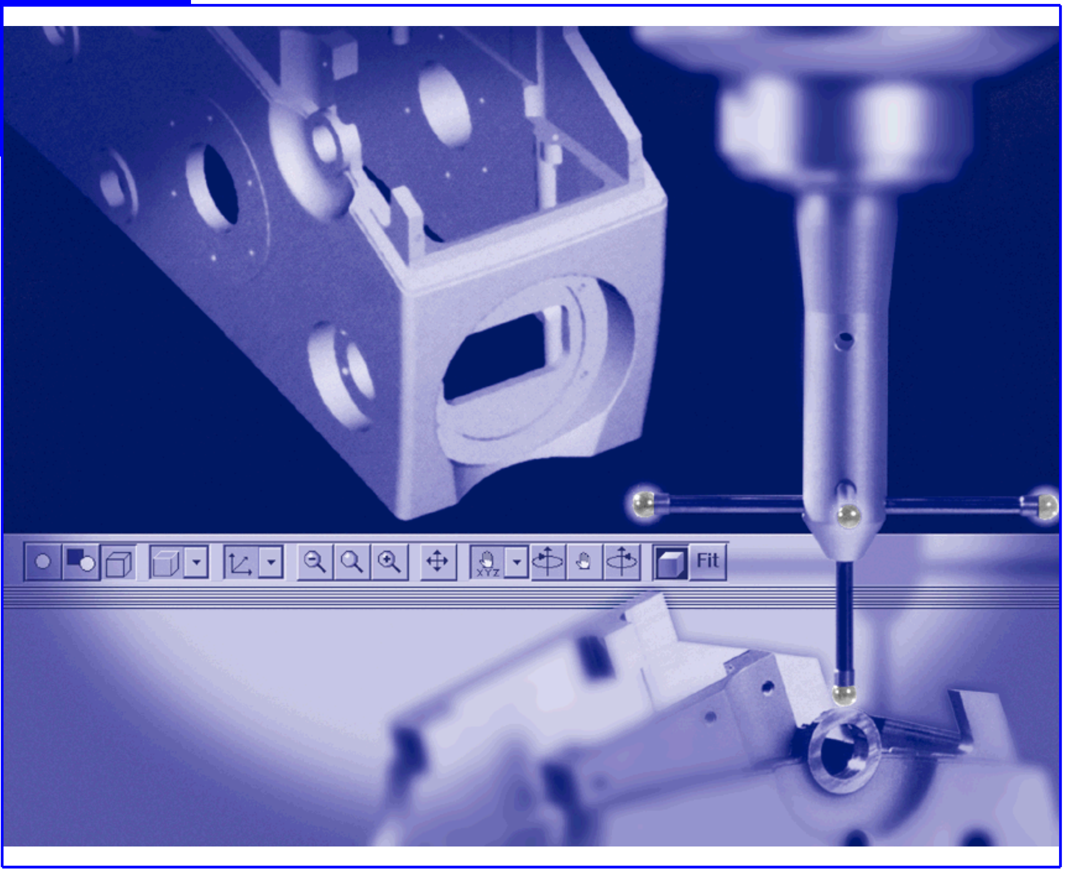
CALYPSO

Option 1
CNC Curve Measuring Software



Operating Instructions

ZEISS

The design and delivered components of the CMM, its options, the program packages, and the relevant documentation are subject to change.

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CALYPSO
Version 2018
Operating Instructions
2018-04-16
61212-2711502

Table of contents

Preface

Information about these operating instructions

The CALYPSO program consists of a base module and additional options for special purposes. You can customize the scope of program to fit your requirements.

These operating instructions describe an option of CALYPSO and are based on the assumption that the user is familiar with the operating instructions for the base module of CALYPSO.

NOTE

The additional CALYPSO options are described in separate manuals.

Reference information about the windows and dialogs can be found in the dialog reference in the CALYPSO Online Help.

Simply Measure – And what you should know to do it right, A metrology primer

Carl Zeiss, Industrial Metrology Division,

Order no.: 612302-9002

Text conventions

The following text conventions are used in these instructions.

Example	Description
Features	Text element of the graphics screen display.
Comment	The **Comment** button on the screen.
<machine name>	Variable text or dummy for a name.
C:\windows\w.ini	The w.ini file in the windows directory on the C:\ drive.
For this section…	A passage containing important information.

Example	Description
➤ *Preface [➪ Preface-1]*	This is a cross reference. When viewing this manual on the screen, you will be guided to the indicated text passage by clicking the reference.
Plan → CNC-Start → Run	The **Run** command in the **CNC-Start** submenu of the **Plan** menu.
CTRL+A	Press the CTRL key and the letter A at the same time.

Icons

Three special symbols containing important information are used in this manual. The icons appear in the marginal column next to the respective text.

You will find a detailed explanation of the safety instructions under Configuration of safety instructions.

Configuration of safety instructions

Safety instructions indicate a personal health hazard. We distinguish three different levels: Danger, warning and caution. All three safety instructions are marked with the same warning symbol. The designation of the safety instruction is shown beside the symbol. The safety instructions used are described below.

Configuration of a safety instruction

A safety instruction may have the following components:

– Warning symbol and designation of the safety instruction (signal word): Danger, warning or caution.

– Source and cause of the danger

– Consequences for the user due to non-observance of the safety instruction

– Required measures to be taken by the user to avoid possible consequences

– A measure may cause an intermediate result.

– At the end of all measures, a final result may be caused.

Personal health hazard

DANGER

A »danger« indicates an imminent risk to life and limb.
Non-observance of this safety instruction when the described risk occurs causes death or serious injuries.
Example: Electric shock due to high electric voltage.

WARNING

A »warning« indicates a possible risk to life and limb.
Non-observance of this safety instruction when the described risk occurs may cause death or serious injuries.
Example: Risk of severe crushing of the body caused by heavy loads.

CAUTION

A »caution« indicates a personal health hazard.
Non-observance of this safety instruction when the described risk occurs may cause slight to moderate injuries.
Example: Risk of minor crushing of the limbs caused by small loads.

Risk of material damage

If there is no personal health hazard, but the CMM or components may get damaged, this is pointed out by the following notice.

This symbol refers to possible damage to the CMM.
Non-observance of this safety instruction when the event occurs may cause damage to the CMM or one of its components.
Example: Collision of the ram with a workpiece.

Chapter 1

Curve Measurement (option)

This chapter contains:

Basics about curve measurement

Introduction to Curve Measurement (option)

Special measuring techniques are required for measuring free-form surfaces. These techniques are provided by the curve measurement function. The “2D curve” and “3D curve” features as well as the curve characteristics are used for measuring and evaluating known and unknown open and closed 2D and 3D curves.

Curve measurement is one of CALYPSO's optional features. You can license this functionality and have it enabled in your system if it can be of use to you.

This chapter assumes that you are familiar with the procedures for defining features and characteristics.

Definition and display of curves

As curves are sophisticated geometric elements, it is important for you to know how CALYPSO evaluates their form and location.

In CALYPSO, a curve is defined by a finite set of points. CALYPSO uses spline functions to interpolate between the curve points in order to display the curve as a continuity in the CAD window.

NOTE
CALYPSO can process a maximum of 20,000 points for a curve. More than 20,000 points may lead to errors.

Both the nominal and the actual values of the curve points are each defined by 6 values:

– 3 point coordinates (X, Y, Z)

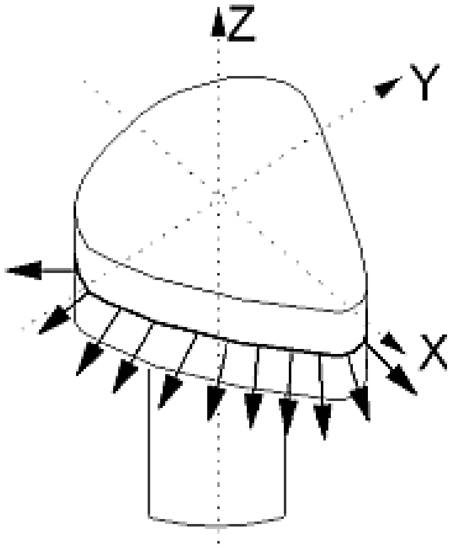
– 1 normal vector (U, V, W) or its 3 direction cosines (NX, NY, NZ).

The three curve types which can be measured and calculated by CALYPSO are presented in the following examples. These examples will help you to understand the principles of the curve measurement.

– **Flat curve** (2D curve)

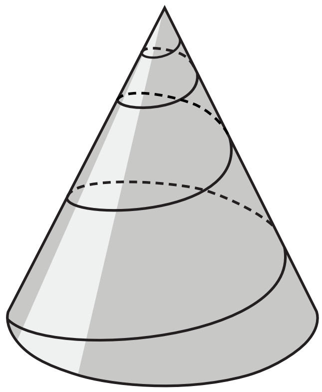
  Flat curves are produced when a plane (imaginary) intersects with a body. Flat curves occur, for example, on workpieces such as camshafts, which exhibit two-dimensional curves.

All the points constituting a flat curve are on a single plane that may (also) have any orientation in space. Consequently, the normal vectors of the curve points, too, are all in the measuring plane. The normal vectors may, however, be changed subsequently in CALYPSO.



– **Spatial curve** (3D curve)

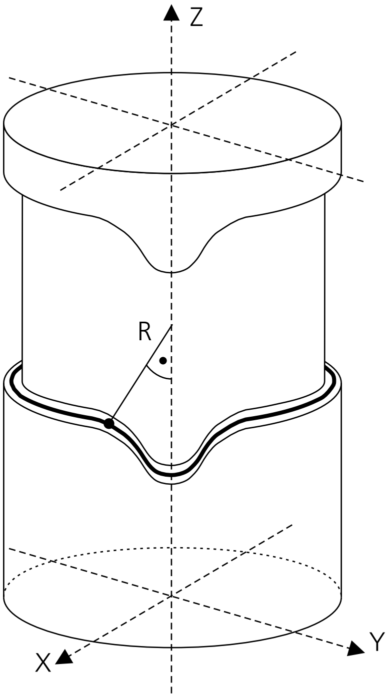
Spatial curves (3D curves) have three degrees of freedom: theoretically, they are not constrained in any direction. You can measure and test 3D curves with CALYPSO.



– **Lift curve** (face curve)

Lift curves, also known as face curves, are special three-dimensional curves that run across cylinder sections. Every point in a lift curve can be described by means of two values: namely by the angle of rotation on the surface of the cylinder and the deviation of the curve from the circular line in a given direction (e.g. radial or axial).

Therefore, the lift curve is a special 3D curve, but has, like the 2D curve, only two degrees of freedom.



The illustration shows an axial lift curve with deviations in the direction of the Z axis.

Performing curve measurement

The procedure for curve measurement does not differ from that for other measurements. The execution of measurements is described in the Basic Operating Instructions under Running a measurement plan. You can measure a complete measurement plan, a mini-plan, or a single characteristic or feature.

Defining the Curve feature

Methods for defining curves

Within the curve feature definition template, Calypso offers the following ways of defining nominal data:

– ➤ *Importing a file [⇨ 1-9]* (in VDA or ASCII format).

– ➤ *Reading ASCII data during the CNC run. [⇨ 1-11]*

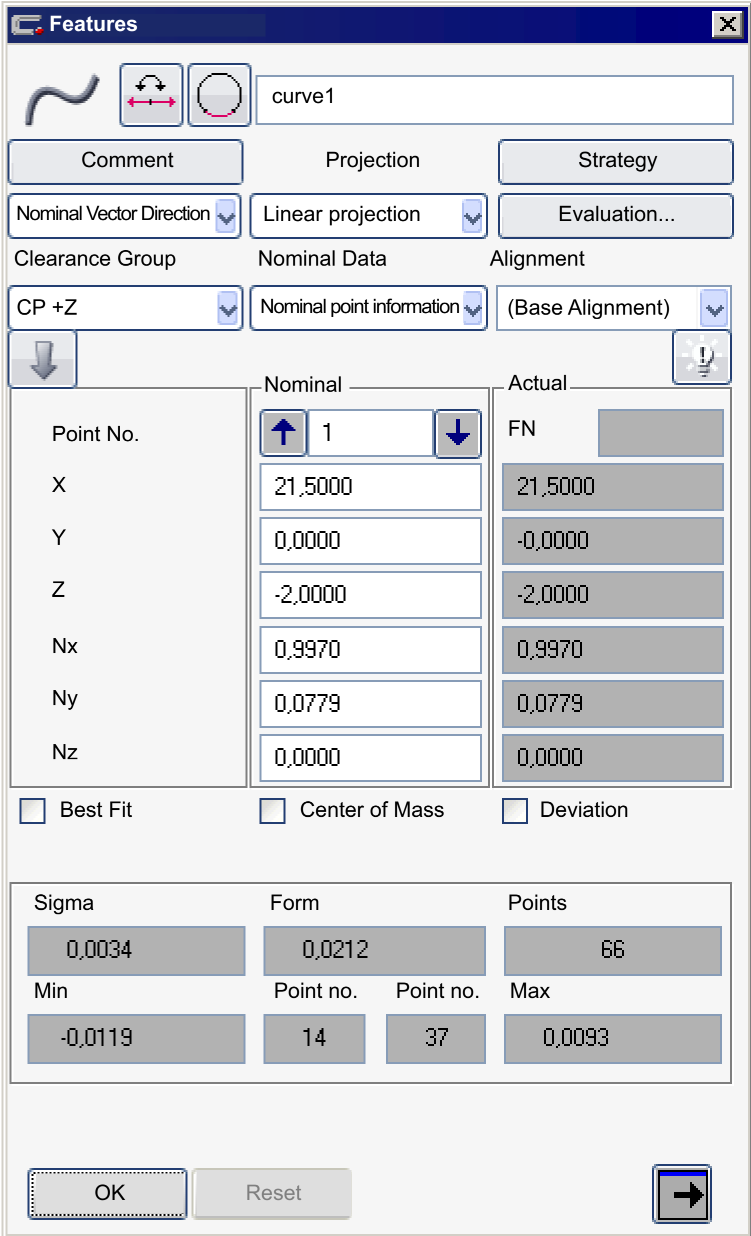
– ➤ *Defining the curve by means of the point generator [⇨ 1-13]*.

– ➤ *Forming the symmetry curve [⇨ 1-17]* from two curves.

– ➤ *Digitizing a curve [⇨ 1-20]*.

– ➤ *Adopting the nominal data of the curve from the CAD model [⇨ 1-33]*.

As with other features, you use a definition template to define two-dimensional and three-dimensional curves. In addition to the buttons and input fields known from other feature templates, this template includes some elements that are new.



This definition template is fully described in the Online Help under Definition template (curve).

2D curves, 3D curves and lift curves – differences

The definition templates for both types of curve are, broadly speaking, the same: they differ only in a few items:

- The definition template for the 3D curve normally does not contain the **Projection** menu – with the two exceptions:
  - Only if the 3D curve is defined as a lift curve, a **Projection** menu with the **No projection** and **Lift curve** menu items is present.
  - Only if the 3D curve is defined as a threaded curve, a **Projection** menu with the **No projection**, **Vertical Projection** and **Helix Projection** menu items is present.
- Deviation calculation for 3D curves is only useful in the actual vector direction and the nominal vector direction.
- The **Additional** → **Move parallel curve** option in the **Nominal Data** menu is not available for 3D curves.

How curves are displayed

In the CAD window, curves are displayed as continuous lines; they are calculated as approximations with the aid of splines.

You have the option of mapping a tape coupled to the curve, in order to highlight the spatial component of a 3D curve.

You can set the width of this tape by clicking **Evaluation** in the **Evaluation** dialog box at **Tape width**. “0” means: no tape.

Marking and unmarking lift curves

Lift curves are 3D curves which are projected onto a cylinder section. You can see here that the **Projection Lift Curve** menu is contained in the definition template of the lift curve in addition to the features of the 3D curve.

You can mark 3D curves as lift curves (by generating the lift curve) or cancel the marking again.

- To mark a 3D curve as a lift curve, you have two options:
  - In the **Change nominal values** window on the **in vector direction** tab, select the **Lift curve** option, tick the **Lift curve** check box and specify the radius and axial direction of the cylinder. Or:
  - In the **Evaluation** window under **3D curve**, tick the **Lift curve** check box.
- To cancel the marking of a 3D curve as a lift curve, you have two options:
  - In the **Change nominal values** window on the **in vector direction** tab, select the **Lift curve** option, untick the **Lift curve** check box and enter “0” explicitly for the **Length** and **Cylinder radius**. Or:
  - In the **Evaluation** window at **3D curve**, untick the **Lift curve** check box.

Defining nominal data for a curve

When defining a curve feature, you first need to define the nominal data of the curve you want to measure.

NOTE

You can use neither the automatic feature recognition nor the strategy macros for this purpose.

To define the nominal data, you can:

– import an existing file.

