01 X0 Y0 Z0 C0 A0 G61
  P1 = COS[P123]*P100
  P2 = SIN[P123]*P100
  NP123 XP1 YP2
  N400 G01 X-P100 Y0 Z0 C0 A0
$ENDFOR

M30
```

3.1.5 Remarks

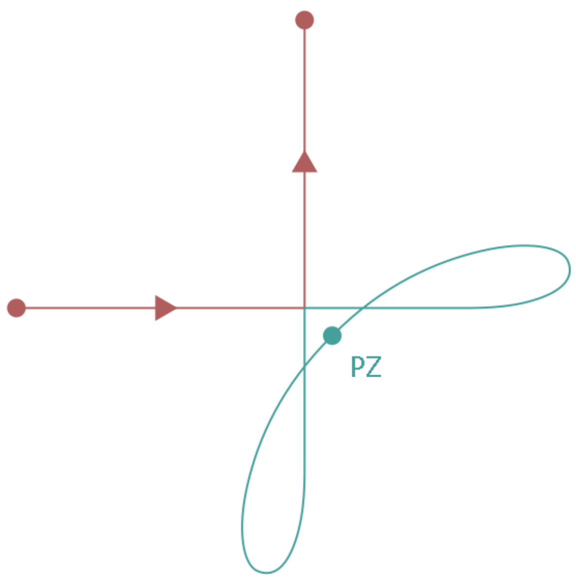
If axes are released or fetched after programming G61 or G261/G260 (contouring at block end), the contouring mode cannot be executed.

Programing Example

Contouring mode is not executed

```
N10 G01  X100  Y0  Z0  F1000
N20 G01  X50   Y50  G61
N30 #PUT AX [Z](Contouring mode is not executed)
N40 G01  X100
N50 M30
```

With interim point contouring, the shape of the curve depends on the choice of interim point. The following curve shape is also possible:



3.2 Surface machining with Surface

The HSC Surface Optimiser was developed to achieve consistent machining results regardless of the point distribution by the CAM system. In particular, the density of interpolation points on neighbouring machining paths can fluctuate with some CAM systems, which would lead to an uneven machining result. The figure below shows a machining result of this kind. The two points marked in red are missing on one of the neighbouring machining paths. This results in a different tool path (blue) in contrast to the neighbouring paths if the smoothing process is not optimised.

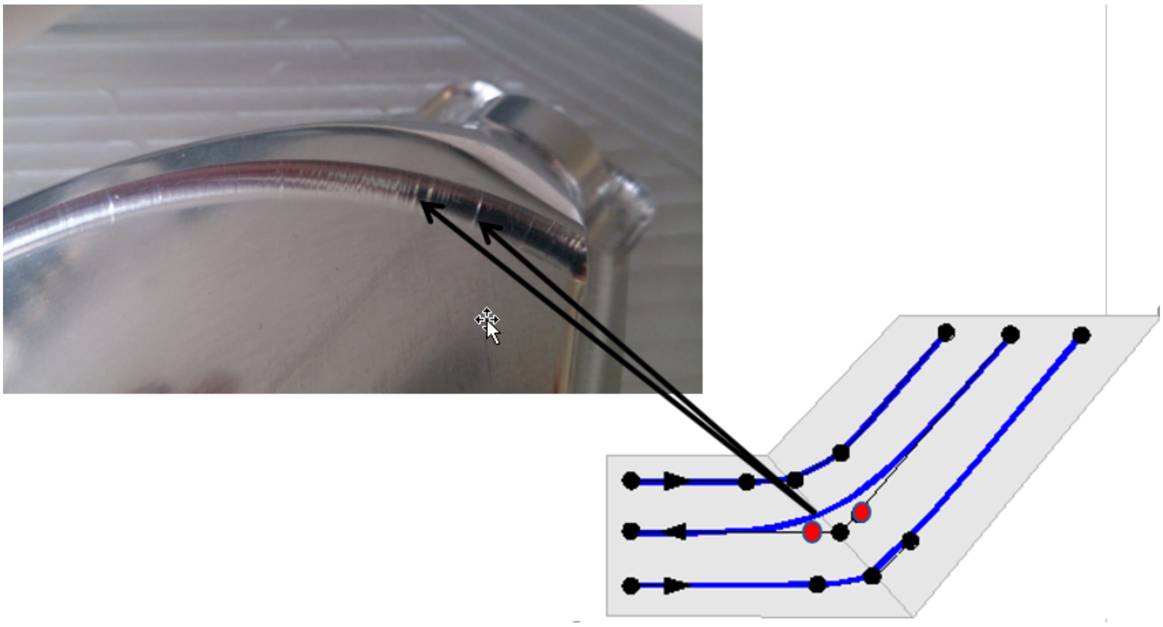


Fig. 21: Problems in workpiece quality due to uneven distribution caused by the CAM system.

In addition to uniform machining paths, the HSC Surface Optimiser ensures a high feed rate that is as constant as possible. Due to the necessary calculations, the use of the Surface Optimiser requires high-performance control hardware.

Programming

Syntax:

#HSC [**ON** | **OFF**] [[**SURFACE** [**PATH_DEV=..**] [**PATH_DEV_G00=..**] [**TRACK_DEV=..**] [**TRACK_DEV_G00=..**]
[**MAX_ANGLE=..**] [**CHECK_JERK=..**] [**AUTO_OFF_G00=..**] [**CIR_MODE=..**]
[**CIR_MIN_ANGLE=..**] [**CIR_MIN_RADIUS**=..] [**MERGE=..**] [**LENGTH_LONG_CIR=..**] **]**]

ON	Enable HSC programming.
OFF	Disable HSC programming.
SURFACE	Keyword for HSC machining with surface optimiser. Must always be programmed as **first** keyword.
PATH_DEV=..	Define maximum contour error. > 0.0: Maximum path deviation in [mm, inch *] Default value: 0.2 mm

Notice

Empirically, the contour error should be set 2 or 3 times larger than the secant error which is defined when the NC program is generated in the CAM system.

The tool is not in contact with the workpiece in G0 motions. As a result, the tolerance can be set significantly larger than PATH_DEF without changing the precision of the workpiece.

PATH_DEV_G00=..	Define maximum contour error for G0-G0 transitions. > 0.0: Maximum path deviation in [mm, inch *] Default value: The value of PATH_DEV applies
TRACK_DEV=..	Define the maximum orientation error. >= 0.0: Maximum path deviation in [°] Default value: 2 °
TRACK_DEV_G00=..	Define the maximum orientation error for G0-G0 transitions. >= 0.0: Maximum path deviation in [°] Default value: The value of TRACK_DEV applies

Notice

If a ball milling cutter is used, the value can be set significantly larger than PATH_DEV (e.g. 10 times).

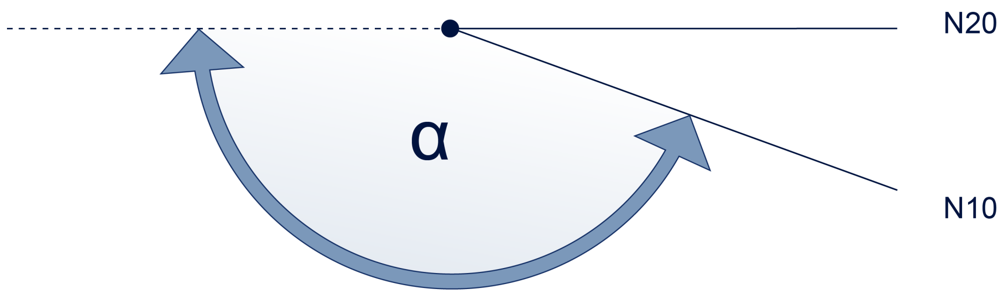
The tool is not in contact with the workpiece in G0 motions. As a result, the tolerance can be set significantly larger than TRACK_DEV without influencing the precision of the workpiece.

MAX_ANGLE=..

Define the maximum contour knee angle in degrees for transitions between two linear blocks up to which this method can be applied. If the angle between the two linear blocks exceeds this limit, the mode is deselected internally.

>= 0.0: Maximum knee angle in [°]

Default value: 160 °



CHECK_JERK=..

Jerk monitoring caused by curvature of the polynomial (cf. P-CHAN-00110). This parameter overwrites the initial state defined in the channel parameter list by P-CHAN-00110 (check_jerk_on_poly_path).

0: No jerk monitoring

1: Jerk monitoring based on the geometric ramp time P-AXIS-00199. This may reduce path velocity.

2: Jerk monitoring based on the ramp times P-AXIS-00195, P-AXIS-00198 of the non-linear velocity profile.

AUTO_OFF_G00=..

Automatic deselection of optimisation with G00 blocks

0: No implicit deselection due to a rapid traverse block (default)

1: Implicit deselection due to a rapid traverse block

CIR_MODE=..

Define contouring of circular motions:

0: No contouring of circular motions G02/G03

1: Circular block contouring. (default)

2: Contour circular blocks and optimise long circular blocks

Available as of V3.1.3075.01

CIR_MIN_ANGLE=..

Define minimum circle angle

Valid values: >= 0.0 : Minimum circle angle in degrees

The minimum circle angle at which circular motions can be traversed by the method using exact interpolation. Circular blocks with small swept angles are approximated by a spline curve for faster processing. (Default value = 30°)

CIR_MIN_RADIUS=..

Define minimum circle radius

Valid values: >= 0.0 : Maximum circle radius in [mm, inch *]

The minimum circle radius defines the circle radius from which circular motions can be traversed by the method using exact interpolation. Circular blocks with a small radius or with the magnitude of PATH_DEV are approximated by a spline curve.

Available as of V3.1.3075.01

MERGE=..	Merge blocks. The maximum deviation is determined depending on the values taken from PATH_DEV and TRACK_DEV. 0: No block merging (default) 1: Merge blocks
LENGTH_LONG_CIR=..	Minimum length of segments for long circular blocks when CIR_MODE= 2 in [mm, inch *] is used (default value= 2) Available as of V3.1.3075.01 *when P-CHAN-00439 is active

Default values of free-form surface machining

PATH_DEV	0.2 mm (default value of PATH_DEV)
TRACK_DEV	2° (default value of TRACK_DEV)
PATH_DEV_G00	PATH_DEV
TRACK_DEV_G00	TRACK_DEV
CIR_MODE	1
MAX_ANGLE	160 °
CHECK_JERK	The valid channel parameter is P-CHAN-00110 (check_jerk_on_poly_path, default value = 1)
AUTO_OFF_G00	0
CIR_MIN_ANGLE	30 °
CIR_MIN_RADIUS	0.0
LENGTH_LONG_CIR	2 mm

Notice

The parameters may also be specified in several steps. For example, this means it is possible to first define the maximum contour deviation ("PATH_DEV "). Then in a second command, jerk monitoring ("CHECK_JERK") and the selection of HSC surface interpolation ("ON") are defined.

Notice

When #HSC[SURFACE] is used, it is recommended to also use #SLOPE[TYPE=HSC] for path velocity preparation.

Attention

Parameterisation cannot be changed while smoothing is active.

One condition to use this function is that it should be parameterised in the start-up list for each channel in which the function is to be used.

Programing Example

Surface machining with Surface Optimiser

Example of a setting in the start-up list:

configuration.channel[].path_preparation.function FCT_DEFAULT|FCT_SURFACE