  The file can have one of the following formats: VDA (Cons, Curve, MDI, PSET, POINT, CIRCLE) or ASCII.

  For ASCII files for curve definition, the imported values are interpreted in the following sequence:

  x-nominal, y-nominal, z-nominal, u-nominal, v-nominal, w-nominal, lTol, uTol, maskEval (masked for evaluation), maskBF (masked for best fit). However, depending on the number of columns, only the first six, eight or ten values of each line are evaluated.

  For ASCII files for axial stroke data, the imported values of each line are interpreted as angles and associated heights.

  For ASCII files for radial stroke data, the imported values of each line are interpreted as angles and associated radii.

– Using the point generator for defining the curve points: either to freely define the curve points mathematically or to import external files with a different format.

– Digitizing a curve. You generate the nominal values of an unknown contour by probing.

– Extracting the nominal data from the CAD mode: using the **CAD Modification** menu and clicking with the mouse.

Once the nominal points have been defined by one of these methods, you can proceed with processing them and thus changing the position and the shape of the curve.

Always check the nominal vectors after defining the curve points, and make sure that the vectors do not point into the material (risk of collision!).

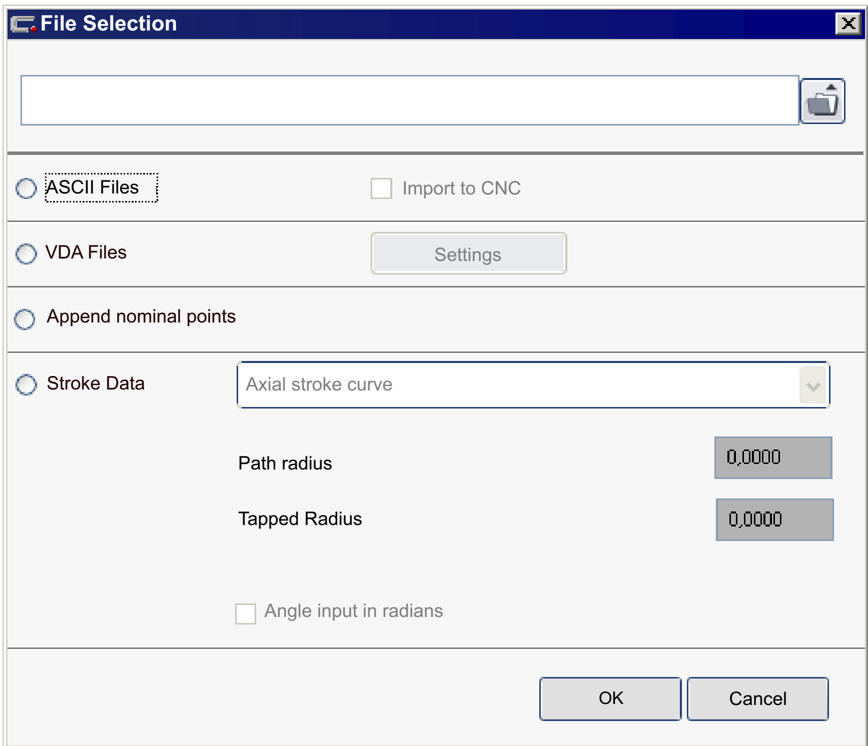
Importing files for nominal value definition of a curve

CALYPSO supports import of the following file formats:

- VDA (the points in a VDA file must be described as Cons, Curve, MDI, PSET, POINT or CIRCLE),
- ASCII (for more information on ASCII files, also see ➤ *Loading ASCII files for nominal value definition of a curve during a CNC run [⇨ 1-11]*),

1 Make sure you have the curve feature template open and displayed on your screen, and that the chosen coordinate system fits the curve to be imported.

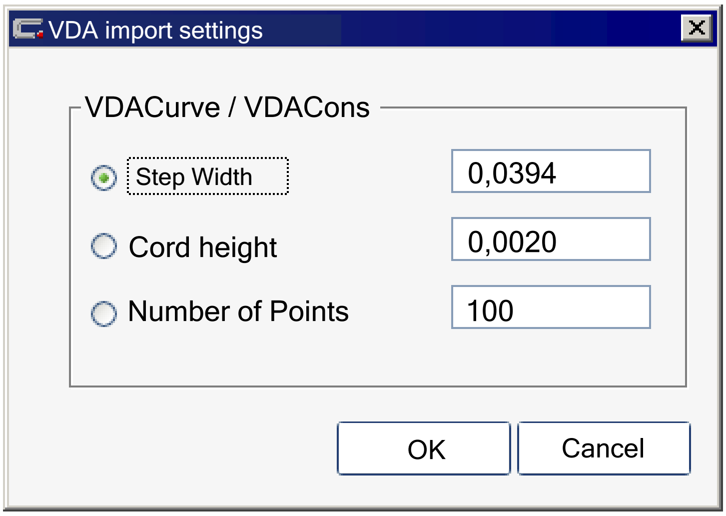
2 Select **Nominal Data → Nominal geometry manipulations → Read nominal values**.
The **File Selection** dialog box appears on the screen.



3 Select the file format (**ASCII Files**, **VDA Files**, or **Stroke Data**).
Note: You can also use the ASCII files to import tolerances.

4 Enter the complete file name or select the desired file.

5 For selective loading of a VDA file, click the **Settings** button, enter the criteria for point selection and confirm with **OK**.



6 If you want to load an ASCII file with **Stroke Data**, enter the curve type and additional data required for conversion into cartesian coordinates. If you specified the angle in radians in the file, tick the corresponding check box.

7 Click **OK**.
The data will now be read from the file.
If you specified selection criteria before importing from a VDA file, the data in the file is imported selectively into the curve feature in accordance with these criteria. The sequence of the curve points derives from the sequence of the points in the VDA file.
The type and name of the converted features are written into the **Comment** for the curve.

You have now defined the curve with its nominal data. Now check the direction of the nominal vectors (see ➤ *Checking the nominal vectors of a curve [➪ 1-48]*).

Reference: Format of stroke data

To ensure that axial or radial stroke data is loaded correctly by CALYPSO, the data must be available in an ASCII file in a defined format.

Axial stroke data

Axial stroke data is entered in two columns. The columns require the headings “Angle” and “Height”. In each line, the value of the angles is stated in the first column and the respective stroke height in the second column.

Example:

```
Angle Height
0     10
10    10
20    10
```

```
30    11
40    13
50    15,5
60    18
70    20,5
80    22
90    24
100   25
...   ...
```

Radial stroke data

Radial stroke data is entered in two columns. The columns require the headings “Radius” and “Angle”. In each line, the value of the angles is stated in the first column and the respective radius in the second column.

Example:

```
Angle Radius
0     500
10    501
20    502
30    502
40    502
50    503
60    504
70    505
80    505
90    505
100   505
...   ...
```

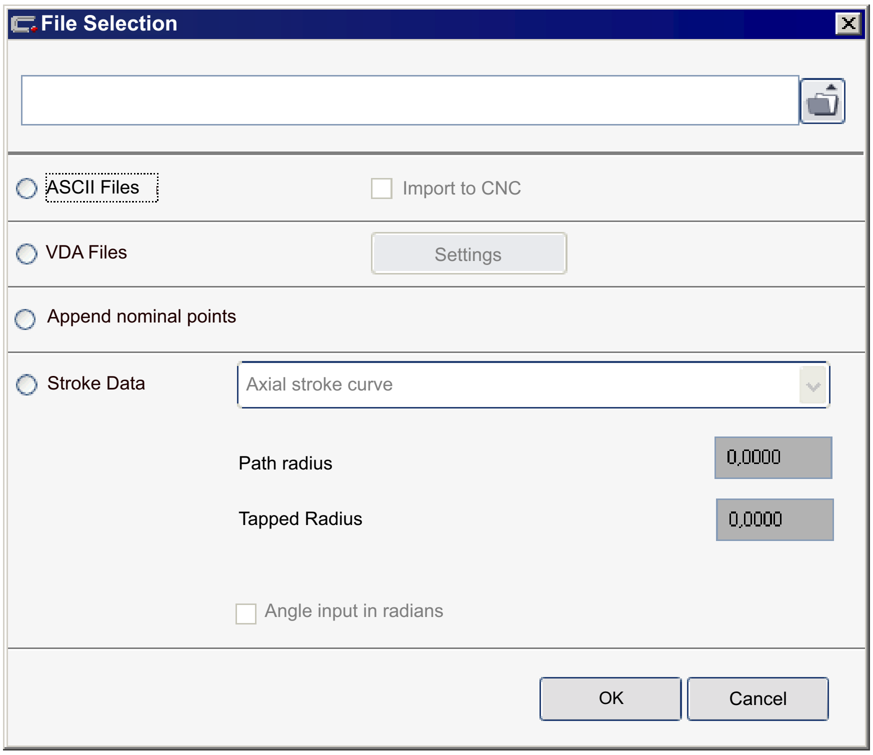
Loading ASCII files for nominal value definition of a curve during a CNC run

CALYPSO enables the reading of an ASCII file for the nominal value definition of the curve and additionally also the curve tolerances during the CNC run. The ASCII file must have a defined format (see ➤ *ASCII file for nominal data definition [➪ 1-12]*) and be available in the defined path.

To load an ASCII file during the CNC run:

1 Make sure you have the curve feature template open and displayed on your screen, and that the chosen coordinate system fits the curve to be imported.

2 Select **Nominal Data** → **Nominal geometry manipulations** → **Read nominal values**.
The **File Selection** dialog box appears on the screen.



3 Select the **ASCII Files** option and tick the **Import to CNC** check box.

4 Enter the path and name of the ASCII file or select it in the file selection dialog.

5 Press **OK** to confirm.
The nominal values of the curve and, if necessary, also its tolerances, will only be determined *during the CNC run* on the basis of the selected file.

Reference: Format of nominal-value files

To ensure that nominal curve values and, if desired, also tolerances and masking data can be loaded correctly by CALYPSO during the CNC run, they must be available in an ASCII file in a defined format.

File format

Every data line of the file contains at least six values, separated by tabs and blanks.

Only the first ten values are interpreted, namely as the three coordinates of the point, the three components of the nominal vector, the lower and upper tolerances, and the masking data.

If fewer than ten values are available, no masking and, if fewer than eight values are available, no tolerances will be imported.

Additionally, the file may contain one or several header lines. These lines will not be evaluated.

NOTE

The nominal vector does not need to be standardized.

Example:

```
XNOM     YNOM     ZNOM    UNOM    VNOM    WNOM    lTol uTol maskEval maskBF
21.5926  0.5645 -2.0000 0.9946 0.1040 0.0000 -0.1 0.1  0         1
21.4906  2.1964 -2.0000 0.9949 0.1008 0.0000 -0.2 0.1  0         1
21.2688  3.7612 -2.0000 0.9846 0.1749 0.0000 -0.2 0.2  0         1
20.9286  5.3328 -2.0000 0.9688 0.2480 0.0000 -0.2 0.2  0         1
20.4721  6.8744 -2.0000 0.9475 0.3196 0.0000 -0.2 0.2  0         1
19.9015  8.3780 -2.0000 0.9210 0.3895 0.0000 -0.2 0.2  0         0
19.2201  9.8346 -2.0000 0.8893 0.4573 0.0000 -0.2 0.1  0         0
18.4322 11.2355 -2.0000 0.8525 0.5277 0.0000 -0.3 0.3  0         0
17.5409 12.5736 -2.0000 0.8111 0.5849 0.0000 -0.3 0.3  0         0
16.5523 13.8422 -2.0000 0.7654 0.6435 0.0000 -0.3 0.2  0         0
15.4728 15.0333 -2.0000 0.7152 0.6990 0.0000 -0.3 0.2  0         0
14.3064 16.1402 -2.0000 0.6606 0.7560 0.0000 -0.3 0.1  0         0
13.0604 17.1559 -2.0000 0.6026 0.7980 0.0000 -0.3 0.2  0         0
11.7418 18.0767 -2.0000 0.5417 0.8406 0.0000 -0.4 0.2  0         0
10.3589 18.8968 -2.0000 0.5442 0.8389 0.0000 -0.4 0.1  0         0
 9.2574 19.6652 -2.0000 0.6607 0.7506 0.0000 -0.4 0.1  0         0
```

Point generator

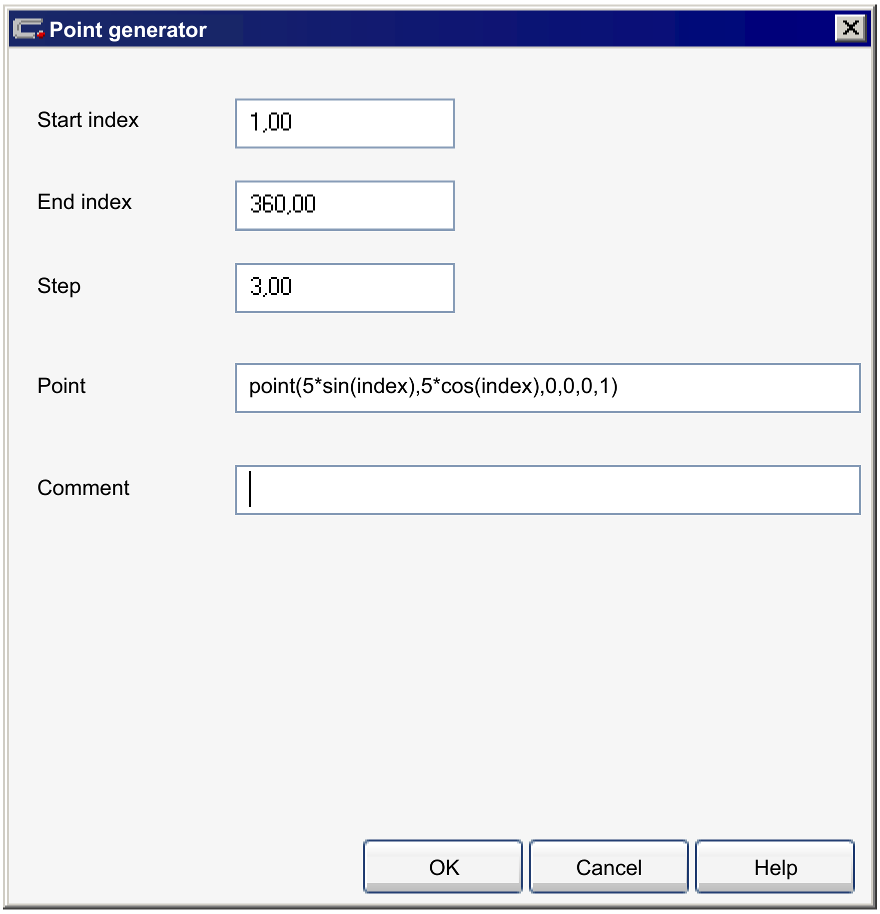
Basics about the point generator

CALYPSO supports the VDA file format and ASCII files with a certain format. If the data you need is in some other file format, you can program formulas to import the information and convert the data to CALYPSO curve data.

You can also use the point generator to freely compute the points of the curve from mathematical formulas.

Alternatively, you may also use PCM commands. You can, for example, create the points of a helical curve by using the `calculatePointOnHelix` PCM function. You can create points on a lateral surface of a cone or a cylinder or on cylindrical or tapered threads by specifying the corresponding parameters.

The point generator has the same characteristics as a loop. You can enter a variable in each input field by right-clicking, opening the Formula window and selecting the variable:



This window is fully described under Point generator in the CALYPSO dialog reference in the Online Help.

– You can use the point generator to define a curve if the mathematical description of the curve is known.

– You can use the point generator to load parameter values into a curve.

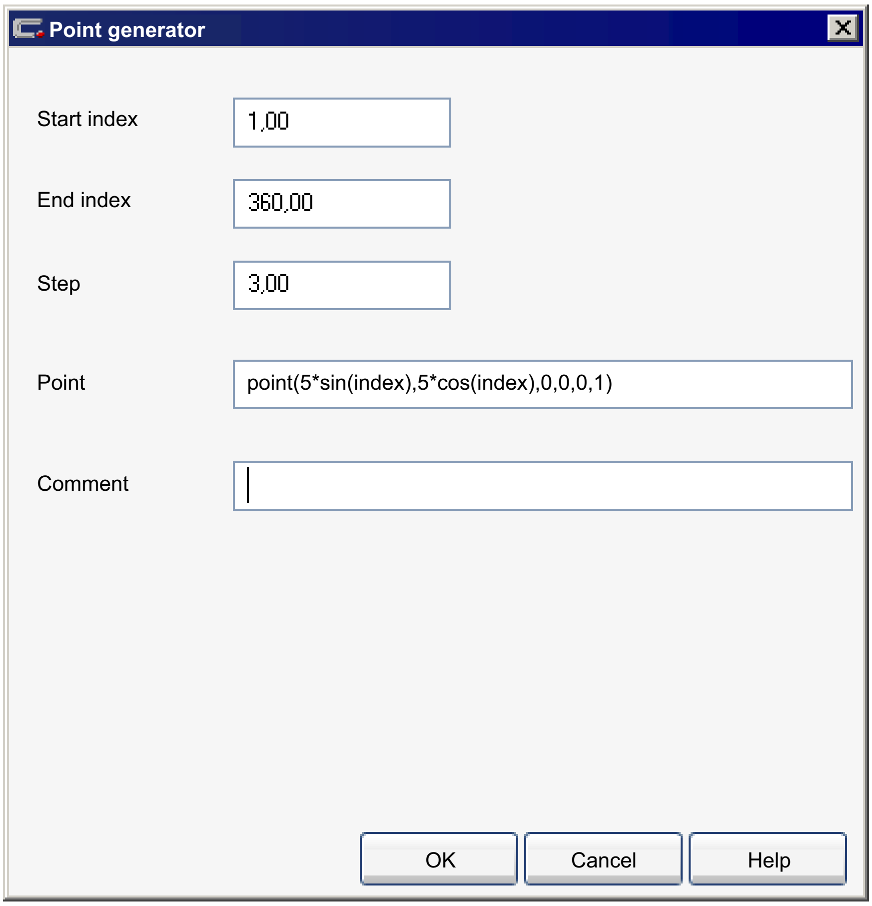
In this process, another point of the curve is defined in each successive step.