```
N20 G00 X0 Y0 Z0 F10000
;Parametrisation + selection
N30 #HSC ON [SURFACE PATH_DEV=0.02 CHECK_JERK=0]
N40   X3     Y25
N50   15     Y15
N60   23     Y12
N70   X25    Y25
N80   X30    Y35
N90   X50    Y37.5
N100  X55    Y32.5
N110  X58    Y12
N120  X70    Y12
N130  X77.5  Y10
N140  X90    Y35
N150  X100   Y37.5
N160 #HSC OFF
N170 M30
```

Alternative programming:

```
N20 G00  X0    Y0    Z0 F10000
N25 #HSC [SURFACE PATH_DEV=0.02 CHECK_JERK=0] ;Parameterisation
N30 #HSC ON ;Select
N40   X3     Y25
N50   15     Y15
N60   23     Y12
N70   X25    Y25
N80   X30    Y35
N90   X50    Y37.5
N100  X55    Y32.5
N110  X58    Y12
N120  X70    Y12
N130  X77.5  Y10
N140  X90    Y35
N150  X100   Y37.5
N160 #HSC OFF
N170 M30
```

3.3 Trimming a contour with B spline

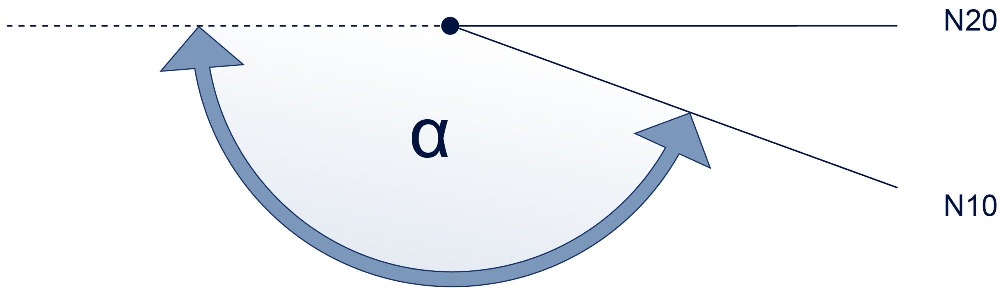
Syntax:

#HSC [**ON** | **OFF**] [**BSPLINE** [**PATH_DEV=..**] [**TRACK_DEV=..**] [**MERGE=..**] [**AUTO_OFF_PATH=..**]
[**AUTO_OFF_TRACK=..**] [**AUTO_OFF_G00=..**] [**AUTO_OFF_G60=..**]
[**MAX_PATH_LENGTH=..**] [**MAX_ANGLE=..**] **]**]

ON	Enable HSC programming.
OFF	Disable HSC programming.
BSPLINE	Keyword for HSC programming with BSPLINE. Must always be programmed as **first** keyword.
PATH_DEV=..	Maximum deviation of B spline from programmed path contour in [mm, inch *]. The spline is deselected automatically if this deviation is exceeded. If the maximum deviation is defined as 0, path deviation is not monitored. Default value: 0.2 mm *when P-CHAN-00439 is active
TRACK_DEV=..	Maximum deviation of tracking axes in [°]. If the maximum deviation is defined as 0, tracking axes is not monitored. Default value: 5 °
MERGE=..	Merge blocks. The maximum deviation is determined depending on the values taken from PATH_DEV and TRACK_DEV. 0: No block merging (default) 1: Merge blocks
AUTO_OFF_PATH=..	Automatic block separation if the programmed B spline deviation of the main axes is exceeded (PATH_DEV). 0: No deselection if deviation is too large (default), block is separated 1: Deselect if deviation is too large
AUTO_OFF_TRACK=..	Automatic block separation if the programmed B spline deviation of the tracking axes is exceeded (TRACK_DEV). 0: No deselection if deviation is too large (default), block is separated 1: Deselect if deviation is too large
AUTO_OFF_G00=..	Automatic deselection of B spline interpolation for G00 blocks. 0: No implicit deselection due to rapid traverse block (default) 1: Implicit deselection due to a rapid traverse block
AUTO_OFF_G60=..	Automatic deselection of B Spline interpolation for programmed exact stop G60 or G360. 0: No implicit deselection due to exact stop (default) 1: Implicit deselection due to exact stop
MAX_PATH_LENGTH=..	Minimum path length of relevant blocks in [mm, inch *]. If blocks are longer than the specified length, the B Spline is deselected implicitly. Default value: 0 mm (implicit deselection due to block length does not take place) *when P-CHAN-00439 is active

MAX_ANGLE=.. Maximum contour knee angle in [°] for transitions between two linear blocks up to which a B spline is inserted. The B Spline is deselected internally if the angle between two linear blocks is greater.

Default value: 160 °



Control points are programmed with linear blocks (G00 and G01). Their target points are used as control points. It must be considered that only the start and end of the curve runs straight through the control points.

Notice

The parameters may also be specified in several steps. For example, this means that it is possible to first define the maximum contour deviation ("PATH_DEV "). Then in a second command, the maximum path length ("MAX_PATH_LENGTH ") and selection of B spline interpolation ("ON") are defined.

Attention

Parameterisation cannot be changed while B spline interpolation is active.

Programing Example

Trimming a contour

```
The spline curve is based on the control points N40 – N155 but in this
case, the spline curve only runs straight through them at N20 and N150.

N20 G00 X0 Y0 Z0 F10000
N30 #HSC ON [BSPLINE PATH_DEV=0.2 MERGE=1 ...] Parametrisation + selec-
tion
N40   X3     Y25
N50   X15    Y15
N60   X23    Y12
N70   X25    Y25
N80   X30    Y35
N90   X50    Y37.5
N100  X55    Y32.5
N110  X58    Y12
N120  X70    Y12
N130  X77.5  Y10
N140  X90    Y35
N150  X100   Y37.5
N160 #HSC OFF
N170 M30
```

... or also

```
N20  G00 X0 Y0 Z0 F10000
N25  #HSC [BSPLINE PATH_DEV=0.2 MERGE=1 ...] Parameterisation
N30 #HSC ON Selection
N40   X3     Y25
N50   X15    Y15
N60   X23    Y12
N70   X25    Y25
N80   X30    Y35
N90   X50    Y37.5
N100  X55    Y32.5
N110  X58    Y12
N120  X70    Y12
N130  X77.5  Y10
N140  X90    Y35
N150  X100   Y37.5
N160 #HSC OFF Deselect
N170 M30
```

3.4 Profile generator (slope)

Generators with TRAPEZ or SIN2-shaped acceleration profiles are ideal for NC programs consisting of long motion blocks that are suitable for #CONTOUR MODE methods. If required, very rigid machines can be operated using STEP profiles.

The HSC profile generator is designed for NC programs consisting of several short blocks which are smoothed using the HSC methods Surface and B spline; the generator distributes acceleration up-gradations and down-gradations uniformly across several blocks, as shown in the figures below. The number of buffered blocks in the profile generator can be set using P-STUP-00071. If the hardware permits, it is recommended to optimise jerk utilisation using the NO_OPT option zero [▸ 47] [PROG] or at start-up using FCT_LOOK_AHEAD_OPT [MDS-CHAN].

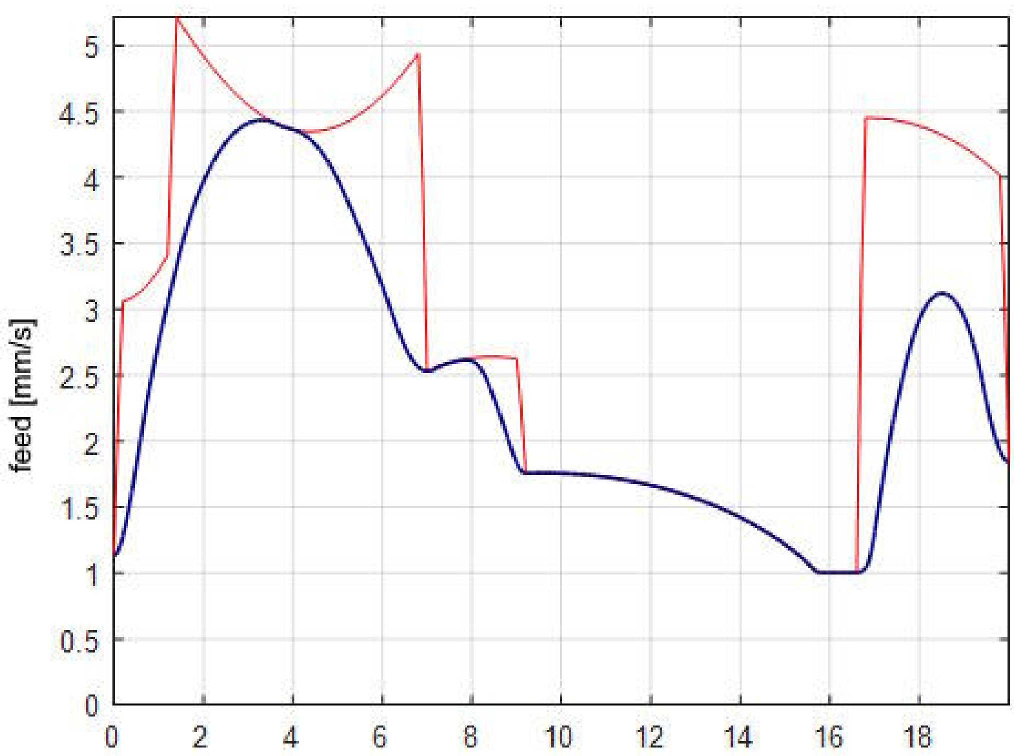


Fig. 22: Feed and acceleration in programs consisting of long blocks

Blue: path velocity, red: maximum permissible path velocity

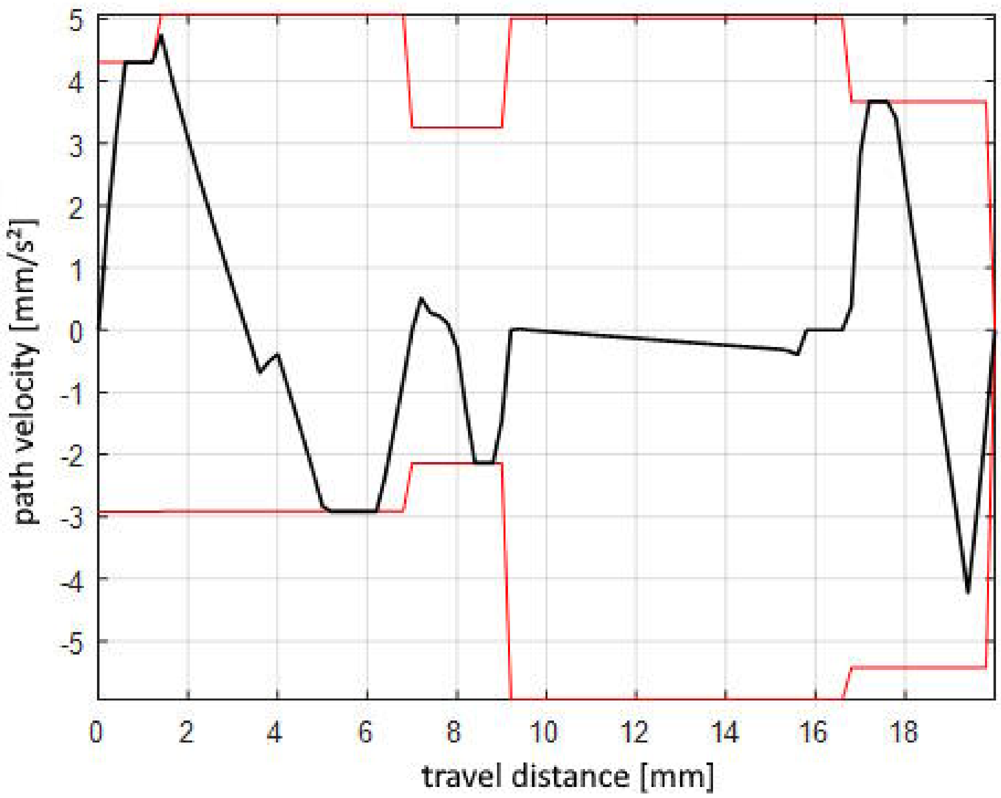


Fig. 23: Feed and acceleration in programs consisting of several short blocks

Black: path velocity, red: path acceleration limit

3.4.1 Selecting operating mode (#SLOPE, #SLOPE DEFAULT)

Release Note

As of Build **V2.11.2010.02** the command **#SLOPE [...]** replaces the command **#SET SLOPE PROFIL [...]**. For compatibility reasons, this command is still available but it recommended not to use it in new NC programs.

Syntax:

#SLOPE [TYPE=<*ident*> [**NO_OPT=..**] **]**

TYPE<*ident*>	Type of acceleration profile. Permitted identifiers: STEP: Step-shaped acceleration profile, (default, linear profile) TRAPEZ: Trapezoidal acceleration profile SIN2: Square-sinusoidal acceleration profile HSC: HSC slope, recommended for "Extended HSC programming" *
NO_OPT**=..**	Switch the optimised use of jerk: 0: Optimised use of jerk is active. This reduces processing time but requires greater computing resources. It must be checked whether the existing hardware is adequate. 1: Optimised use of jerk is **not** active (default).

Notice

* The use of this feature for selecting the HSC slope profile type requires a licence for the "HSC" extension package. It is not included in the scope of the standard license.

Notice

The specific weighting adaptation of ramp time (G132/G133) and acceleration (G130/G131) is no longer supported by the command #SLOPE [...]. Weightings always act on all ramp times and accelerations (default).

`Syntax:`

#SLOPE DEFAULT

The programming of #SLOPE DEFAULT restores the initial state (as after start-up). This means that the slope type is set from the channel parameter set P-CHAN-00071.

The initial state is produced at every program start and for every manual block.

Programing Example

Select the operation mode

```
N10 G01 X50 Y10 Z0 F1000      (step-shaped accel.profile, default)
N20 #SLOPE [TYPE=TRAPEZ]      (trapezoidal accel.profile)
N30 X10 Y30
N40 #SLOPE [TYPE=SIN2]      (sinusoidal accel.profile)
N50 X15
N60 Y50
N70 M30
```

The following velocity curve results on the programmed path:

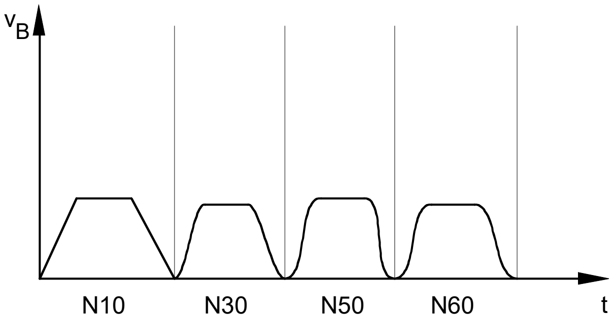


Fig. 24: Velocity curve depending on the programmed path.

3.4.2 Influence of dynamic characteristics

As required, axis-specific parameters can be adjusted to lower or higher values up to maximum permissible acceleration. The path parameters calculated by the NC can also be adjusted by NC programming to lower values. This avoids critical acceleration processes within the NC program that affect contour accuracy.

Examples of weighting axis accelerations and ramp times in the NC program:

```
N10 G130 X50 Y75 Z75
N20 G132 X75 Y75 Z75
```

N10: The axis acceleration used for the X axis is reduced to 50%, and for the Y and Z axes to 75%. N20: The ramp time used for the X, Y, Z axes is reduced to 75%.

If all axes are to be weighted, the G functions G131 and G133 can also be used.