Working with the point generator

You can define a curve with the aid of a "point generator". The point generator acts like a loop in which another point on the curve is defined in each successive step. The loop variable used by the point generator is "index".

1 In the definition template of the curve, select **Nominal Data** and then select the **Parameter Data** function.

The Point Generator window is opened.



2 Enter the start index, the end index and the step (increment). Each input box also accepts a formula. If you want to enter a formula, right-click in the box, select **Formula** from the context menu and use the Formula Interface window to enter the formula.

3 In the **Point** box, enter the point to be defined in the respective step.

- If the mathematical description of the curve is known, you can enter it here in the form of a formula.
- If the points are stored in a file, you can enter the name of the file here and import the points. Right-click in the box, select **Formula** from the shortcut menu and use the Formula Interface window to enter the formula or the instruction.

4 You can also enter an optional comment indicating the nature of the curve.
This comment appears only in CALYPSO's table file. You can activate output to the table file by selecting **Resources → Results to File** in the Result To File window.

5 Click **OK** to close the Point Generator window.

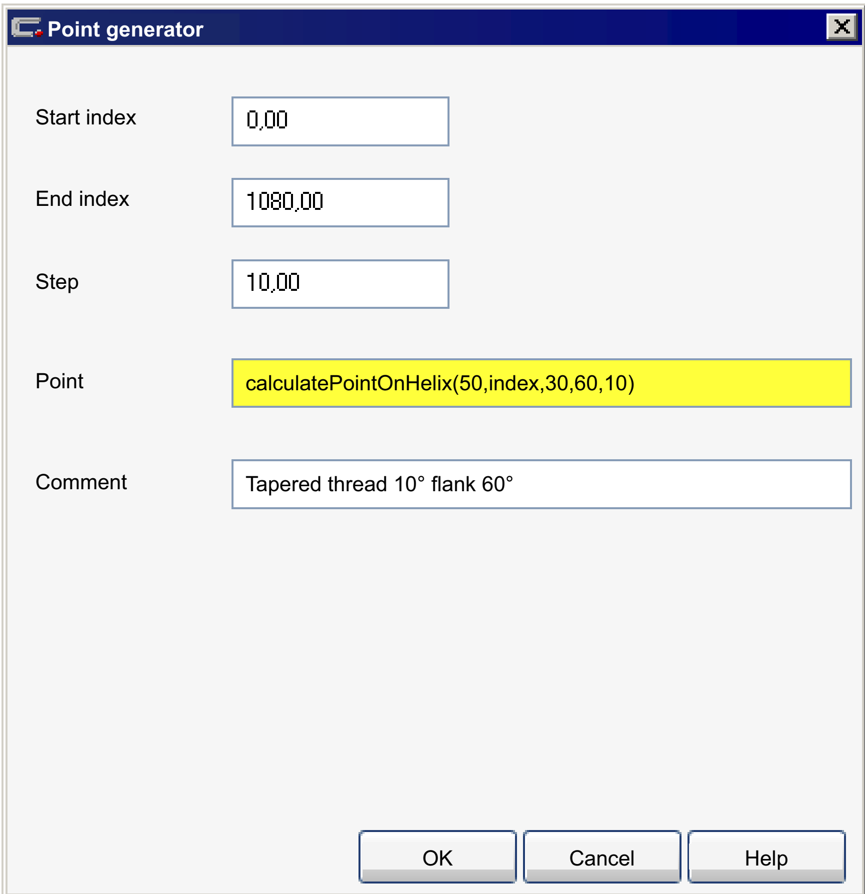
CALYPSO evaluates the points according to your entries and loads them into the definition template. You have now defined the nominals of the curve.

Example: Creating a helical curve with the point generator

When using the point generator and the `calculatePointOnHelix` PCM command, you can create the nominal points of a helical curve. In this example, a tapered thread with a cone angle of 10° and a flank inclination of 60° is created.

1 Create a “3D curve” feature in the measurement plan.

2 In the definition template of the 3D curve, select **Nominal Data** and then select the **Parameter Data** function.
The Point Generator window is opened.



3 Enter the start angle under **Start index**, the end angle under **End index** and the angular distance of the nominal points under **Step**.

4 Click with the right mouse button in the **Point** input field and select **Formula**.

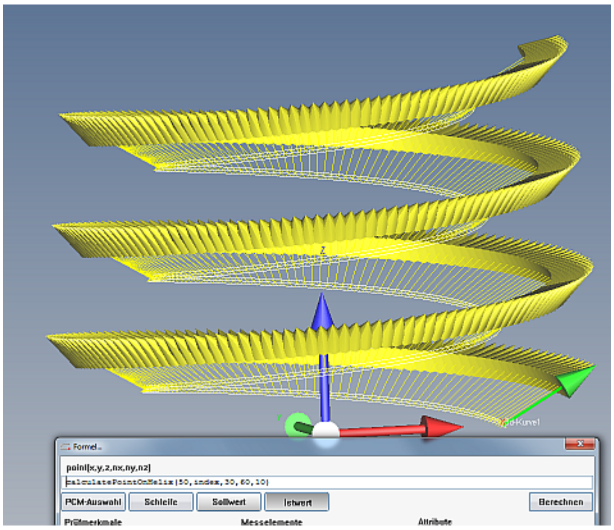
5 Click the **Function** button in the formula window and select **Mathematical Functions → calculatePointOnHelix**.

6 Use the following syntax in the formula field: `calculatePointOnHelix`(*Radius*, `index`, *pitch*, *trapezoid angle*, *cone angle*)

Radius	Radius of the cylinder or initial radius of the cone
Pitch	Slope of the helix path per revolution
Trapezoid angle	Inclination of the nominal normal relative to the cylinder or cone axis in degrees, which, in case of threads, corresponds to the flank angle: =0: Direction of normal parallel to the axis <0: Normal tilted to the inside >0: Normal tilted to the outside =90: Normal perpendicular to the axis
Cone angle	Round cone angle; the entered value must be between 0° and 180°.

7 Click **OK** to close the Point Generator window.

CALYPSO evaluates the points according to your entries and loads them into the definition template. You have now defined the nominals of the curve. The created points are immediately shown in the CAD window.



Symmetry curve from two curves

Two types of symmetry curves

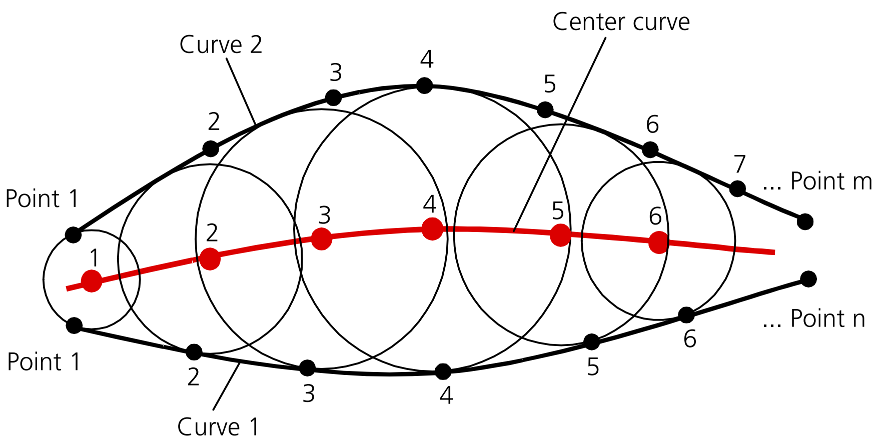
CALYPSO allows you to transfer the center or symmetry curve of two curves as a new feature into the measurement plan. Center curves are required, for example, for turbine blades.

Definition

The center curve is the curve whose points have the same distance from the two defined curves. The mathematical construction consists of the center points of inside circles which touch the two curves on the inside.

NOTE

To obtain a useful result, both curves must have the same orientation, i.e. the beginning and the end of both curves must be on the same side.



Calculation mode

The calculation starts from the first curve and approximately generates on each point the tangential circle to the second curve. The center point of the tangential circle becomes the point of the center curve so that the center curve has the same number of points as the first curve.

By defining the maximum curve distance, you avoid long computing times and, in the case of curves with a large curvature, superfluous intersection points.

Theoretical element / measurable element

You can define the center curve in two different versions:

– as a ➤ *construction [➪ 1-18]* composed of two curves that *cannot* be measured.

– as a ➤ *feature [➪ 1-19]* that can be measured using a measurement strategy.

NOTE

When changing the nominal values of the origin curves, the previously defined values of the center curve are not changed.

Center Curve construction

The “Center Curve” construction is defined via the definition template of the curve. From the **Nominal Data** selection list, select the **Symmetry Curve** menu item.

Tick the **View curve as symmetry curve** check box in the **Symmetry Curve** dialog box, enter the Maximum Curve Distance and determine the original curves as characteristics.

Nominal values

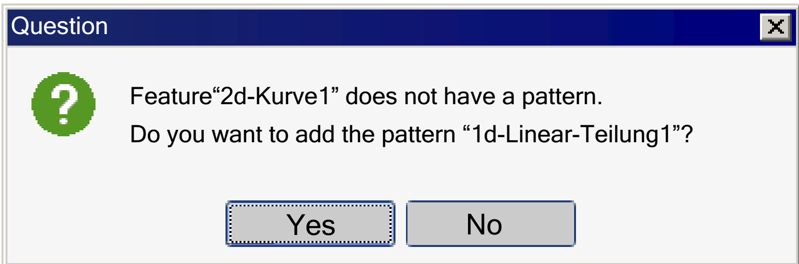
The nominal values of the center curve are calculated from the nominal values of both curves and saved.

NOTE

When changing the nominal values of the origin curves, the previously defined values of the center curve are not changed.

Center Curve and Pattern construction

When creating a Center Curve construction composed of two curves with pattern, the program starts by generating the nominal curve using the first pattern feature of each curve. CALYPSO then asks you whether you want the pattern of the initial curves to be applied to the construction as well.



In this case, the nominal values of the construction are defined according to the pattern defaults. Analogously, the actual values resulting from the measurement of the curves, each with identical pattern index, are combined to form one center curve each.

Actual values

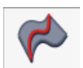
An individual strategy for the “Center Curve” construction does not exist. The two initial curves are measured to determine the actual values. After approximation and stylus radius correction, an actual center curve is calculated from this data. Actual points are formed from this actual center curve and assigned to the nominal points of the symmetry curve.

Thus you can use all evaluations (distance calculations, offset calculations, coordinate systems, form plot, etc.) for the center curve.

Curve form

You can check the “Center Curve” construction for the curve form and output the corresponding plot.

Center Curve feature



The “Center Curve” feature is defined via the definition template of the curve. From the **Nominal Data** selection list, select the **Symmetry Curve** menu item.

Untick the **View curve as symmetry curve** check box in the **Symmetry Curve** dialog box, enter the Maximum Curve Distance and determine the two original curves as characteristics.

The nominal values of the center curve are calculated from the nominal values of both curves and saved.

NOTE
When changing the nominal values of the origin curves, the previously defined values of the center curve are not changed.

You can edit the curve in the same way as other curves. You can also change the calculated nominal values later.

Center Curve and Pattern feature

If you create the center curve from two curves with pattern, the nominal values will be determined using only the first curves of the pattern. If the center curve generated by you is to have a pattern as well, you have to define it yourself.

Actual values

The actual values of the Center Curve feature are obtained by probing the workpiece.

Curve form

You can check the curve form for the center curve and output the corresponding plot.

Creating nominal values of a curve by digitizing

What is digitizing?

What is digitizing?

You use digitization when you do not have nominal data for a curve. Digitization means obtaining the nominal data of a curve by a series of probing operations (i.e. probing an unknown contour).

Procedure

Probing should be performed on a workpiece that can be used as a pattern (master workpiece), in other words a precision-manufactured part. The actual values obtained by probing are subsequently converted into nominal data. In this way, you use a master workpiece to obtain the nominal data for other, identical curves.

You have two options: You can determine the course of the curve by performing individual manual probing operations and you can scan the desired curve.

Digitizing 2D curves

To scan 2D curves, select the “Unknown Cut” method (see ➤ *How to scan an unknown contour using the “Unknown Cut” method [➪ 1-22]*).

Digitizing 3D curves

To scan a 3D curve, you have two options:

– The “3D curve” method – you have to run three scans so that CALYPSO can compute the transverse curvature of the three-dimensional curve (see ➤ *Digitizing 3D curves [⇨ 1-25]*).

– The “3D grid” method – here you enter the corner points of an approximate rectangle which is then scanned by CALYPSO in a meandering style in several paths. (See ➤ *Digitizing 3D curves [⇨ 1-25]*).

– The “Lift curve” method – three scan procedures like for the 3D curve but on a cylinder section (see ➤ *How to scan an unknown contour using the “Lift curve” method [⇨ 1-27]*). As to the lift curve, see ➤ *Basics about curve measurement [⇨ 1-2]*.

– The “Cam groove” method – a scan procedure using the rotary table (see ➤ *Scanning an unknown contour using the “Cam groove” method [⇨ 1-30]*).

Settings for digitization

Stylus radius correction

If the automatic radius correction is not activated in the “Digitizing” mode, you must carry out the radius correction manually. See ➤ *Defining tolerances for a curve [⇨ 1-59]* and ➤ *How to change the nominal points of a curve [⇨ 1-48]*, step 3.

Immersion depth

The derivative action of the stylus, called “immersion depth”, serves to avoid scanning “in the air” (outside the object) when scanning an unknown contour. The default value for the immersion depth of 0.3 mm may be too high for very flat objects so that there is a risk of touching the material. For such cases, you can set the **Immersion Depth for Scanning Unknown Contour** to “Middle” or “Low” in the Measurement Plan Editor Features.

Smoothing nominal points

In case of a too strong dispersion of the nominal points gained by digitizing, running of the CMM and the rotary table will not be sufficiently smooth. In order to avoid this effect, you may smooth the nominal points by means of the low-pass filtering (➤ *How to smooth digitized nominal data of the curve [⇨ 1-52]*).

Optical sensor

You can also obtain the nominal values of the curve by **scanning unknown contour** using an optical sensor. The current camera and light parameters are set in the **Segment** dialog box on the **Optics** index card.

Generating the nominal values of a curve by manual probing

Digitizing a curve by single probing

1 Open the definition template of a new curve or a curve without nominal values.

2 In the **Nominal Data** selection list, select **Additional** → **Digitizing On**.
The place of the **Nominal Data** selection list is now taken by a red button labeled **Digitizing Off**.

3 In the case of a 2D curve, tick the **Stylus Correction** check box to correct the measured points by the stylus tip radius.
The normal vectors of a 3D curve are generally not located in a plane. The nominal values gained after digitizing must then be corrected manually.

4 Click the **Open/Closed Curve** button to select an open curve.

5 If you want to project the nominal points onto a plane, select a projection plane from the **Projection** selection list.

6 Now start recording the measured points on the workpiece.
Every probing point is shown directly in the definition template and in the CAD window. As soon as you have probed three points, CALYPSO will calculate the curve. The entire curve is recalculated for every new point you probe.

7 As soon as you have defined the curve by probing, click the **Digitizing Off** button.

8 Click **OK** to save the values and close the definition template.

You have now determined the nominal values for an unknown curve. Note that these values correspond to the stylus center. To correct the stylus radius, please read ➤ *Working with the nominal curve values [⇨ 1-34]*.