```
N10 G131 50
N20 G133 50
```

N10: The axis acceleration used for all axes is reduced to 50%.
N20: The ramp time used for all axes is reduced to 50%.

The path accelerations or velocities calculated by the look-ahead function can be limited by the commands #VECTOR LIMIT ON [ACC..] and #VECTOR LIMIT ON [VEL..]. The limit values are then either explicitly programmed or taken from the channel-specific list.

3.4.3 FAQ velocity fluctuations

Influencing factors

In general, machining speeds and, as a result, production times depend on the following factors:

- data throughput dependent on the cycle times of the processes in the NC controller
- motion path of motion blocks
- maximum velocities and accelerations of axes
- type of profile generator (slope)
- Path profile: curvatures and uniform distribution of programmed positions.
- Cartesian transformations in the tool coordinate system and kinematics

Dynamics

In general, it can be said that high permissible accelerations and short ramp times have a favourable effect on the maximum possible path velocity. A list of the dynamic parameters used by the CNC is provided in the Parameters [59] section.

Data throughput

The following factors must also be checked to ensure that a programmed path velocity can be achieved:

- interpolator buffer size
- required number of blocks per cycle

The buffer size determines the braking distance and therefore the theoretically maximum achievable velocity. The braking distance is generally longer with the non-linear slope function; therefore, a larger buffer and more blocks per cycle are required here to achieve the same path velocity.

The number of blocks per cycle required after stabilisation can be estimated from the feed rate and the cycle time. For example, at F=10 m/min and a cycle time of 5 ms per cycle, motion paths of at least 0.84 mm per sampling interval are required.

These parameters are specified by the machine manufacturer and cannot be changed by the user.

Contour path and curvature

The parameters are specified by the CAD/CAM system based on the precision requirements for the workpiece. A workpiece with a pronounced contour curvature generally results in relatively short motion blocks and low velocity. If the contour curvature varies significantly, fluctuations in velocity are unavoidable when the feed rate is set high for the path.

It is important that the path of the interpolation points is smooth, especially with short NC blocks. This means that the fluctuation range of the relative motion paths of the individual axes referred to the motion path in space of successive blocks should be as small as possible (scanned by the CAD/CAM system). Otherwise, it is not possible to move at constant path velocity since the resulting curvatures and changes in curvature cause the CNC to reduce path velocity.

A B spline allows a certain degree of smoothing of “noisy” interpolation points.

Nevertheless, the resulting path velocity profiles are not optimal and the axis velocities fluctuate significantly depending on the motion components of the individual axes. In this case, it is recommended to use a suitable smoothing algorithm in the CAD/CAM system.

3.5 Filter programming (#FILTER)

Release Note

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

In order to achieve a high surface finish in free-form surface machining, any excitation of machine oscillations must be avoided as far as possible.

FIR axis filters (Finite Impulse Response filters) provide the user with the option of smoothing the axis command values for the drives to minimise excitations in the machine.

The precondition for using a FIR filter using the #FILTER command is a configured filter type (P-AXIS-00586**) of the corresponding axes.**

Notice

This function is an additional option requiring a license.

```
Syntax:
```

#FILTER [**ON** | **OFF**] [**ORDER**=.. **ORDER_TIME**=.. **SHARE**=.. **AX_DEV**=.. **FCUT**=.. **ACC_FACT**=.. **QUALITY**=.. **]**

ON	Enable FIR filter.
OFF	Disable FIR filter.
ORDER=..	Specify filter order
ORDER_TIME=..	Specify filter order over time in [µs]
SHARE=..	Define the degree of effectiveness (analogous to P-AXIS-00590) of the filter in [%] value range 0 – 100 default value = 100
AX_DEV=..	Specify the tolerance for tolerance monitoring in [mm, inch *]. Default value = 0 (no tolerance monitoring). *with active P-CHAN-00439
FCUT=..	Specify the cut-off frequency (analogous to (P-AXIS-00585) of the filter in [Hz] default value = 30
ACC_FACT=..	Increase the path velocity at block transitions with FIR filter enabled. The greater the value setting, the less the velocity is reduced at the block transition. This requires a valid setting of P-AXIS-00013 (a_trans_weight) for the axes. Value range = 1.0 – 10.0 Default value =: 1.0
QUALITY=..	Specify the filter quality of the filter core curve value range: 0 < QUALITY <= 1 default value = 1.0 Parameter available as of V3.1.3075.04

Notice

The #FILTER ON/OFF command enables or disables all the FIR filters of the axes in the channel.

It is possible to use FIR filters on all axes. It is also possible to use different filters for each axis by axis-specific configuration in the axis lists.

FIR filters can be globally enabled or disabled and reparameterised across all axes in the NC program during machining (see Programming example).

Notice

Tolerance monitoring can only be configured and activated in the NC program.

Tolerance monitoring is programmed by the parameter AX_DEV. It ensures that every axis remains within the specified tolerance [mm, inch].

Tolerance monitoring always monitors all axes and therefore can only be controlled globally in the NC program.

Tolerance monitoring in only active if AX_DEF was specified with a corresponding tolerance.

For further information see [FCT-C37//Description]

This command replaces the previously available #FILTER ON [HSC] command.

3.6 Other HSC methods with Akima spline, OP1 and OP2

Besides the recommended standard methods, there are a number of other, e.g.

- interpolation with the Akima spline [PROG],
- direct programming of B spline control points [PROG] using linear blocks and
- older HSC functions using OP1 and OP2 [PROG].

4 Applications with programming examples

The examples are based on the following dynamic characteristics and parameters:

	a (G01)	Max. acceleration	Max. velocity	Ramp time
translatory axes	2000 mm/s2	6000 mm/s2	1000 mm/s	150 ms
rotary axes	2000 mm/s2	2000 mm/s2	120 mm/s	60 ms
Cycle time		4 ms		
Slope profile type		HSC		

4.1 2.5D machining

4.1.1 Surface and 2.5D machining

Programing Example

Surface

The test program below approximates a circle of radius 80 mm using 64 interpolation points. In the first pass, the spline function is disabled and the linear blocks are interpolated. In the second pass, the spline function is enabled.

The approach and departure blocks are programmed in such a way that the tool enters tangentially into the scanned ideal circle contour.

```
%L uprg_secant
N01 #AKIMA TRANS[START=TANGENTIAL END=TANGENTIAL]
N01 P5 = 80         ( radius                  )
N02 P3 = 64         ( number of interpolation points )
N03 P4 = 360/P3     ( angle gradations      )
N04 G01 X-P5 F20
N05     X0
N06 G151            ( select spline        )
N07 $FOR P1=1, P3, 1
N08  P2=P1*P4 F20
N09  X=P5*SIN[P2] Y=P5*[1.0-COS[P2]] ( calculate secant interpolation
points )
N10 $ENDFOR
N11 G150            ( deselect spline       )
N12 XP5
M29

%L uprg_cir
N01 P5 = 80         ( radius                  )
N02 G01 X-P5 Y0 F20
N03     X0
N04 G03 JP5
N05 G01 XP5
M29