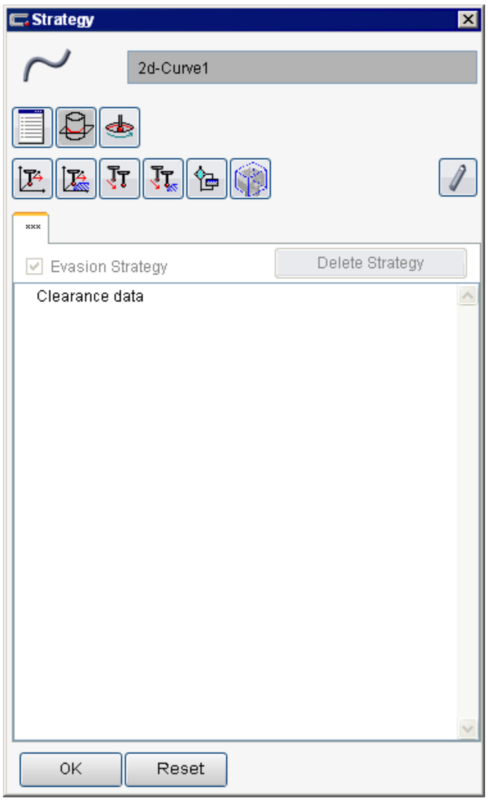
Scanning an unknown contour using the “Unknown Cut” method

1 Open the definition template of a new 2D curve or a 2D curve without nominal values.

2 In the **Nominal Data** selection list, select **Additional** → **Digitizing On**.
The place of the **Nominal Data** selection list is now taken by a red button labeled **Digitizing Off**.

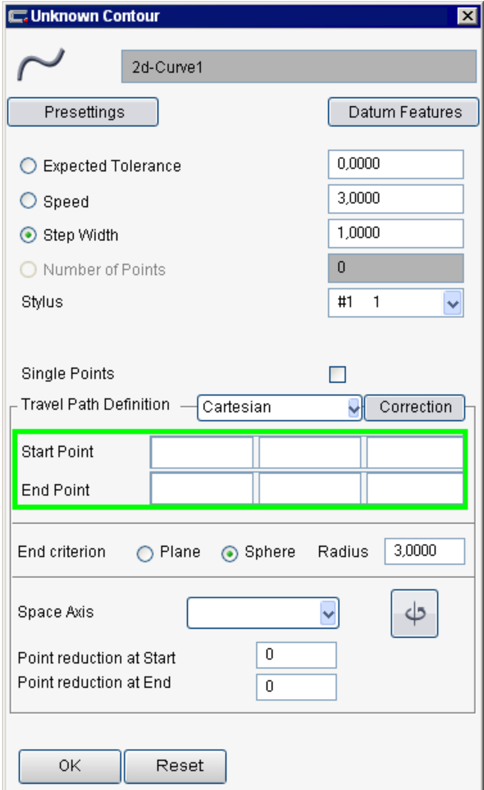
3 Click the **Strategy** button.

The Strategy window is opened.



4 Select the “Unknown Cut” method to measure the curve as a free planar section.
The **Unknown contour 1** entry appears in the dialog box.

5 Double-click the entry.
The Segment window is opened.



6 Enter the parameters. For the start and the end points, you can choose the coordinate system type.

- CALYPSO recognizes the probing direction by roughly probing the start point. The coordinates of the probing will be entered in the fields for the start point.
- If necessary, edit the coordinates entered in the **Start Point** field.
- Enter the coordinates of the end point in the **End Point** field, or else probe the workpiece to define the end point.
- In the **Space Axis** selection list, select a space axis to which the scanning plane is to be perpendicular.

- If necessary, click the button to change the **Direction**.

7 Enter a speed for the CMM in the **Speed** field or select the requisite accuracy.

8 Enter a pitch between points in the **Step Width** field or define the number of points.
Once all the parameters have been defined in full, the red **Execute** button appears and you can click it to start scanning.

9 Check that the CMM is ready to move and that there is no risk of collision. Position the stylus in front of the start point.

10 Click the red **Execute** button to start scanning the unknown contour.

The CMM starts scanning the contour.

Digitizing 3D curves

When you digitize a 2D curve using the unknown cut method, the normal vectors are calculated by CALYPSO – by definition, they are in the plane of the cut.

A single digitization process is not enough to probe a 3D curve with transverse curvatures on the workpiece, because in this case the orientation of the nominal vectors is unknown.

When you digitize a 3D curve, therefore, you have to scan an unknown contour in such a way as to obtain three cuts – each a certain distance "above" and "below" the 3D curve as such.

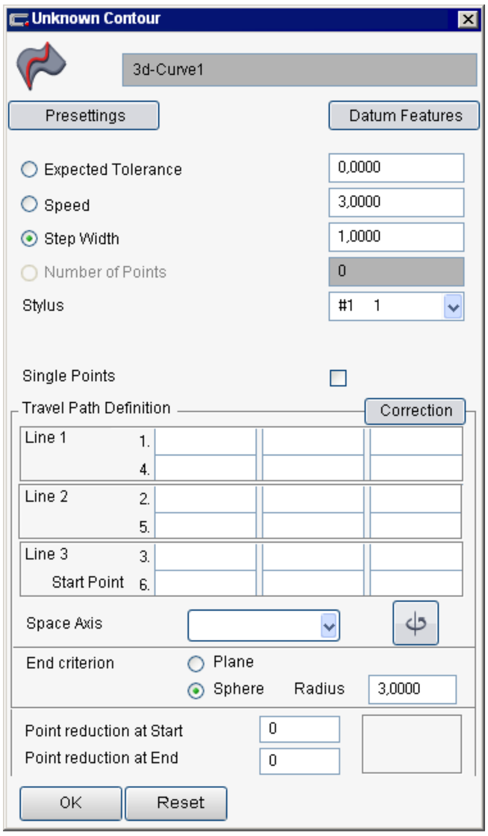
CALYPSO then uses this information to compute the nominal vectors and thus the transverse curvature of the 3D curve.

Start the process by clicking the **Digitize 3D Curve** button in the Strategy window for 3D curves.

NOTE

If the feature does not have any nominal values, you will have to select the **Digitizing On** item under **Nominal Data** before you open the Strategy window.

In the **Segment** dialog box, go to **Travel Path Definition** and define the three paths, then click **Execute** to start digitization.



Path specification by probing

To specify the start and end points of the three paths by probing with the CMM, first probe the three start points of the paths (points 1 to 3), then probe the three end points of the paths (points 4 to 6).

Directions during travel

When traveling along the three paths, the CMM moves in a meandering style: the direction of movement alternates from one path to the next.

Digitizing 3D curve in area

Using the 3D Curve feature, you can also digitize a three-dimensional curve over an entire area. CALYPSO employs the technique of probing surfaces along intersection lines to effect a meander-formed probing of an entire surface area and in this way creates a 3D curve.

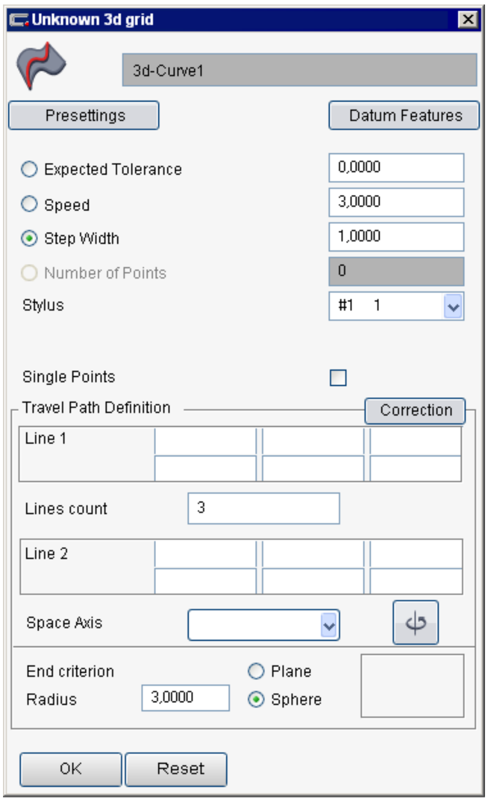
It will be necessary here to enter the four corner points of the surface that is to be digitized. These four points must more or less form a rectangle.

Start the process by clicking the **Digitize 3D Grid** button in the Strategy window for 3D curves.

NOTE

If the feature does not have any nominal values, you will have to select the **Digitizing On** item under **Nominal Data** before you open the Strategy window.

In the **Segment** window, go to **Travel Path Definition** and define the number of paths, then click **Execute** to start digitization.



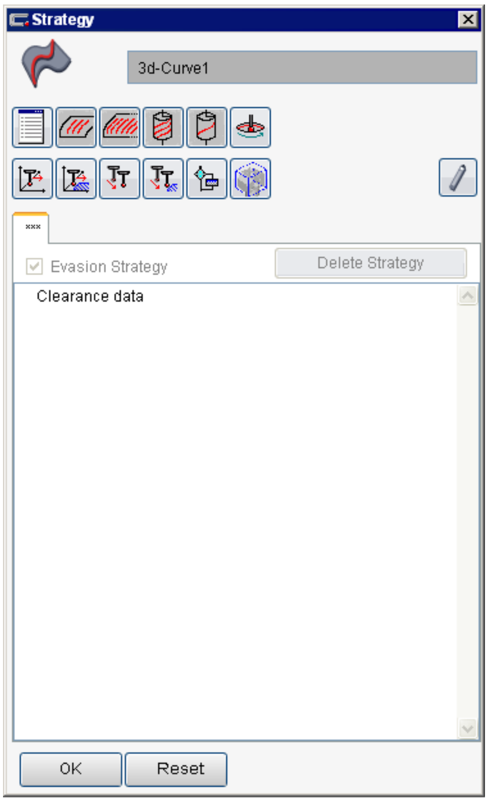
Directions during travel When traveling along the paths, the CMM moves in a meandering style: the direction of movement alternates from one path to the next.

Scanning an unknown contour using the “Lift curve” method

1 Open the definition template of a new 3D curve or a 3D curve without nominal values.

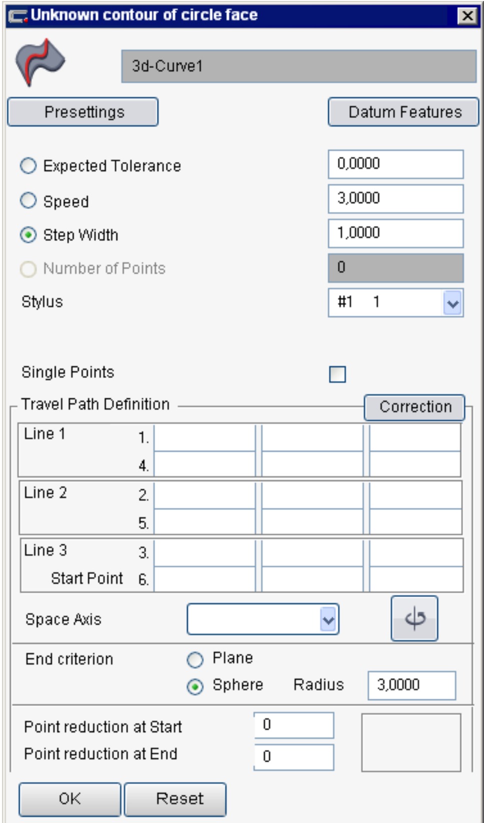
2 In the **Nominal Data** selection list, select the **Digitizing On** command.
The place of the **Nominal Data** selection list is now taken by a red button labeled **Digitizing Off**.

3 Click **Strategy**.
The Strategy dialog box is opened.



4 Select the “Lift curve” method in order to measure the curve as a lift curve along an annular surface (cylinder circumference).
The **Unknown contour of circle face** entry appears in the dialog box.

5 Double-click the **Unknown contour of circle face** entry.
The Segment window appears on the screen.



To specify the start and end points of the three paths by probing with the CMM, first probe the three start points of the paths (points 1 to 3), then probe the three end points of the paths (points 4 to 6).
Note: “Start point” indicates that the CMM will start scanning at the last end point.
Note: Check the entered values and bear in mind that the lift curve is probed on an area along the cylinder section, so that the specified radius must be correspondingly larger than the radius of the reference feature.
The center must also be at the central point of the lift curve. Usually, the automatically entered center is in the center of a base area of the reference feature.

6 Enter a speed for the CMM in the **Speed** field or select the requisite accuracy.

7 Enter a pitch between points in the **Step Width** field or define the number of points.
Once all the parameters have been defined in full, the **Execute** button appears and you can click it to start scanning.

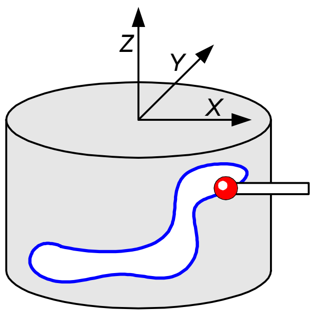
8 Check that the CMM is ready to move and that there is no risk of collision.

9 Click the red **Execute** button to start scanning the unknown contour.

The CMM starts scanning the contour.

Scanning an unknown contour using the “Cam groove” method

CALYPSO allows you to scan a cam groove as an unknown contour. For this procedure, you use the rotary table.



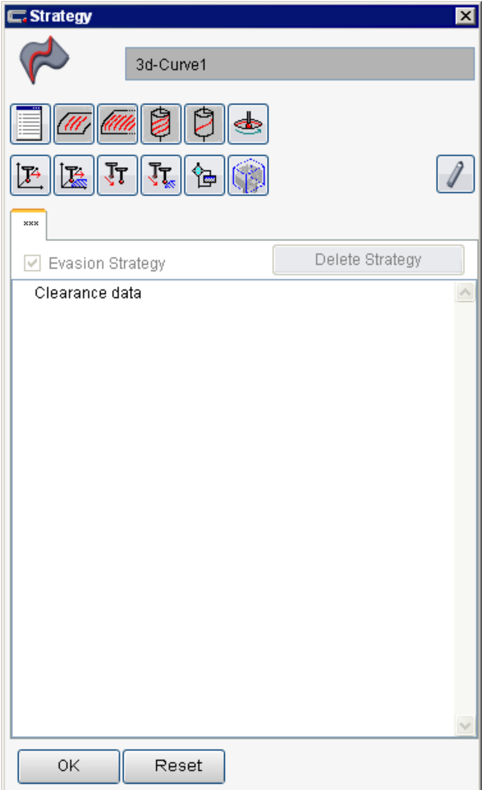
Conditions

- The cylinder with the cam groove to be scanned must be centrically fixed on the rotary table.
- The rotary table axis has been chosen as the Z axis of the base alignment.

1 Open the definition template of a new 3D curve or a 3D curve without nominal values.

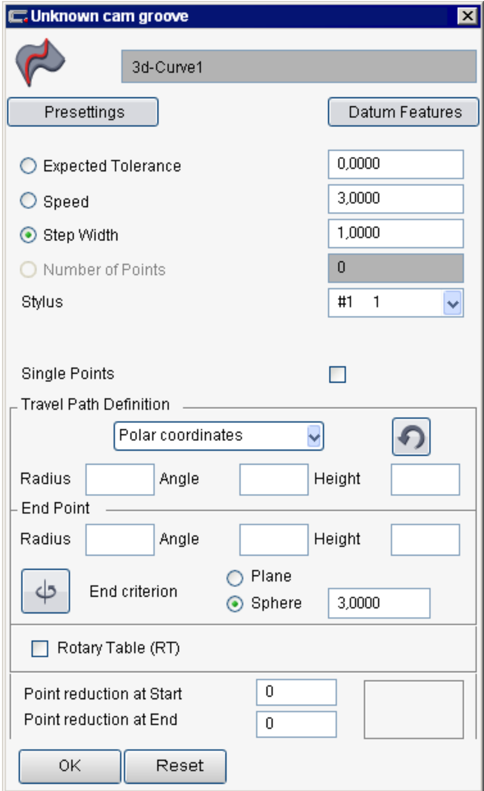
2 In the **Nominal Data** selection list, select the **Digitizing On** command.
The place of the **Nominal Data** selection list is now taken by a red button labeled **Digitizing Off**.

3 Click **Strategy**.
The Strategy dialog box is opened.



4 Select the “Cam groove” method in order to measure the curve as a groove along an annular surface (cylinder circumference).
The **Unknown cam groove** entry appears in the dialog box.

5 Double-click the **Unknown cam groove** entry.
The Segment window appears on the screen.



6 Enter a speed for the CMM in the **Speed** field or select the requisite accuracy.

7 Enter a pitch between points in the **Step Width** field or define the number of points.
You can define the radius. If you enter nothing, the radius of the first probing point will be used.

8 Tick the **Rotary Table** check box and select **Cylindrical Coordinates**.

9 Enter **Radius** / **Angle** / **Height** of the cam groove.
Once all the parameters have been defined in full, the **Execute** button appears and you can click it to start scanning.

10 Check that the CMM is ready to move and that there is no risk of collision.

11 Click the red **Execute** button to start scanning the unknown cam groove.

The CMM starts scanning the cam groove.

Adopting nominal data of the curve from the CAD model

You can also adopt the nominal data for a curve from the CAD model into the CAD window.

1 Select **CAD → Creating features**.
The **Create feature** window appears on the screen.

2 To generate a 2D curve: select a line in the CAD model.

3 Under **Points**, enter the desired number of points and click the symbol for the curve.
The 2D curve is generated and entered into the measurement plan. This can take a few seconds to complete.
The vector normal to the plane of intersection is automatically calculated for each point on a 2D curve.

4 To generate a 3D curve: Switch the CAD model to rendered mode and select an area on which the curve should be positioned.
All “edges” you select subsequently will refer to this “face”, until you select a different “face”.

5 Then change to normal mode and select one or more “edges” (with the Ctrl key).

6 Under **Points**, enter the desired number of points and click the symbol for the curve.
The 3D curve is generated and entered into the measurement plan. This can take a few seconds to complete. The curve's vectors will be taken from the CAD surface you clicked:

- For a “cylindrical face”, the vectors are calculated perpendicular to the cylinder axis.
- For a “conical face”, the vectors are calculated perpendicular to the cone axis rotated around the opening angle (from the plane).
- For a “planar edge”, the vectors are positioned parallel to the plane vector.

7 When the process is completed, confirm by clicking **Close**.

You have now transferred the curve defined in the CAD model to your measurement plan. You can edit the curve in the usual way.

Working with the nominal curve values

Overview: Working with the nominal curve values

If the nominal values for a curve have already been determined, you have the following possibilities for editing the nominal values:

– Modifying nominals. Here you can move the curve in various ways, including rotating and shifting.

– ➤ *Editing the single points of the nominals list [➪ 1-42]*

– ➤ *Considering material thickness (sheet thickness) in the nominal values [➪ 1-43]*

– ➤ *Adopting deviations of a reference curve [➪ 1-44]*

– ➤ *Adding nominal points of another curve [➪ 1-46]*

– ➤ *Correcting nominal values by an offset [➪ 1-47]*

– ➤ *Checking nominal vectors [➪ 1-48]*

– ➤ *Changing nominal vectors [➪ 1-48]*

– ➤ *Creating new nominal vectors of a 3D curve [➪ 1-49]*

– ➤ *Changing the approach direction vector of a 3D curve [➪ 1-51]*

– ➤ *Smoothing nominal points [➪ 1-52]* gained by digitizing

Changing the nominal points of a curve

You can transform the nominal values of a curve in different ways.

This may be necessary for the following applications:

– You have read a curve from a file and want to move it to a certain position on your workpiece.

– You have obtained a 3D curve by digitizing and you want to convert it into a lift curve.

Note: You *must* transform the nominal values if you want to perform stylus radius correction after digitizing a curve.

Possibilities for changing

You can change the nominal points as follows:

– ➤ *Changing nominal points in vector direction [➪ 1-36]*

– ➤ *Changing the number of nominal points [➪ 1-38]*

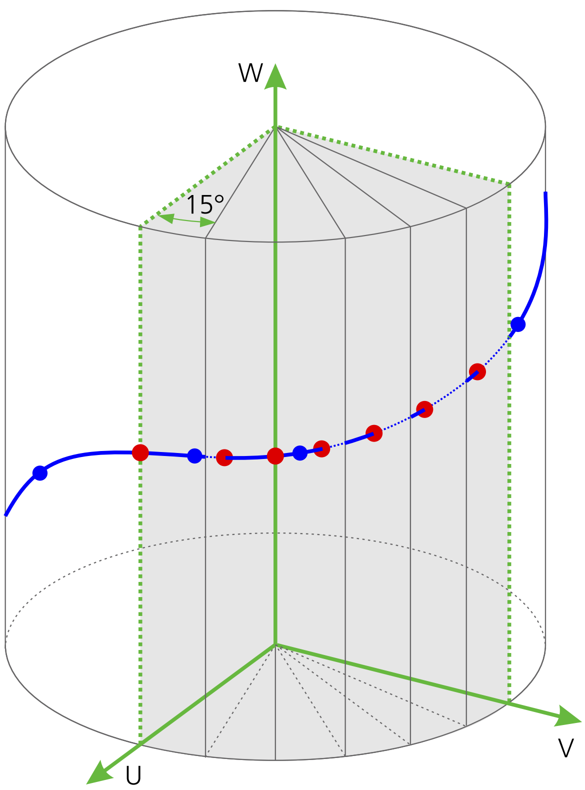
– ➤ *Changing nominal points in the coordinate axis direction [➪ 1-40]*

Note: If you change the number of points and confirm with **OK**, you will create new nominal points for the curve. The original curve cannot be restored afterwards. For this reason, it is important that you use the Simulation function to check the result beforehand. Only use this function with great care and after careful thought.

Nominal points on a curve with preset angle

You can define new nominal points with preset angular distance for 2D and 3D curves. For the angle specifications, you have to define the reference for the conversion of the cartesian coordinates to polar coordinates.

This reference may be one of the axes of the base alignment or the local feature alignment of a reference feature.



The generation of the new nominal points begins after the specified start angle or start point. A nominal point is generated on the curve at each intersection point of the curve with one of the angle planes. The existing nominal points are no longer required. The curve will be redefined.

When selecting a start angle of 0°, the first nominal point is located on the plane intersecting the U axis, with a start angle of 90°, the first nominal point is on the plane intersecting the V axis of the datum reference frame.

Curve segments

New nominal points can be generated for the entire curve and also for defined curve segments.

To do so, you have to define a start and end angle or a start and end point for the corresponding curve segment. In this area, the nominal points will be generated at your predefined angular distance. The curve will be redefined exclusively from the new nominal points defined in this way.

Changing nominal points in vector direction

You can change the nominal points of a curve by moving it in vector direction.

The curve can be

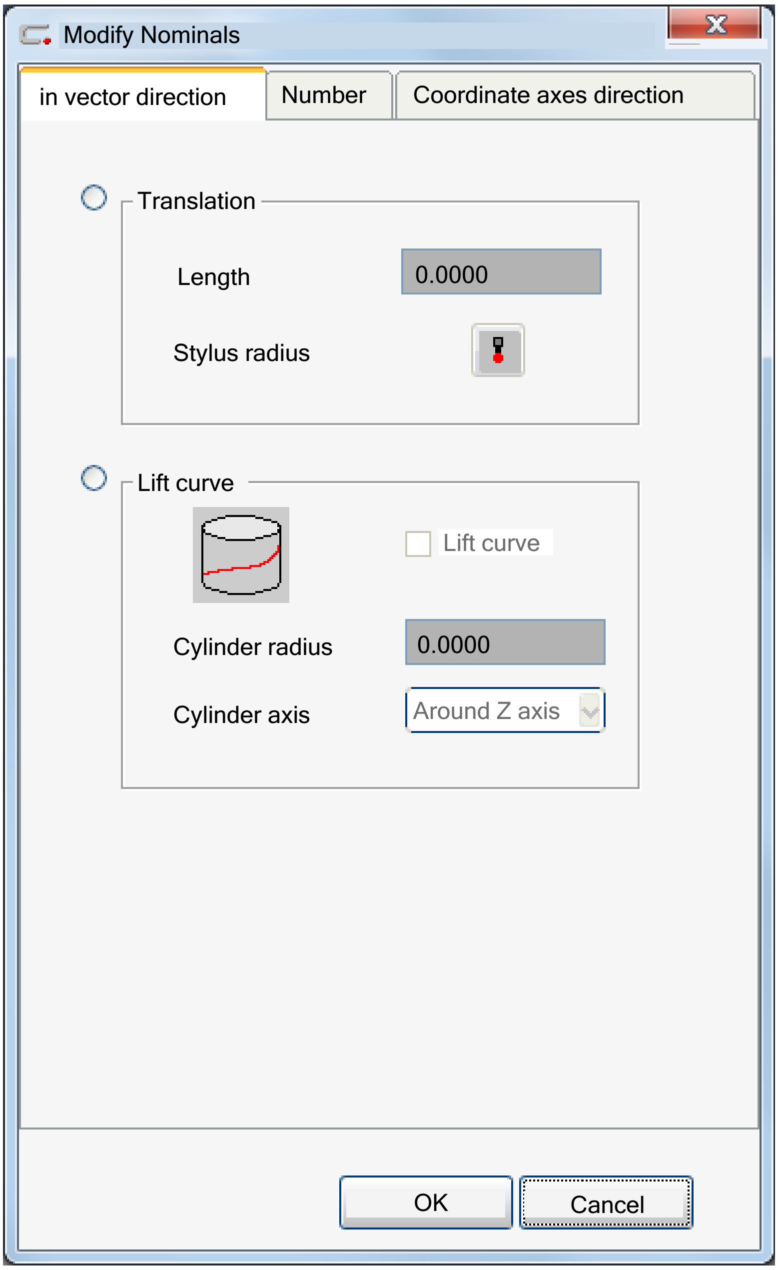
– moved in direction of the normal vectors (offset curve, especially for correcting stylus radius)

– projected perpendicularly to the cylinder axis onto the cylinder section, in order to get a lift curve

1 Open the definition template of the curve.

2 Select **Nominal Data** → **Nominal geometry manipulations** → **Modify Nominals**.
The Modify Nominals window appears on the screen.

3 To move the curve points, select the **in vector direction** tab.



4 To move the curve in normal direction, activate the **Translation** option and under **Length**, enter the value by which you wish to move the curve.

5 If you have obtained the measured values of the curve by means of digitization, click the **Stylus radius** button.
The radius of the stylus used is automatically entered in the input field.

6 If you want to project the points of a curve onto a cylinder section in order to obtain a lift curve, activate the **Lift curve** option and enter the radius and axis of the cylinder.
To mark the curve as a lift curve, tick the **Lift curve** check box.

7 Click **OK** to confirm.

The nominal points are modified immediately.

Note: Please note that the nominal points of the curve are then recalculated internally. Applying this function again may accidentally change the form of the curve.

Changing the number of points

You can change the number of nominal points of a curve.

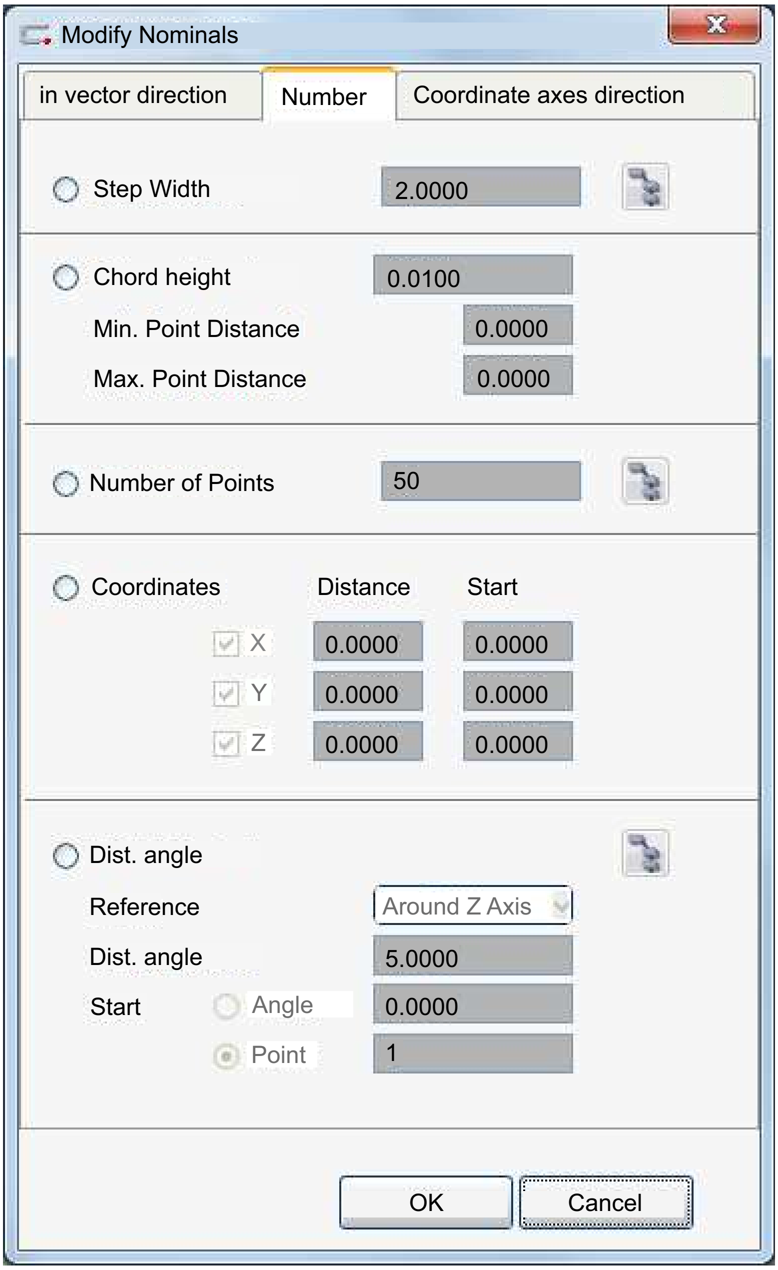
This may be useful for a very large number of points, which would lead to very slow probing.

The modification of the nominal points regarding the step distance, the number of points and the angular distance can also be specified for defined curve segments.

1 Open the definition template of the curve.

2 Select **Nominal Data** → **Nominal geometry manipulations** → **Modify Nominals**.
The Modify Nominals window appears on the screen.

3 To modify the number of nominal points, select the **Number** tab.



4 Activate the **Step Width**, **Chord height**, **Number of Points**, **Coordinates** or **Dist. angle** option and define the corresponding parameters for the whole curve.

- If, with activated **Step Width**, **Number of Points** or **Dist. angle** option, you do not want to define the same parameters for the entire curve but different parameters for individual curve segments, open the corresponding dialog box.
- Define the segments.
- Click **OK** to confirm.

5 Click **OK** to confirm.

The nominal points are modified immediately.

Note: Please note that the nominal points of the curve are then recalculated internally. Applying this function again may accidentally change the form of the curve.

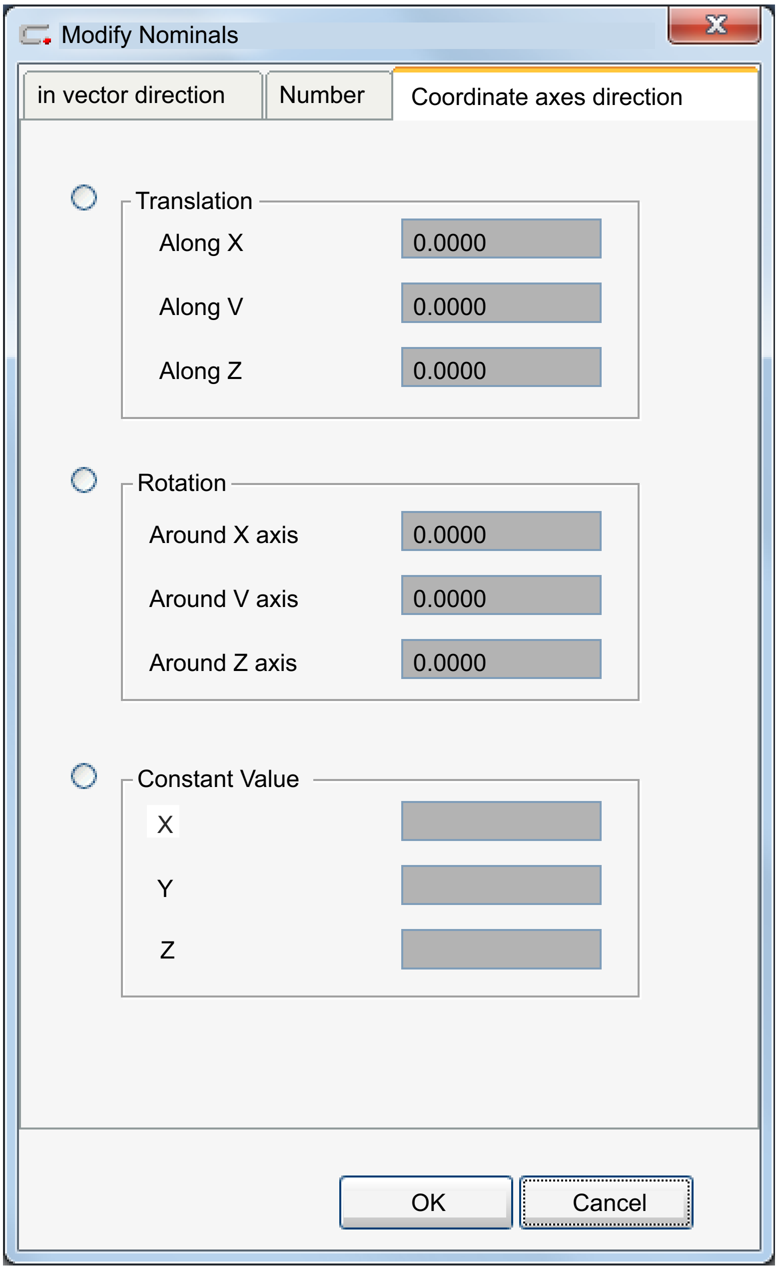
Changing nominal points in the coordinate axis direction

You can move the nominal points of a curve in the direction of the coordinate axis or rotate them around the coordinate axis.