%Main
N100 LL uprg_secant
N200 LL uprg_cir
M30
```

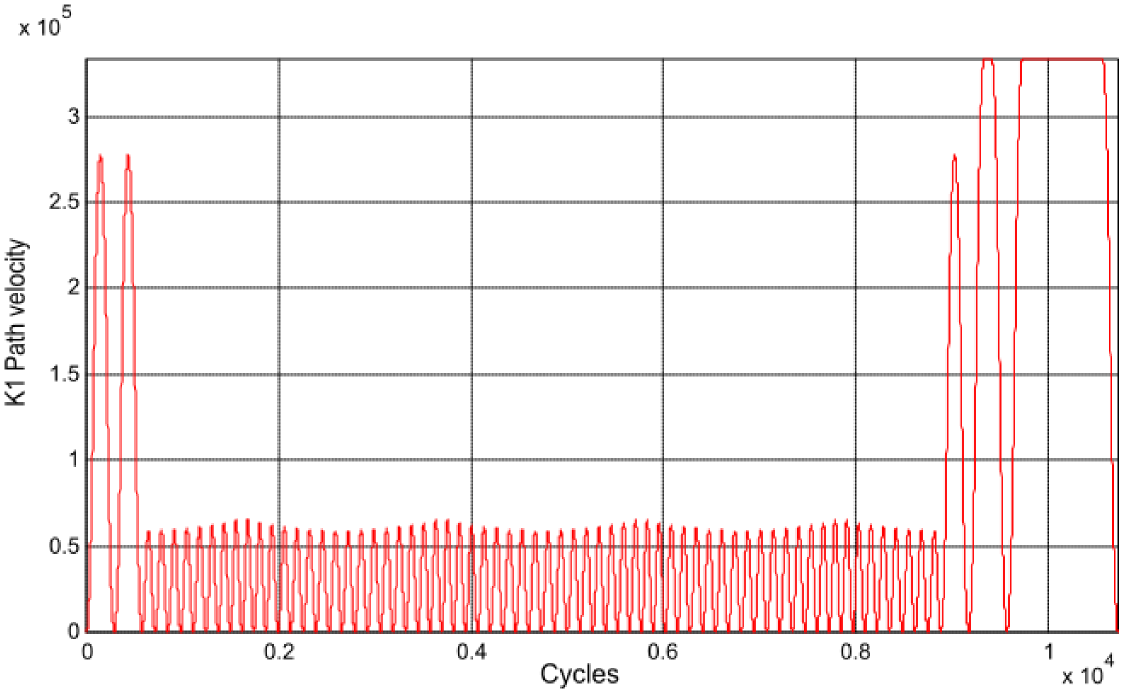


Fig. 25: Path feed rate with interpolation of secant contour (64 interpolation points)

The feed rate fluctuates quite significantly since the non-linear slope reduces the velocity to 0 at the corners of the linear blocks.

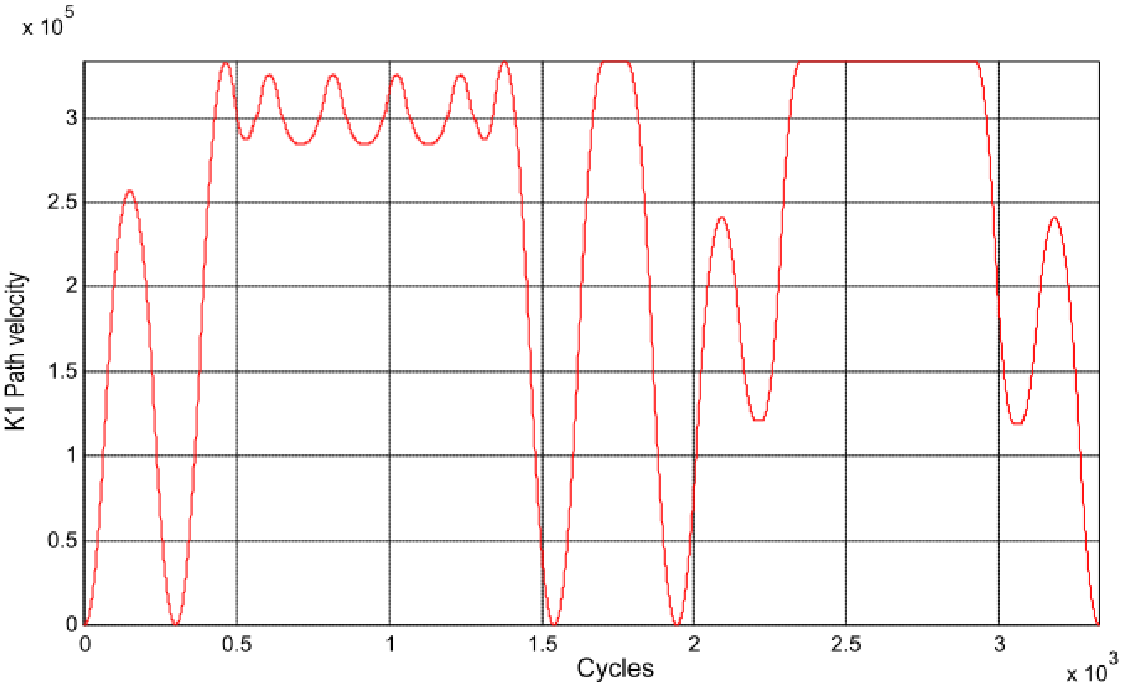


Fig. 26: Path feed rate with spline curve interpolation (64 interpolation points)

When the spline function is used, the interpolation time within the approximated circle drops to about 1/10 of the value for linear interpolation; the programmed feed rate is achieved.

4.2 Example of five-axis machining

4.2.1 SURFACE and five-axis machining

Programing Example

Surface

In addition to motion in the x-y plane, the program below guides the tool of a 5-axis head perpendicularly to a secant contour.

```
%L uprg_secant
N010 #HSC ON[SURFACE PATH_DEV 0.1]
N020 #SLOPE [TYPE=HSC]
N030 P5 = 80 ( radius )
N040 P3 = 64 ( number of interpolation points )
N050 P4 = 360/P3 ( angle gradations )
N060 G01 X-P5 F20
N070 X0
N080 $FOR P1=1, P3, 1
N090 P2=P1*P4 F20
N100 X=P5*SIN[P2] Y=P5*[1.0-COS[P2]] C[-90+P2]
N110 $ENDFOR
N120 XP5
N130 M29