1 Open the definition template of the curve.

2 Select **Nominal Data → Nominal geometry manipulations → Modify Nominals**.
The Modify Nominals window appears on the screen.

3 To move or rotate the curve in the direction of the coordinate axes, select the **Coordinate axes direction** tab.



4 Enter the values by which you wish to mode and/or rotate the curve in the **Translation** or **Rotation** area.

5 If you wish to set a fixed value for individual coordinates of all curve points, define a value under **Constant Value**.

6 Click **OK** to confirm.

The nominal points are modified immediately.

Note: Please note that the nominal points of the curve are then recalculated internally. Applying this function again may accidentally change the form of the curve.

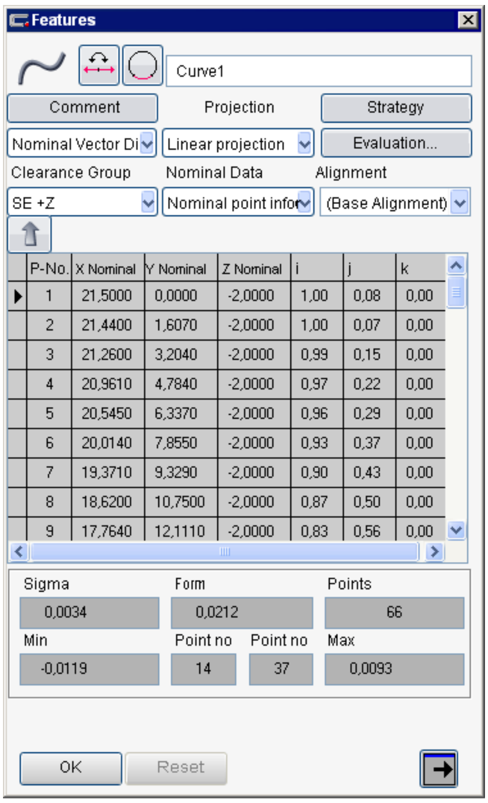
Working with the nominals list

Using the Nominal Data option in the Features window, you edit all curve points in common, whereas, in the **Nominals list**, you edit the individual curve points:

- Showing points in the CAD model
- Deleting points
- Editing point coordinates in the **Point** window
- Adding a new single point
- Copying a single point and insert it at another place
- Changing the order of two consecutive points
- Inverting all vectors (exchanging inside and outside)

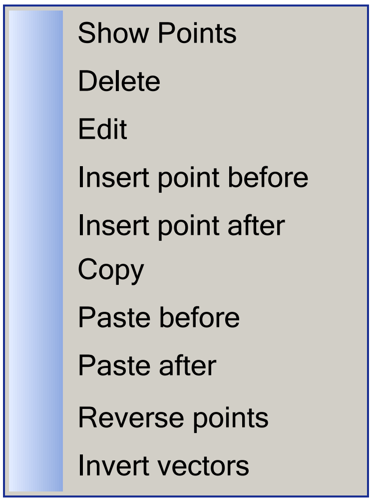
Editing the single points of the nominals list

1 Open the definition template of the curve and click the Change to Point List button.
The nominal points list is opened.



2 Highlight the desired single points using the mouse; multiple selection is possible for several consecutive points.
Triangles appear in the first column of the list.

3 Open the context menu.



4 Select an entry to edit the single points.

Considering material thickness in nominal values

Usually, material thicknesses of less than 0.5 mm are not considered in drawings. The surface or curve is drawn without thickness and the “material thickness” attribute is assigned.

With CALYPSO, the nominal values used for controlling can be temporarily shifted by the material thickness, thus taking the sheet thickness into account.

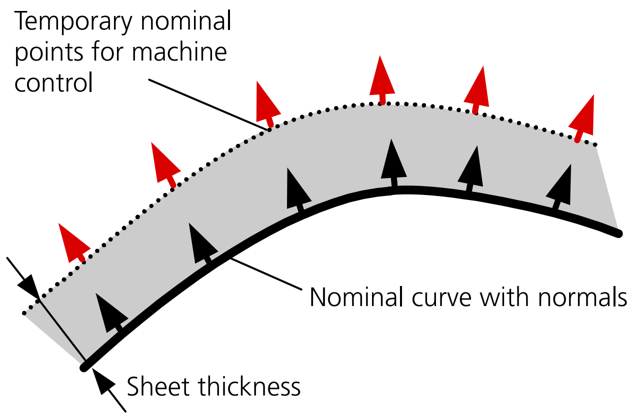
NOTE

The errors are calculated and output referenced to the original nominal points of the curve.

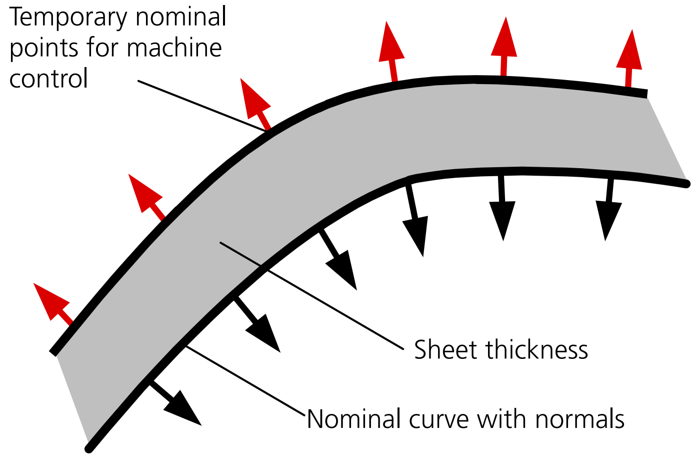
Positive or negative values

You have two options of defining the material thickness:

– If you enter the sheet thickness as a positive dimension, the nominal points are moved temporarily by the sheet thickness in the direction of the nominal vectors. The control uses these values for scanning according to nominal data.



– If you enter the sheet thickness as a negative measure, the nominal points are temporarily moved by the sheet thickness counter to the nominal vectors and the nominal vectors are temporarily inverted.



You can, for example, use this procedure if you do not want to measure on the lower side of the material. You measure on the upper side and obtain actual values as if measuring on the lower side.

When using this function, it may be possible that the curve cannot be reached anymore without collision. In this case, you should use intermediate points.

Adopting the deviations of a reference curve

In CALYPSO, you can adopt the actual deviations of a measured 2D curve (the reference curve) for the nominal values of the current 2D curve. This makes sense if the workpiece has a number of curved lines of the same shape at different positions.

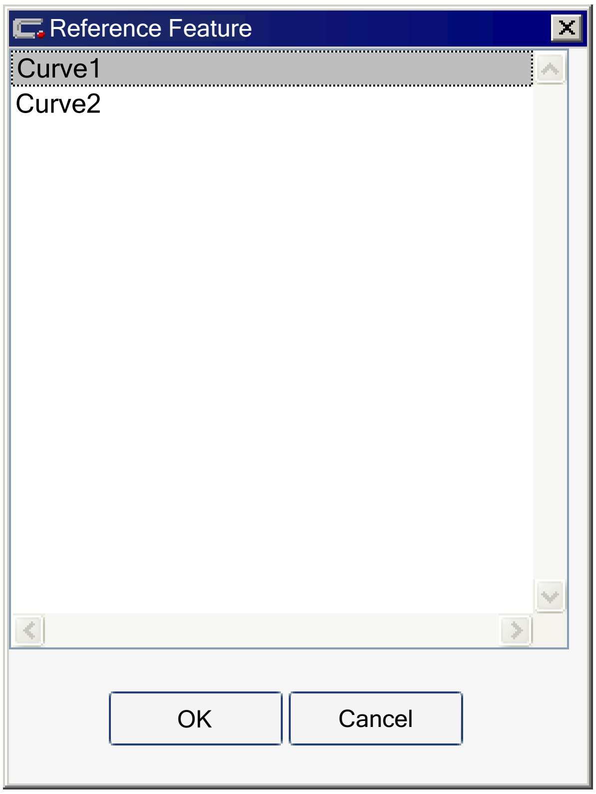
This function has been conceived for use in conjunction with the **Nominal Data → Parameter Data** function (see ➤ *Basics about the point generator [⇨ 1-13]*). Here, you use the point generator to create a parallel group of curves which are then measured one after the other.

As an example, there are two curves on the same workpiece, curve 2 being shifted exactly 100 mm from curve 1 in Y. If it turns out on measuring curve 1 that the actual deviations always lie in a certain range (e.g. approx. 0.5 mm), it can be assumed that the results also deviate by this value (0.5 mm) for curve 2. In order to avoid a collision, you can shift the nominal points of curve 2 by 0.5 mm.

Another example of the application would be to use a single parameter file for all different sizes of workpieces of a certain line of products (e.g. monitors). The required curves are created from a file with only one offset for the workpiece size. In this way, the entire line of products can be measured using one file.

1 Open the definition template of the 2D curve to which the deviation of a reference curve is to be added.

2 Select **Nominal Data → Additional → Move parallel curve**. You can see the **Reference Feature** window in which all defined 2D curves are listed.



3 Highlight the name of the curve you want to use as reference curve.

If no values have yet been measured for this curve, a message is issued.

4 Click the **OK** button.

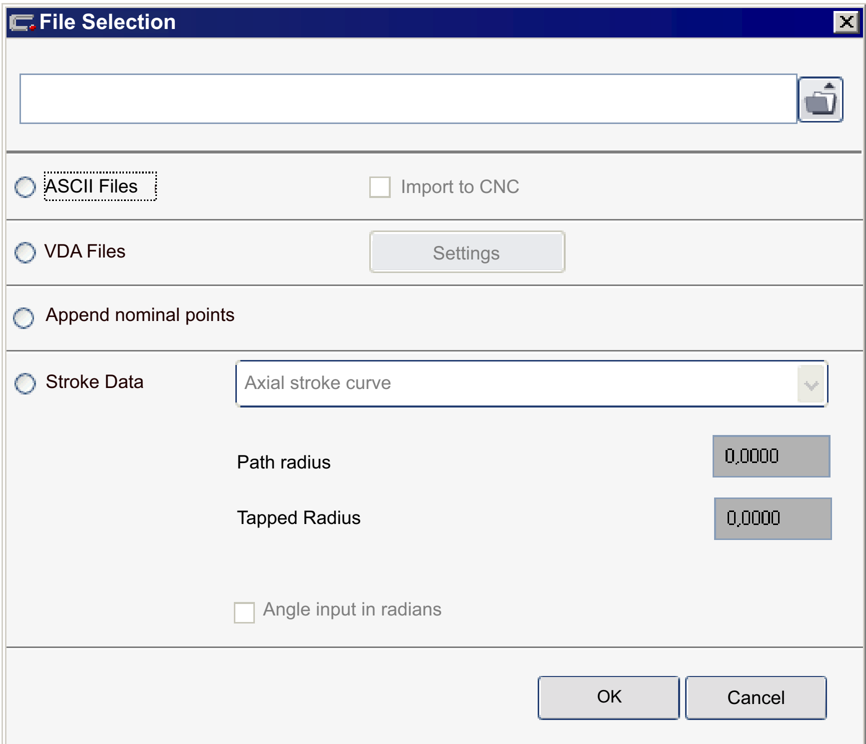
CALYPSO will convert the deviations of the reference curve to the current curve immediately.

Adding nominal points of a curve to the current curve

You can complement the nominal points of a curve by the nominal points of a different curve. This makes it possible to put several curves together to one single curve.

1 Open the definition template of the curve.

2 Select **Nominal Data → Nominal geometry manipulations → Read nominal values**.
The **File Selection** window appears on the screen.



3 Select the **Append nominal points** option and click the **Curve selection** icon.
The **Reference Feature** window, containing a list of all curves of the measurement plan, is opened.

4 Select the desired curve and confirm with **OK**.

The nominal points of the selected curve are now added to the nominal points of the current curve.

Correcting nominal curve values by an offset

You can compensate the known nominal data or workpiece errors by correcting the nominal data by an offset value. The offset is calculated from the determined deviations (distance between point and spline) of the curve values and added to each nominal curve value.

You have the following options for determining the offset:

– Average

– Maximum Value

– Minimum Value

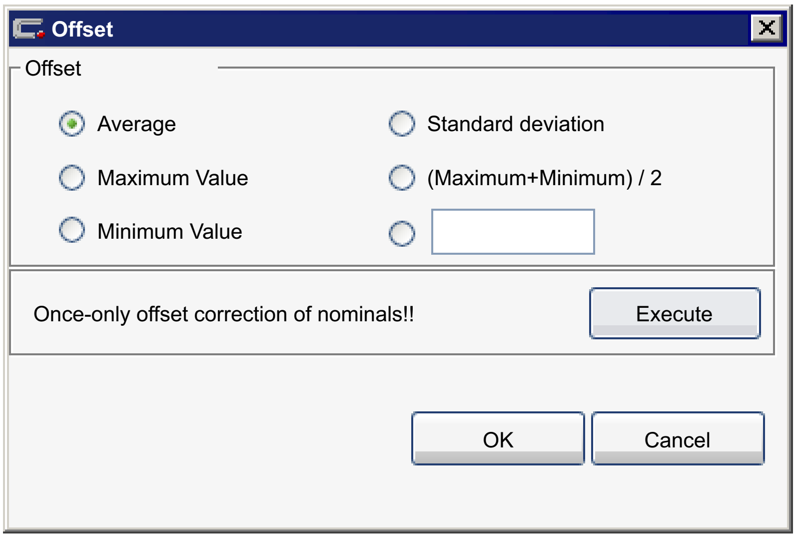
– Standard deviation

– Arithmetic average calculated from the largest and shortest distance

– Any entry

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box is opened.

2 Under **Offset**, tick the **Offset** check box and click **Settings**.
The **Offset** window for selecting the offset calculation will be displayed.



3 Select the mode of offset calculation and click **Execute**.
Note: By clicking again **Execute**, the offset calculation (this time with the newly calculated values!) and the addition will be repeated.

4 Close the **Offset** window with **Cancel**.
Note: If you do not close the window with **Cancel** but with **OK**, the calculated offset will be added to the measuring results of the curve.

5 Close the **Evaluation** window with **OK**.

The selected offset is now added to all nominal curve values.

Checking the nominal vectors of a curve

In CALYPSO, the curve is only defined by points and directions. Therefore, after defining the curves nominal data, you should check two important things concerning the nominal vectors:

– Has a nominal vector been defined for each curve point?

  If there are no nominal vectors for some (or all) points, you can enter them manually (see How to change the nominal vectors of the curve).

– Is the direction of the nominal vectors OK?

  The nominal vectors must always point away from the part. A nominal vector must never point *into* the material of the part.

If a nominal vector has the wrong direction, this will invariably result in a collision because the approach direction of the CMM will be wrong.

To check the nominal vectors, you have the following options:

– You can check the vectors in the CAD window – this is the quickest and most reliable way. You can display each curve point with its nominal vector (refer to ➤ *The context menu for curves in the CAD window [➪ 1-79]*).

– You can check the nominal vectors using the direction components in the definition template.

If you just need to change the directions of all nominal vectors at once, you can also use the **Change Direction** button.

Changing the nominal vectors of the curve

Each curve point is determined by three point coordinates and a normal vector. For each curve you can use in CALYPSO, the normal vectors of the nominal points are in the same direction (see ➤ *Basics about curve measurement [➪ 1-2]*).

It is possible to modify the nominal vectors as follows:

– by perpendicularly aligning to the axis of a reference feature

– by aligning parallel to the axis of a reference feature

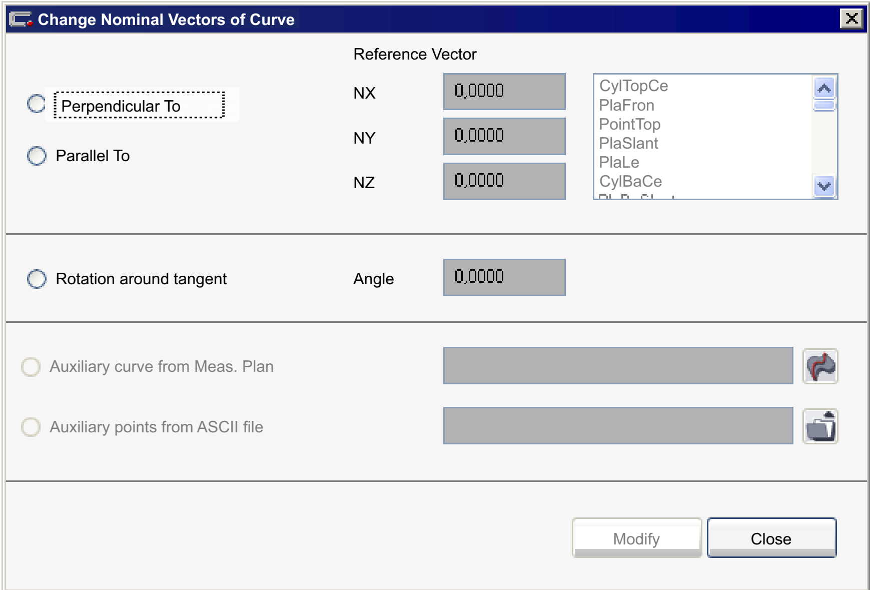
– by rotating through a given angle about the tangent of the curve

– by determining through manual input

1 Open the definition template of the curve.

2 Select **Nominal Data** → **Nominal Geometry Manipulations** → **Change nominal vectors**.

You define the new direction in the Change Nominal Vectors of Curve window.



3 To determine the nominal vectors by a reference vector:

- Select whether you want to align the nominal vectors **Perpendicular to** or **Parallel to** a reference feature.
- Select from the list the feature to be used as reference for the change, thus applying the axis as **Reference Vector**.
- - or -
- Go to **Reference Vector** and enter the N_X, N_Y and N_Z directional components.

4 If you want to rotate the vectors around the tangent of the curve:

- Mark the **Rotation around tangent** radio button.
- Enter the angle of rotation in the **Angle** field.

5 Click **Modify** to apply the change.
The new direction for the nominal vectors will be taken over from these values.

6 Click **OK** to close the window.

Creating new nominal vectors of the 3D curve

Each curve point is determined by three point coordinates and a normal vector (also see ➤ *Basics about curve measurement [⇨ 1-2]*). If, when transferring nominal curve points, e.g. from a file, no nominal vectors have been transferred, the curve definition will be incomplete. CALYPSO requires the nominal vectors for the measurement.

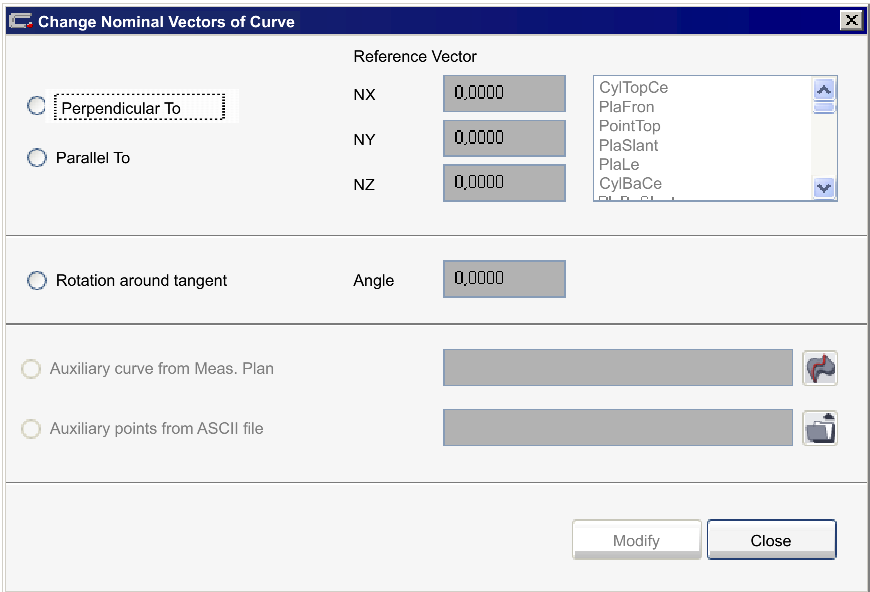
In such a case, you can newly create the missing nominal vectors. You have the following options:

– Calculation using an auxiliary curve of the measurement plan

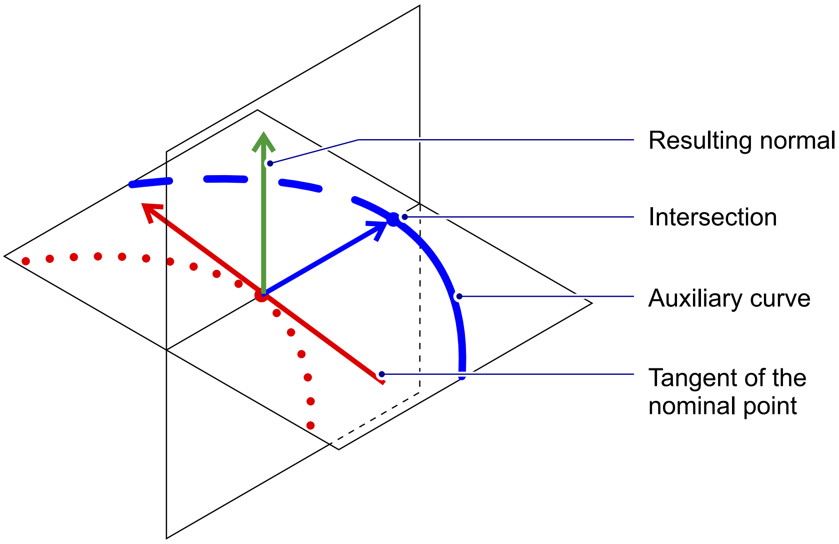
– Import from an ASCII file

1 Open the definition template of the 3D curve.

2 Select **Nominal Data → Nominal Geometry Manipulations → Change nominal vectors**.
You define the directions in the Change Nominal Vectors of Curve window.



3 To compute the nominal vectors using an auxiliary curve: Select **Auxiliary curve from Meas. Plan** and enter the name of the curve or click the icon and select the corresponding curve.
For computing, CALYPSO uses the nominal point to determine a plane perpendicular to the tangent and determines the intersection point with the auxiliary curve. Then the direction of the new nominal vector results from the crossing product of the vector from the nominal point to the intersection point and the vector of the tangent.



Note: Make sure that the selected auxiliary curve is as close as possible to the original curve and has a similar form. To allow the intersection points to be computed, the auxiliary curve must be at least as long as the original curve.

4 To import the nominal vectors from a file: Select **Auxiliary points from ASCII file** and enter the path and name of the file or click the icon and select the corresponding file.
The file must be in the usual ASCII file format for describing curves (see ➤ *Reference: Format of the ASCII file [⇨ 1-12]*).

5 Click **Modify** to apply the change.
The new direction for the nominal vectors will be taken over from these values.

6 Click **OK** to close the window.

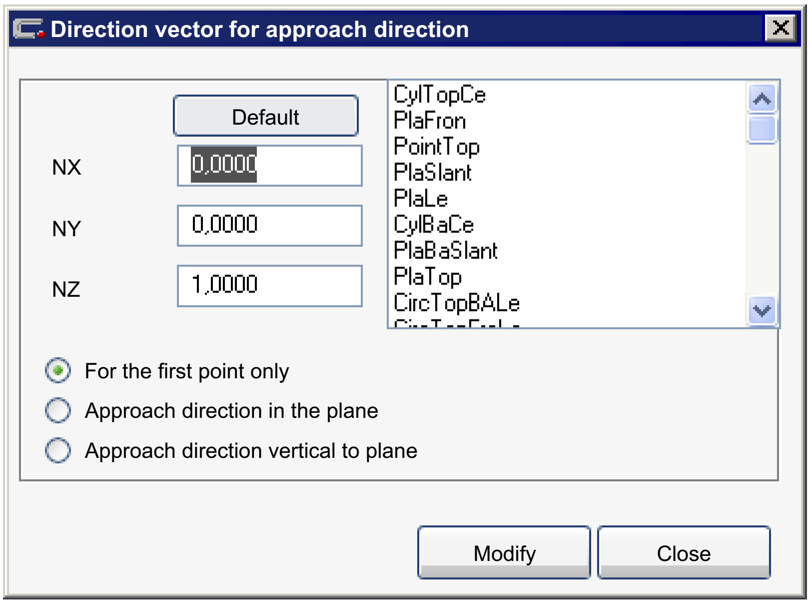
Changing the approach direction of the 3D curve

The approach direction of the 3D curve is used to position the CMM before carrying out measurements. It is shown with a blue arrow at the first curve point in the CAD window.

You can change this approach direction for the 3D curve measurement.

1 Open the definition template of the 3D curve.

2 Select **Nominal Data** → **Additional** → **Change approach direction vector**.



The Direction vector for approach direction window shows the components of the current approach vector in the base alignment.

3 Select **Approach direction in the plane**.
- or -
Select **Approach direction vertical the plane**.
- or -
Select **For the first point only** and define another approach direction:

- Enter the vector components directly.

- or -

- Click **Default** to accept the default setting (with 2D curves the normal vector of the intersection plane and with 3D curves the normal vector of the first curve point).

- or -

- Highlight a feature in the list. The appropriate normal vector will be entered as approach vector.

The direction vector will be changed automatically whenever a change is made so that you can check the effect of your entry.

4 Press **Modify** to confirm.
The new approach direction will be accepted according to your entries.

5 Click **OK** to close the window.

Smoothing digitized nominal data of the curve

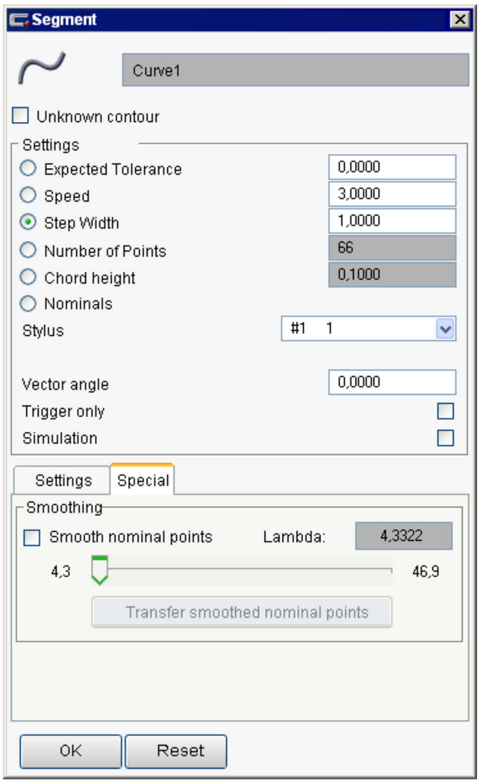
If the nominal values of the curve are distorted as they have been created by digitizing, the CMM and the rotatory table will not run harmoniously when scanning according to nominal data. You have the possibility to smooth the nominal data in order to obtain a harmonious movement of CMM and rotary table. This will be realized by low-pass filtering.

1 Open the definition template for the 2D curve whose nominal values have been created by digitizing.

2 Click the **Strategy** button.
The Strategy window is opened.

3 Open the segment.

4 Double-click the **Segment** entry.
The Segment window is opened.



5 On the **Special Settings** tab, tick the **Smooth nominal points** check box and enter the Lambda value in the input field or by means of the slider.
The display in the CAD window will show you which Lambda value is suitable.

6 Click the **Transfer smoothed nominal points** button.
Note: After overwriting with the smoothed nominal points, it will not be possible to restore the "old" points.

7 If you are sure, answer the confirmation prompt by clicking **Yes**.

The previous nominal points are now replaced by the smoothed ones.

Checking the clearance planes of a curve

When you define a feature, CALYPSO assigns clearance planes to the feature. In the case of curve measurement, you should check this automatic assignment to make sure that the clearance planes really guarantee a safe approach for the CMM. If the approach is not safe, make the requisite changes as described in the Basic Operating Instructions under Editing the travel paths.

Accelerating curve measurement

When measuring and evaluating curves, several factors may cause CALYPSO to execute a number of operations which take a while to perform. All the calculations and operations are not always needed to achieve your desired or required accuracy.

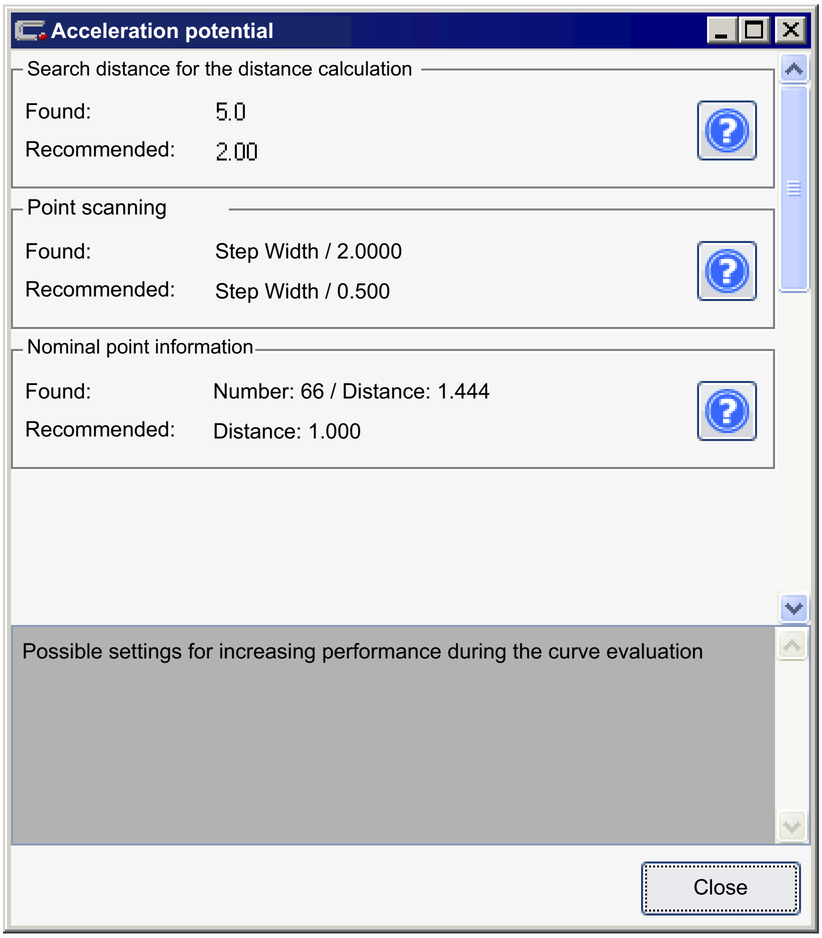
Making certain changes in parameters and settings is often enough to achieve a sufficiently accurate result at a reasonable effort.

CALYPSO analyses your entries for the definition of the curve and gives recommendations on the acceleration of evaluations.

Conditions

– The definition template of the curve is open.

1 Click the icon for **Potential for accelerating the curve evaluation** located on the right above the discrete point view/point list. The **Acceleration potential** dialog box appears on the screen.



2 Read the recommendations and use them if necessary.

The measurement runs are accelerated.

Defining constructions with the aid of curves

What is a construction?

Specially constructed elements of a workpiece that cannot be probed directly, e.g. the center of a bore or the intersection of two features. These features can be calculated using features that can be probed. CALYPSO provides different constructions for this purpose.

With CALYPSO, you can mathematically construct regular geometric elements and, in this way, define the feature you require. You can also parameterize the features to be constructed, i.e. by using formulas.

You can use either the actual or nominal geometry for the construction.

NOTE

As constructions cannot be probed, automatic feature recognition is not available here.

In the measurement plan, a construction is indicated by the letter “T” next to the icon. CALYPSO supports the following constructions for curves:

– Minimum Point construction
– Maximum Point construction
– Intersection construction

Minimum/Maximum Point constructions

You can also define the following constructions with the aid of curves:

– Minimum Point
– Maximum Point

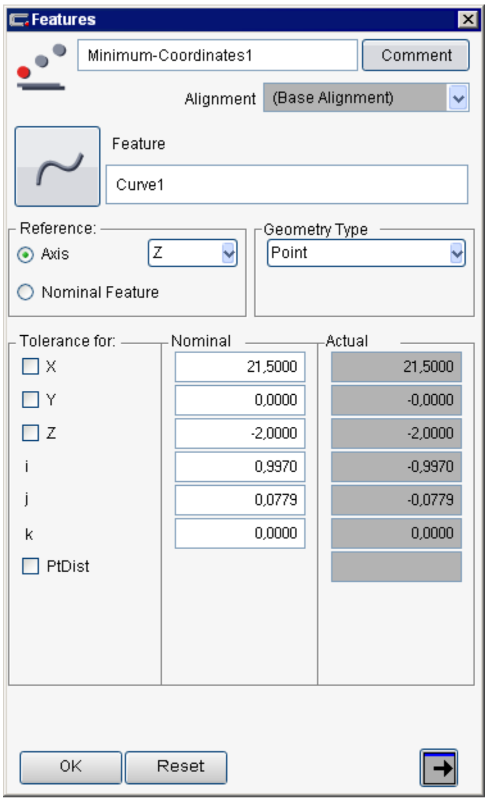
To do so, add the construction to the measurement plan via **Construct → Minimum Point** or **Maximum Point**.

Use

You can, for example, use the Maximum Point construction if the farthest external point is required for the alignment of turbine blades.