%Main
N140 #KIN ID[9]
N150 #TRAFO ON
N160 A90 C-90
N170 LL uprg_secant
N180 #TRAFO OFF
N190 M30
```

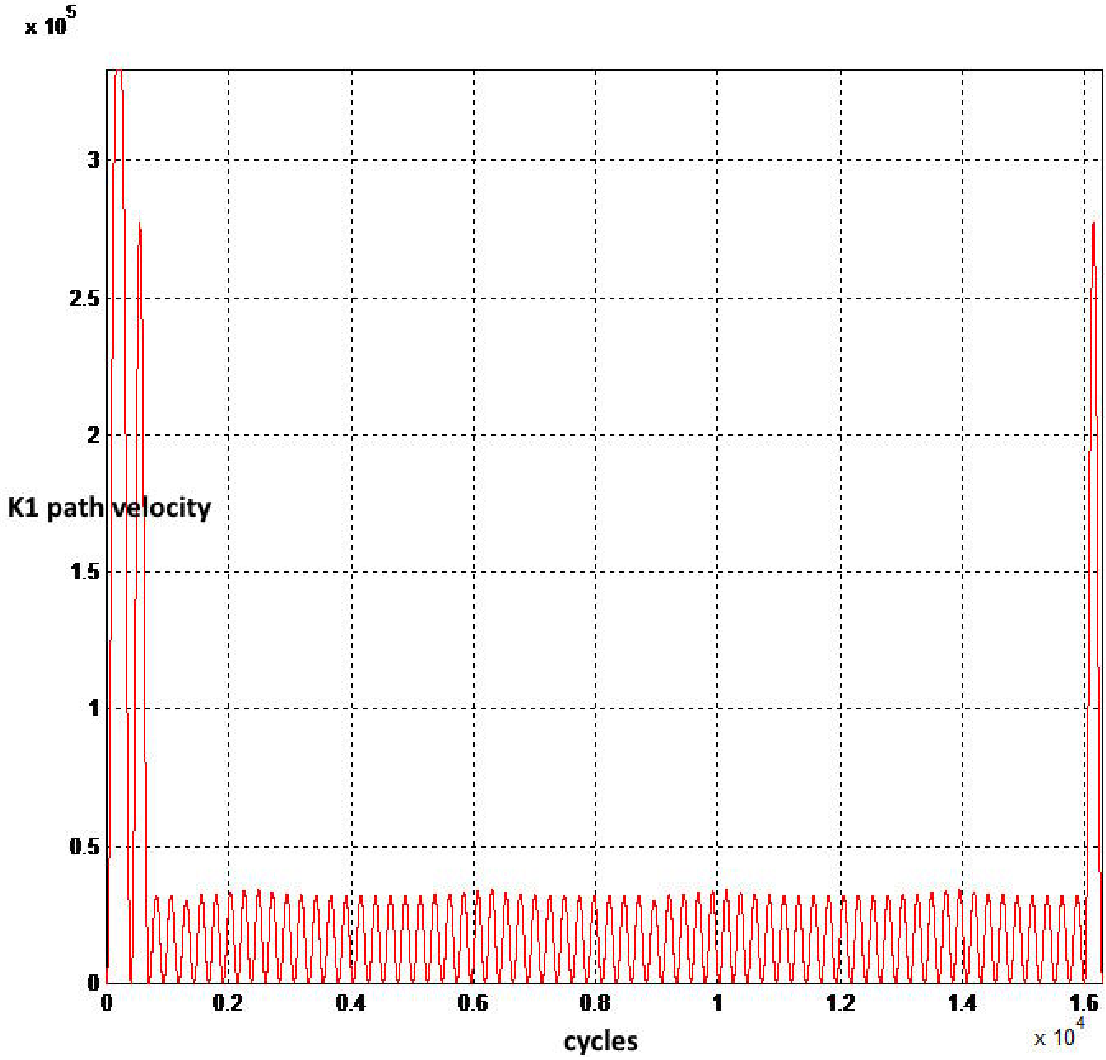


Fig. 27: Path velocity with linear blocks and perpendicularly oriented tool

The feed rate fluctuates significantly due to the inconsistency of the rotary axis.

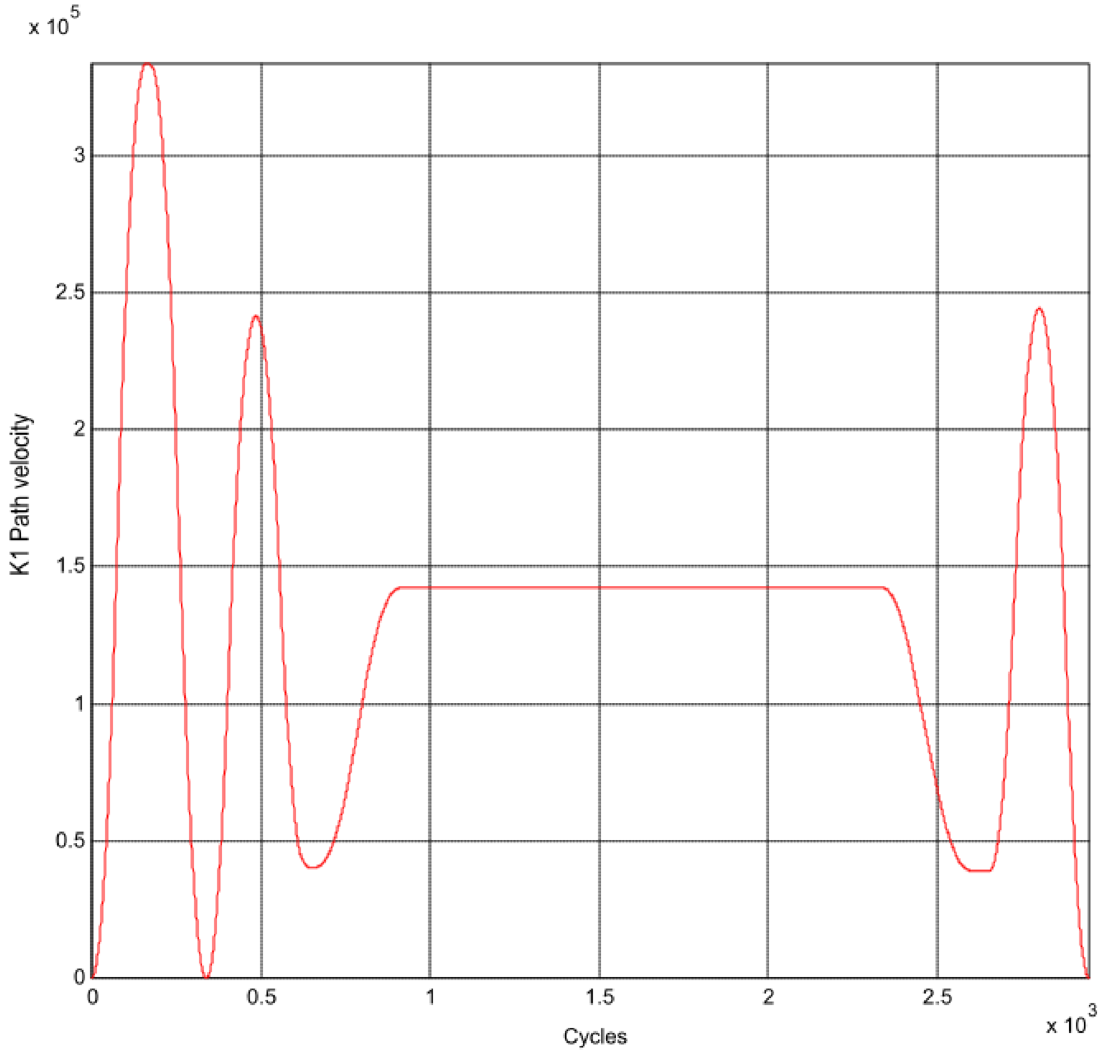


Fig. 28: Path velocity with spline curve and perpendicularly oriented tool

When the spline function is enabled, the path velocity is constant. The programmed path velocity cannot be reached due to the limited rotation speed of the orientation axis. In addition, since the motion part of the rotary axis cannot change due to the constant contour curvature, the velocity level on the path can be kept constant.

5 Parameter

5.1 Overview

General dynamic characteristics

ID	Parameter	Description
P-AXIS-00008	a_max	Maximum permissible axis acceleration
P-AXIS-00209	vb_eilgang	Rapid traverse velocity
P-AXIS-00212	vb_max	Maximum permissible axis velocity

Characteristics and control flags for non-linear slope function

ID	Parameter	Description
P-AXIS-00001	a_beschl	a on acceleration
P-AXIS-00002	a_brems	a on deceleration
P-AXIS-00004	a_grenz	Rapid traverse acceleration
P-AXIS-00013	a_trans_weight	Weighting of acceleration at block transition
P-AXIS-00154	r_trans_weight	Weighting of jerk at block transition
P-AXIS-00195	tr_beschl_ab	Ramp time for acceleration down-gradation
P-AXIS-00196	tr_beschl_zu	Ramp time for acceleration up-gradation
P-AXIS-00197	tr_brems_ab	Ramp time for deceleration down-gradation
P-AXIS-00198	tr_brems_zu	Ramp time for deceleration up-gradation
P-AXIS-00199	tr_geom	Ramp time for curved contours
P-AXIS-00200	tr_grenz	Rapid traverse ramp time

ID	Parameter	Description
P-CHAN-00009	corr_v_trans_jerk	Enable jerk limitation at tangential block transitions

Characteristics for linear slope function

ID	Parameter	Description
P-AXIS-00005	a_grenz_stufe_1	Rapid traverse acceleration step 1
P-AXIS-00006	a_grenz_stufe_2	Rapid traverse acceleration step 2
P-AXIS-00011	a_stufe_1	Acceleration step 1
P-AXIS-00012	a_stufe_2	Acceleration step 2
P-AXIS-00211	vb_grenz_stufe_1_2	Rapid traverse changeover speed step 1 -> step 2

ID	Parameter	Description
P-AXIS-00221	vb_stufe_1_2	Changeover speed step 1 -> step 2

Pre-assignment of path-specific characteristics (option)

The following parameters are effective in conjunction with path-specific commands.

ID	Parameter	Description
P-CHAN-00002	acceleration	Maximum permissible acceleration in space
P-CHAN-00090	velocity	Maximum permissible velocity in space

Effect of override

ID	Parameter	Description
P-CHAN-00066	over-ride_weight_prog_feed	Control flag for influence of override

Default assignment of acceleration profile

ID	Parameter	Description
P-CHAN-00071	profile	Slope type 0: Step-shaped acceleration profile (default) 1: Trapezoidal acceleration profile 2: Sine-square acceleration profile 3: Trapezoidal HSC acceleration profile

Polynomials on internal B spline deselection

ID	Parameter	Description
P-CHAN-00239	hsc.bspline.auto_con-tour_mode	Automatic insertion of polynomials on internal B spline deselection

Enabling functionalities at start-up

ID	Parameter	Description
P-CHAN-00605	configuration.path_pre-paration.fct_enable	Conditional enable of the functionalities

5.2 Description

5.2.1 Axis parameters

P-AXIS-00001	**Acceleration at machining feed (non-linear slope)**	
Description	The parameter represents the axis acceleration with increasing velocity.	
Parameter	getriebe[i].slope_profil.a_beschl	
Data type	UNS32	
Data range	1 ≤ a_beschl ≤ P-AXIS-00008	
Axis types	T, R	
Dimension	T: mm/s²	R,S: °/s²
Default value	1000	
Drive types	----	
Remarks	The acceleration ramps can be changed in the NC program. The appropriate NC commands are described in [PROG//G130/G131] in greater detail.	

P-AXIS-00002	**Deceleration at machining feed (non-linear slope)**	
Description	The parameter represents the axis deceleration with decreasing velocity.	
Parameter	getriebe[i].slope_profil.a_brems	
Data type	UNS32	
Data range	1 ≤ a_brems ≤ P-AXIS-00008	
Axis types	T, R, S	
Dimension	T: mm/s²	R,S: °/s²
Default value	1000	
Drive types	----	
Remarks	The acceleration ramps can be changed in the NC program. The appropriate NC commands are described in [PROG//G130/G131] in greater detail.	

P-AXIS-00004	**Acceleration at rapid movement (non-linear slope)**	
Description	This acceleration parameter is active for deceleration and acceleration with rapid traverse movements (G00).	
Parameter	getriebe[i].slope_profil.a_grenz	
Data type	UNS32	
Data range	1 ≤ a_grenz ≤ P-AXIS-00008	
Axis types	T, R, S	
Dimension	T: mm/s²	R,S: °/s²
Default value	1000	
Drive types	----	
Remarks	The acceleration ramps can be changed in the NC program. The appropriate NC commands are described in [PROG//G231] in greater detail.	

P-AXIS-00005	**Acceleration of step 1 in rapid mode (linear slope)**	
Description	The parameter defines the step 1 rapid traverse acceleration (G00). For positioning in rapid traverse (G00), ramps are often chosen steeper than for the linear and circular interpolation (G01, G02, G03).	
Parameter	getriebe[i].lslope_profil.a_grenz_stufe_1	
Data type	UNS32	
Data range	1 ≤ a_grenz_stufe_1 ≤ P-AXIS-00008	
Axis types	T, R, S	
Dimension	T: mm/s²	R,S: °/s²
Default value	1000	
Drive types	----	
Remarks	This limit acceleration is generally set close to the current limit to achieve fast positioning and fast deceleration values. The acceleration ramps can be changed in the NC program. The appropriate NC commands are described in [PROG//G231] in greater detail.	

P-AXIS-00006	Acceleration of step 2 in rapid mode (linear slope)	
Description	The parameter defines the step 2 rapid traverse acceleration (G00). For positioning in rapid traverse (G00), ramps are often chosen steeper than for the linear and circular interpolation (G01, G02, G03).	
Parameter	getriebe[i].lslope_profil.a_grenz_stufe_2	
Data type	UNS32	
Data range	1 ≤ a_grenz_stufe_2 ≤ P-AXIS-00008	
Axis types	T, R, S	
Dimension	T: mm/s²	R,S: °/s²
Default value	1000	
Drive types	----	
Remarks	This limit acceleration is generally set close to the current limit to achieve fast positioning and fast deceleration values. The acceleration ramps can be changed in the NC program. The appropriate NC commands are described in [PROG//G231] in greater detail.	

P-AXIS-00008	Maximum permissible axis acceleration	
Description	The parameter defines the maximum permissible axis acceleration.	
Parameter	getriebe[i].dynamik.a_max	
Data type	UNS32	
Data range	1 ≤ a_max ≤ 100000000 (Presetting of maximum axis acceleration, plausibility limit, application-specific)	
Axis types	T, R, S	
Dimension	T: mm/s²	R,S: °/s²
Default value	1000	
Drive types	----	
Remarks		

P-AXIS-00011	**Acceleration of step 1 (linear slope)**	
Description	The parameter only becomes active during the deceleration phases. It defines the acceleration in step 1.	
Parameter	getriebe[i].lslope_profil.a_stufe_1	
Data type	UNS32	
Data range	1 ≤ a_stufe_1 ≤ P-AXIS-00008	
Axis types	T, R, S	
Dimension	T: mm/s²	R: °/s²
Default value	1000	
Drive types	----	
Remarks	The acceleration ramps can be changed in the NC program. The appropriate NC commands are described in detail in [PROG//G130, G131]. This parameter has no effect with spindles.	

P-AXIS-00012	**Acceleration of step 2 (linear slope)**	
Description	The parameter only becomes active during the deceleration phases. It defines the acceleration in step 2.	
Parameter	getriebe[i].lslope_profil.a_stufe_2	
Data type	UNS32	
Data range	1 ≤ a_stufe_2 ≤ P-AXIS-00008	
Axis types	T, R, S	
Dimension	T: mm/s²	R,S: °/s²
Default value	1000	
Drive types	----	
Remarks	The acceleration ramps can be changed in the NC program. The appropriate NC commands are described in detail in [PROG//G130, G131] in greater detail.	

P-AXIS-00013	Weighting of acceleration at motion block transition	
Description	This parameter weights the permissible acceleration at a motion block transition. If the value 0 is not specified in the parameter list, the weighting of the permissible acceleration with the cycle time/ramp time factor is valid (default setting).	
Parameter	getriebe[i].dynamik.a_trans_weight	
Data type	UNS32	
Data range	1 ≤ a_trans_weight ≤ 1000	
Axis types	T, R, S	
Dimension	T: 0.1%	R,S: 0.1%
Default value	0	
Drive types	----	
Remarks	This parameter is only considered if the non-linear slope is used as soon as the contour has a kink angle. To define the slope type, see • P-CHAN-00071 [▹ 74] • program command #SLOPE [TYPE [▹ 47]=…]	

P-AXIS-00154	Weighting of jerk at block transition	
Description	At the block transition from linear to circular block or vice versa, a jump in acceleration occurs, even if there is a tangential transition. The parameter weights the permissible jerk at these types of movement transitions. Jerk is only considered if P-CHAN-00009 [▹ 72] is set. If P-AXIS-00154 is not set in the parameter list, the velocity is reduced to such an extent that the permissible jerk at the block transition is maintained.	
Parameter	getriebe[i].dynamik.r_trans_weight	
Data type	UNS32	
Data range	0 ≤ r_trans_weight ≤ 1000	
Axis types	T, R, S	
Dimension	T: 0.1%	R,S: 0.1%
Default value	1000	
Drive types	----	
Remarks	This parameter is only considered if the non-linear slope is used and for circular - linear, circular - circular or linear - circular transitions. To define the slope type, see • P-CHAN-00071 [▹ 74] • program command #SLOPE [TYPE [▹ 47]=…]	

P-AXIS-00195	**Ramp time for acceleration down-gradation (non-linear slope)**	
Description	The parameter defines the acceleration ramp time for the down-gradation of acceleration P-AXIS-00001.	
Parameter	getriebe[i].slope_profil.tr_beschl_ab	
Data type	UNS32	
Data range	P-AXIS-00201 ≤ tr_beschl_ab ≤ MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs
Default value	50000	
drive types.	----	
Remarks	The ramp time can be changed in the NC program. The appropriate NC commands are described in [PROG//Ramp time weighting (G132/G133/G134/G232/G233/G338/G339)] in greater detail.	

P-AXIS-00196	**Ramp time for acceleration up-gradation (non-linear slope)**	
Description	The parameter defines the acceleration ramp time for the up-gradation of the acceleration P-AXIS-00001.	
Parameter	getriebe[i].slope_profil.tr_beschl_zu	
Data type	UNS32	
Data range	P-AXIS-00201 ≤ tr_beschl_zu ≤ MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs
Default value	50000	
drive types.	----	
Remarks	The ramp time can be changed in the NC program. The appropriate NC commands are described in [PROG//Ramp time weighting (G132/G133/G134/G232/G233/G338/G339)] in greater detail. The default value for ramp time weighting can be defined in P-CHAN-00073.	

P-AXIS-00197	Ramp time for deceleration down-gradation (non-linear slope)	
Description	The parameter defines the acceleration ramp time for the down-gradation of deceleration P-AXIS-00002.	
Parameter	getriebe[i].slope_profil.tr_brems_ab	
Data type	UNS32	
Data range	P-AXIS-00201 ≤ tr_brems_ab ≤ MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs
Default value	50000	
drive types.	----	
Remarks	The ramp time can be changed in the NC program. The appropriate NC commands are described in [PROG//Ramp time weighting (G132/G133/G134/G232/G233/G338/G339)] in greater detail.	

P-AXIS-00198	Ramp time for deceleration up-gradation (non-linear slope)	
Description	The parameter defines the acceleration ramp time for the up-gradation of deceleration P-AXIS-00002.	
Parameter	getriebe[i].slope_profil.tr_brems_zu	
Data type	UNS32	
Data range	P-AXIS-00201 ≤ tr_brems_zu ≤ MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs
Default value	50000	
drive types.	----	
Remarks	The ramp time can be changed in the NC program. The appropriate NC commands are described in [PROG//Ramp time weighting (G132/G133/G134/G232/G233/G338/G339)] in greater detail.	

P-AXIS-00199	**Geometric ramp time**	
Description	The parameter defines the permissible geometric ramp time. This parameter limits axis jerk caused by the programmed contour.	
Parameter	getriebe[i].dynamik.tr_geom	
Data type	UNS32	
Data range	0 (Preset of minimum ramp time, application-specific) ≤ tr_geom ≤ MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs
Default value	10000	
drive types.	----	
Remarks	The ramp time can be changed in the NC program. The appropriate NC commands are described in [PROG//Ramp time weighting (G132/G133/G134/G232/G233/G338/G339)] in greater detail.	

P-AXIS-00200	**Ramp time at rapid movement (non-linear slope)**	
Description	The ramp time parameter is active with rapid traverse motions (G00) for acceleration and deceleration. In this case it replaces the 2 ramp times for acceleration (P-AXIS-00195, P-AXIS-00196) or the 2 ramp times for deceleration (P-AXIS-00197, P-AXIS-00198).	
Parameter	getriebe[i].slope_profil.tr_grenz	
Data type	UNS32	
Data range	P-AXIS-00201 ≤ tr_grenz ≤ MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs
Default value	10000	
Drive types	----	
Remarks	The ramp time can be changed in the NC program. The appropriate NC commands are described in detail in [PROG//G232/G233].	

P-AXIS-00209	**Rapid mode velocity**	
Description	The rapid traverse velocity is specified for positioning in rapid traverse (G00).	
Parameter	getriebe[i].vb_eilgang	
Data type	UNS32	
Data range	1 ≤ vb_eilgang ≤ P-AXIS-00212	
Axis types	T, R, S	
Dimension	T: µm/s	R,S: 0.001°/s
Default value	166666	
Drive types	----	
Remarks		

P-AXIS-00211	**Changeover speed in rapid mode (linear slope)**	
Description	For positioning in rapid traverse (G00), ramps are often chosen steeper than for the linear and circular interpolation (G01, G02, G03). The parameter defines the acceleration and deceleration phases for these cases. It defines the changeover speed between step 1 and step 2 (P-AXIS-00005 and P-AXIS-00006 orP-AXIS-00281 and P-AXIS-00280).	
Parameter	getriebe[i].lslope_profil.vb_grenz_stufe_1_2	
Data type	UNS32	
Data range	1 ≤ vb_grenz_stufe_1_2 ≤ P-AXIS-00212	
Axis types	T, R, S	
Dimension	T: µm/s	R,S: 0.001°/s
Default value	100000	
Drive types	----	
Remarks		

P-AXIS-00212	**Maximum permissible axis velocity**	
Description	The parameter defines the maximum permissible axis velocity.	
Parameter	getriebe[i].dynamik.vb_max	
Data type	UNS32	
Data range	1 < hb_v_max_track ≤ 2000000000 (Presetting of maximum axis velocity, plausibility limit, application-specific)	
Axis types	T, R, S	
Dimension	T: µm/s	R,S: 0,001°/s
Default value	200000	
Drive types	----	
Remarks	In the case of axes of the type 'ACHSTYP_TRANSLATOR' and 'ACHSTYP_ROTATOR' it is presumed that while setting the maximum permissible axis velocity the resolution limits of the measuring system will also be taken into consideration. In the case of axes of the type 'ACHSTYP_SPINDEL' which are controlled by a spindle interpolator, the limit at which the measuring system delivers no valid values is set using the parameter P-AXIS-00220 . **Examples:** **Spindle speed at 10000 rpm** value = 10000 * 6 * 1000 = 60000000 (unit 0.001 °/s) With units (10000 [rpm] * 360 [°/rev] * 1000 [0.001 °/°]) / 60 [s/min] = 60000000 [0.001 °/s] **Translator at 1000 mm/min** value = 1000 * 1000 / 60 = 16666 (unit 0.001 µm/s) With units (1000 [rpm] * 1000 [0.001 µm/mm]) / 60 [s/min] = 16666 [0.001 µm/s]	

P-AXIS-00221	Changeover speed (linear slope)	
Description	The parameter becomes active during the acceleration and deceleration phases. It defines the changeover speed between step 1 and step 2 (P-AXIS-00011 and P-AXIS-00012 or P-AXIS-00283 and P-AXIS-00282).	
Parameter	getriebe[i].lslope_profil.vb_stufe_1_2	
Data type	UNS32	
Data range	1 ≤ vb_stufe_1_2 ≤ P-AXIS-00212	
Axis types	T, R, S	
Dimension	T: µm/s	R,S: 0.001°/s
Default value	100000	
Drive types	----	
Remarks		

5.2.2 Channel parameters

P-CHAN-00002	**Path acceleration limit**
Description	If no change is made to the parameter values by NC programming, this value limits path acceleration after it is activated in the NC program.
Parameter	vector.acceleration
Data type	REAL64
Data range	0 ... Maximum acceleration, application-specific
Dimension	mm/min² or mm/s² *
Default value	100000000
Remarks	* The dimension used depends on P-CHAN-00351. Parameterisation example: `vector.acceleration 1800000` The specified default value is in mm/min².

P-CHAN-00009	**Reduction of tangential transition velocity between circles**
Description	Tangential block transitions between circles with different radii and circles and linear blocks and vice versa lead to a jerk depending on circle radius. A jerk produced by activating this function can be reduced in order to reduce the excitation of vibrations on the machine when non-linear velocity profiles are active. At tangential block transitions, the speed is reduced dependent on the permissible jerk. The calculation is based on axis-specific jerk parameters for non-linear speed profiles (see also [AXIS] documentation). On the other hand, the reduction of speed at tangential block transitions is not acceptable with specific machining technologies since the machining process has a very sensitive reaction to a reduction in velocity.
Parameter	corr_v_trans_jerk
Data type	BOOLEAN
Data range	0: No inclusion of jerk at tangential block transitions. 1: Inclusion of jerk at tangential block transitions.
Dimension	----
Default value	0
Remarks	

P-CHAN-00066	**Influence of override on feed**
Description	This parameter defines how feed is calculated in conjunction with path feed override. This means, for example, the parameter sets whether the override bandwidth is applied to the programmed feed or to the minimum programmed feed and the maximum permissible feed in the block (v_{max}). The CNC calculates the feed based on the permissible axis dynamics. The following velocities have an influence: v_{max}: Calculated maximum velocity of the CNC with no consideration given to reduced velocity v_{red}: Calculated reduced velocity of the CNC, taken from vb_max_red (P-AXIS-00214) of the axes v_{prog}: programmed velocity of the operator (F word) **Value 0 for P-CHAN-00066:** $v = MIN (v_{prog}, v_{max}) * Override$ If this parameter is set to 0, a change of override always leads to a change of velocity in the machine (linear correlation). **Value 1 for P-CHAN-00066:** $v = MIN (v_{prog} * Override, v_{max})$ If this parameter is set to 1, the override always refers to the programmed feed. If the maximum feed in the block is smaller than the programmed feed multiplied by the current override, the current path feed is not changed when there is a change in override. **Value 2 for P-CHAN-00066:** Calculation is executed • as for the value 0 provided there are no active functions that reduce velocity. For example, REDUCED_SPEED, REDUCED_SPEED_ZONE, IPO_ACTIVATE_TCP_VEL_LIMIT • as for the value 1 provided there are no active functions that reduce velocity If velocity drops are not desired for technological reasons, this parameter must be set to 1.
Parameter	override_weight_prog_feed
Data type	UNS16
Data range	0: Change in override causes a change of velocity. 1: An override change only causes a velocity change if the programmed feed * override < maximum permissible velocity in the block 2: Override effect in conjunction with reduced velocity (available as of Build V3.1.3079.42)
Dimension	----
Default value	0
Remarks	**Example of values**: v_{max}: 50m/min v_{prog}: 80m/min v_{red}: 5m/min Override: 50% **P-CHAN-00066=0** a) active reduced velocity v_{set} = 2.5m/min b) inactive reduced velocity v_{set} = 25m/min

	P-CHAN-00066=1 a) active reduced velocity v_{set} = 5m/min b) inactive reduced velocity v_{set} = 40m/min **P-CHAN-00066=2** a) active reduced velocity v_{set} = 5m/min b) inactive reduced velocity v_{set} = 25m/min

P-CHAN-00071	**Default acceleration profile at program start**
Description	Default value for the selected acceleration profile type with path motions and oscillating axis motions.
Parameter	prog_start.slope.profile
Data type	SGN16
Data range	0: Step-shaped acceleration profile, (default, linear profile) 1: Trapezoidal acceleration profile 2: Sine-square acceleration profile 3: Trapezoidal HSC acceleration profile (across blocks)
Dimension	----
Default value	0
Remarks	The acceleration profile and the associated acceleration and ramp time weighting can be programmed in the NC program with the #SLOPE [TYPE..] command [PROG [47]]. The maximum of the weighted ramp times P-AXIS-00195 is always effective with the trapezoidal HSC acceleration profile. P-AXIS-00198. For every independent axis, the acceleration profile can also be programmed specifically in the NC command with the key word SLOPE_TYPE [PROG [47]].

P-CHAN-00090	**Path velocity limit**
Description	If no change is made to the parameter values by NC programming, this value limits path velocity after it is activated in the NC program.
Parameter	vector.velocity
Data type	REAL64
Data range	0 ... Maximum acceleration, application-specific
Dimension	mm/min
Default value	2000000000
Remarks	Parameterisation example: `vector.velocity 1500`

P-CHAN-00239	**Automatic insertion of polynomials on internal B spline deselection**
Description	This parameter automatically selects polynomial contouring (G261, #CONTOUR MODE [...]) when the B spline is deselected internally. The B spline #HSC[BSPLINE PATH_DEV=**X** TRACK_DEV=**Y**] then adopts the following parameters for polynomial contouring: #CONTOUR MODE[DEV PATH_DEV=**X** TRACK_DEV=**Y** RELEVANT_PATH=**X** RELEVANT_TRACK=**Y**] The exact response of the parameters is described in[PROG//section Polynomial contouring (G260/G261)].
Parameter	hsc.bspline.auto_contour_mode
Data type	UNS32
Data range	0: Deactivated (default) 1: General insertion of smoothing polynomial if B spline is internally deselected. 2: Insert smoothing polynomial on linear-circular, circular-circular and circular-linear transitions (recommended mode).
Dimension	----
Default value	0
Remarks	

P-CHAN-00605	**Conditional enable of the functionalities**
Description	This parameter can be used to configure functions of the CNC that are activated in the channel depending on the program start mode. Several settings can be predefined for activation as soon as an NC program is started in the machining mode listed under the condition P-CHAN-00606 .
Parameter	configuration.path_preparation.fct_enable[<idx>] where idx 0, 1
Data type	STRING
Data range	See Path preparation function table
Dimension	----
Default value	FCT_DEFAULT
Remarks	If no individual machining mode is set at the start of the program, this corresponds to the setting ISG_STANDARD. The default settings under index 0 ("fct_enable[0]") are used. For reasons of backward compatibility, P-CHAN-00605 "fct_enable[0]" corresponds to the previous parameter "function" P-CHAN-00600. Both notations or parameters can be used alternatively.

6 Appendix

6.1 Suggestions, corrections and the latest documentation

Did you find any errors? Do you have any suggestions or constructive criticism? Then please contact us at documentation@isg-stuttgart.de.

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Keyword index

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