Definition

The construction is defined via the definition template (example: Minimum Point).



The result of the construction is a point with the smallest or largest value in the direction of the defined axis or the smallest or largest deviation from the nominal point.

You can edit this point in the same way as other points.

Intersection construction

You can intersect curves with other features. To do so, add the *Intersection* construction to the measurement plan via **Construct → Intersection**.

You can intersect a curve with the following features:

Feature intersects...		Curve:	3D Curve:
2-D Line		Intersection points of the curve with the plane of the 2D line	Intersection points of the curve with the plane of the 2D line
3-D Line		Intersection points of the curve with the line projected into the plane of the curve	–
Plane		Intersection points of the curve with the plane	Intersection points of the curve with the plane
Symmetry Plane		Intersection points of the curve with the center plane	Intersection points of the curve with the center plane

Feature intersects...		Curve:	3D Curve:
Circle		Intersection points of the curve with the associated cylinder section	Intersection points of the curve with the associated cylinder section
Cylinder		Intersection points of the curve with the cylinder axis or cylinder section	Intersection points of the curve with the cylinder axis or cylinder section
Cone		Intersection points of the curve with the cone axis projected into the plane of the curve	–

CALYPSO usually contains several intersection points, being numbered according to their arrangement on the curve. You then select one of these points as the result of the intersection.

Defining tolerances for a curve

Overview: Defining tolerances for a curve

In the definition template for the curve, the tolerances can be defined as follows:

- ➤ *Entering tolerances for the entire curve [➪ 1-60]*
- ➤ *Entering tolerances for tolerance segments [➪ 1-61]*
- ➤ *Importing tolerances for tolerance segments from file [➪ 1-64]*
- ➤ *Calculating linear tolerances for curve points [➪ 1-68]*
- ➤ *Defining the curve jump tolerance for the entire curve [➪ 1-71]*

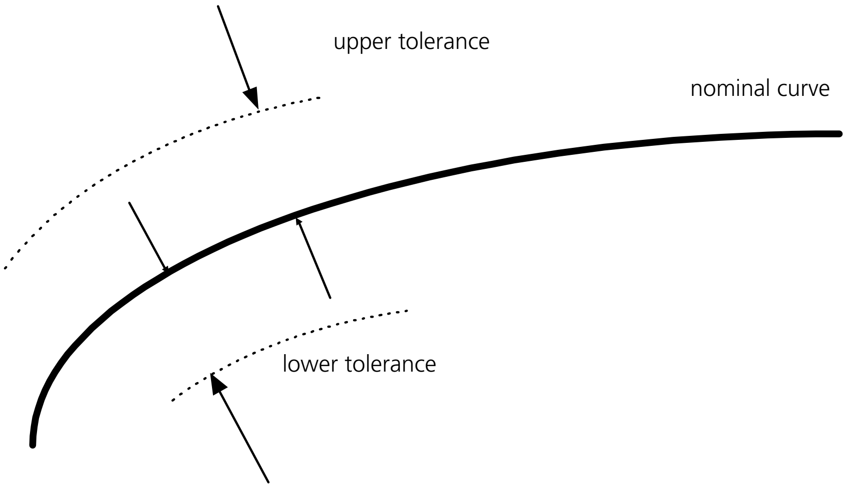
NOTE

These entries in the definition template do *not automatically define any characteristics* and add them to the list of characteristics.

You can also import the tolerances together with the nominal values from an ASCII file or have them imported during the CNC run:

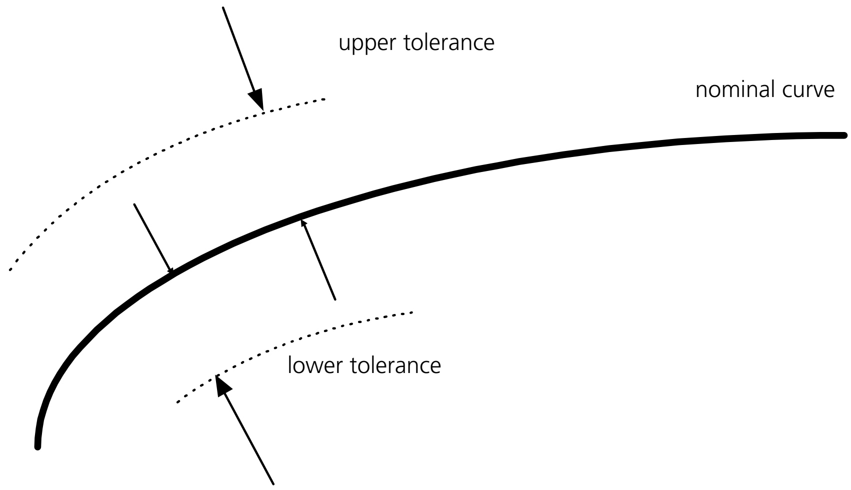
- ➤ *Importing files for nominal value definition of a curve [➪ 1-9]*
- ➤ *Loading ASCII files for nominal value definition of a curve during a CNC run [➪ 1-11]*

The dimensional tolerances refer to the nominal-actual comparison of the curve points. You can enter an upper and/or lower tolerance.



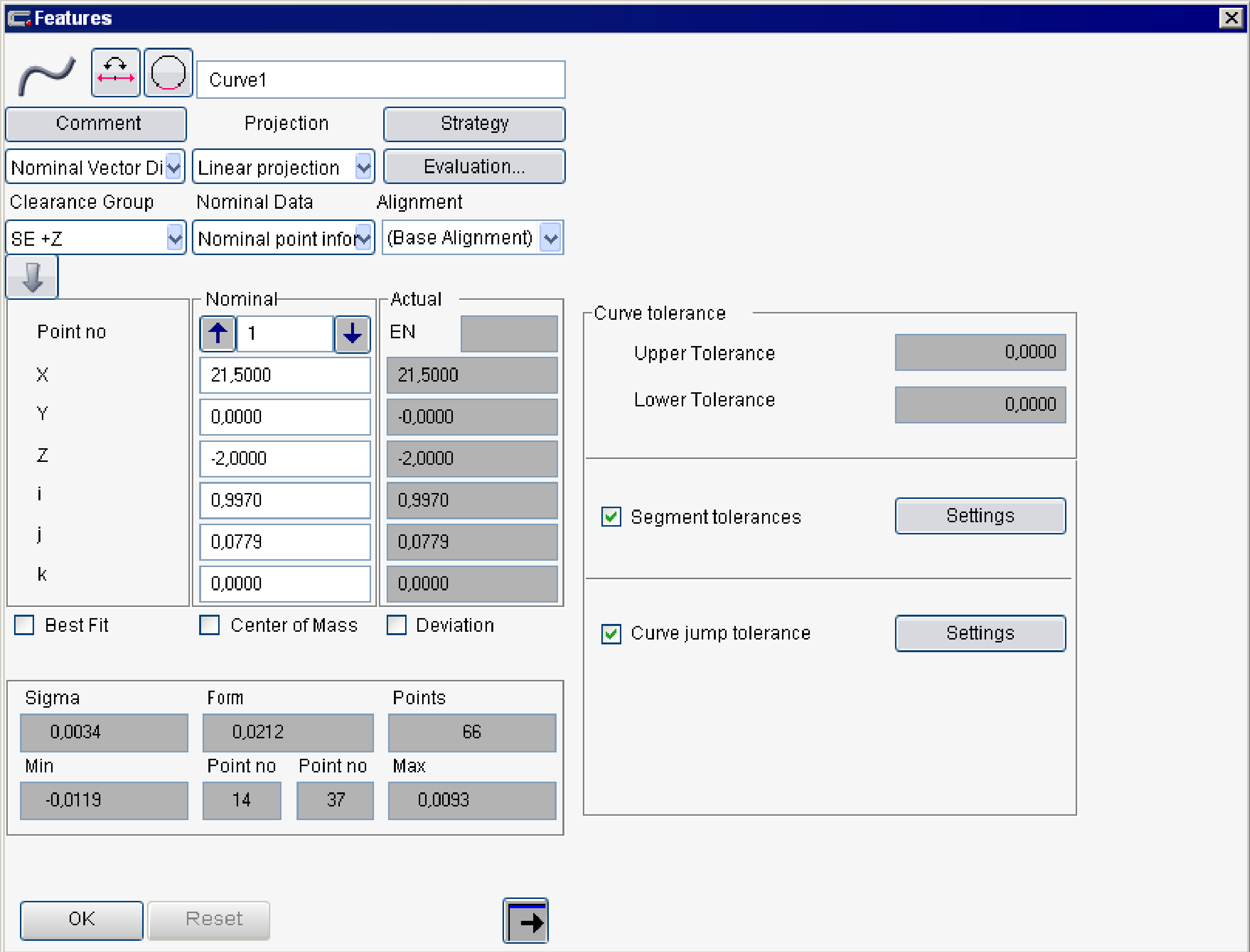
Entering tolerances for the entire curve

The entry of the dimensional tolerances refers to the nominal-actual comparison of the curve points. You can enter an upper and/or lower tolerance.



1 Open the definition template of the curve.

2 Click the button for tolerances.
The definition template of the curve is extended.



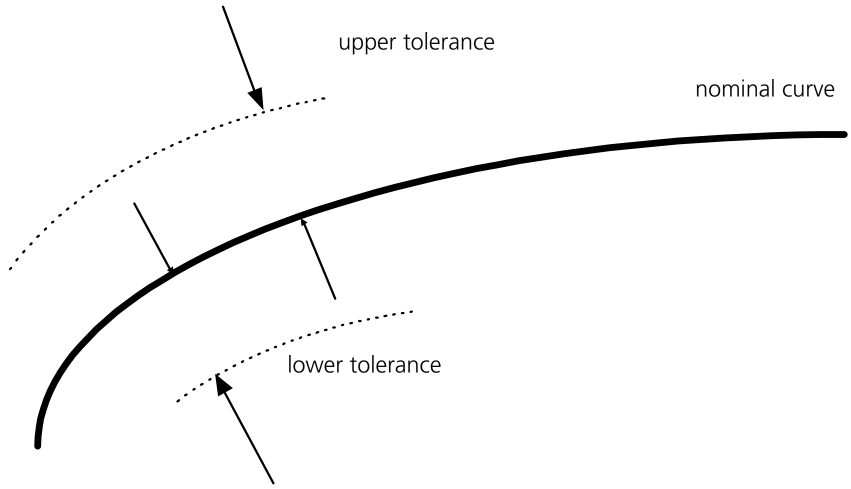
3 Enter a value for the **Upper Tolerance** and/or **Lower Tolerance**.

4 Click **OK** to close the definition template.

The tolerance you entered will be checked the next time the curve is measured.

Entering tolerances for tolerance segments

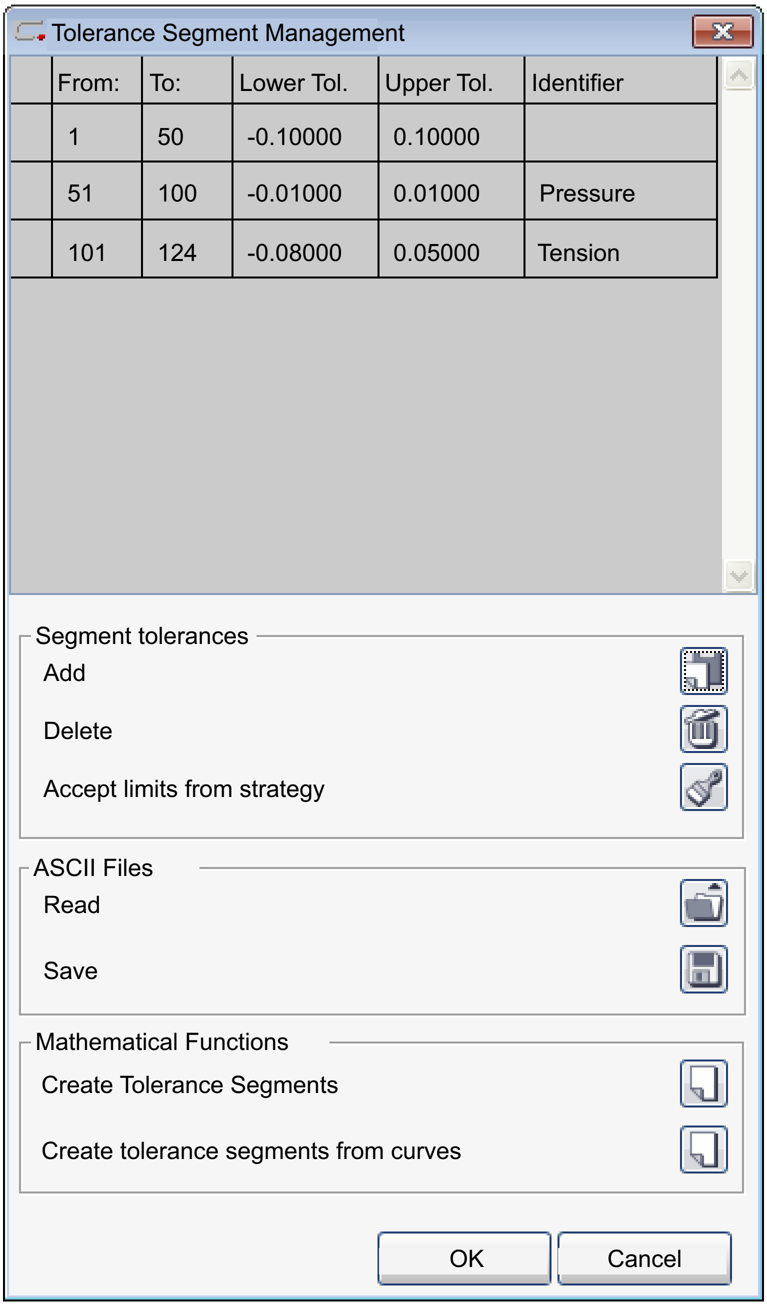
The entry of the dimensional tolerances refers to the nominal-actual comparison of the curve points. You can divide the curve into any number of segments and enter an upper and/or lower tolerance for each one of these tolerance segments.



1 Open the definition template of the curve.

2 Click the button for tolerances.
The definition template of the curve is extended.

3 Enable **Segment tolerances**, then click the **Settings** button.
The **Tolerance Segment Management** dialog box appears on the screen.



4 Click **Accept limits from strategy** to apply the curve segments from the curve's strategy as tolerance segments.

5 As an alternative, you may create your own tolerance segments manually.

- Use the **Add** and **Delete** buttons to create as many table rows as the number of tolerance segments required.
- Click in the table and enter the start and end points of the tolerance segments.

6 Specify the upper and lower tolerances for the tolerance segments.

7 If required, enter designations for the tolerance segments.

Notice: The designations will be included in the printout if you select **Evaluate tolerance segments individually** for the Curve Form or Line Profile characteristics. If no designation is specifed, the tolerance segments will be numbered in ascending order in the printout.

8 Confirm the window with **OK** and click **OK** to close the definition template.

The tolerances specified will take effect the next time the curve is measured.

Reading tolerances from a file

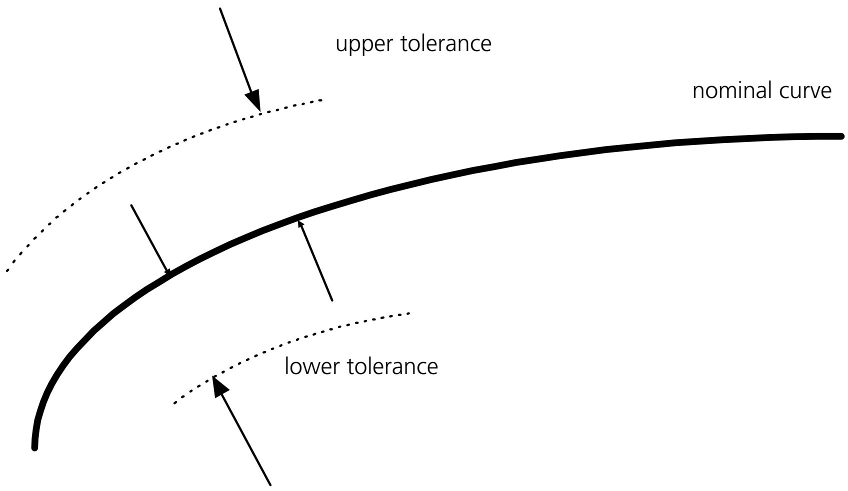
Reading tolerances for segments from a file

The entry of the dimensional tolerances refers to the nominal-actual comparison of the curve points. You can divide the curve into any number of segments and enter an upper and/or lower tolerance for each one of these tolerance segments.

Note: You can also manually import the tolerances together with the nominal values from an ASCII file or have them imported during the CNC run:

➤ *Importing files for nominal value definition of a curve [➪ 1-9]*

➤ *Loading ASCII files for nominal value definition of a curve during a CNC run [➪ 1-11]*

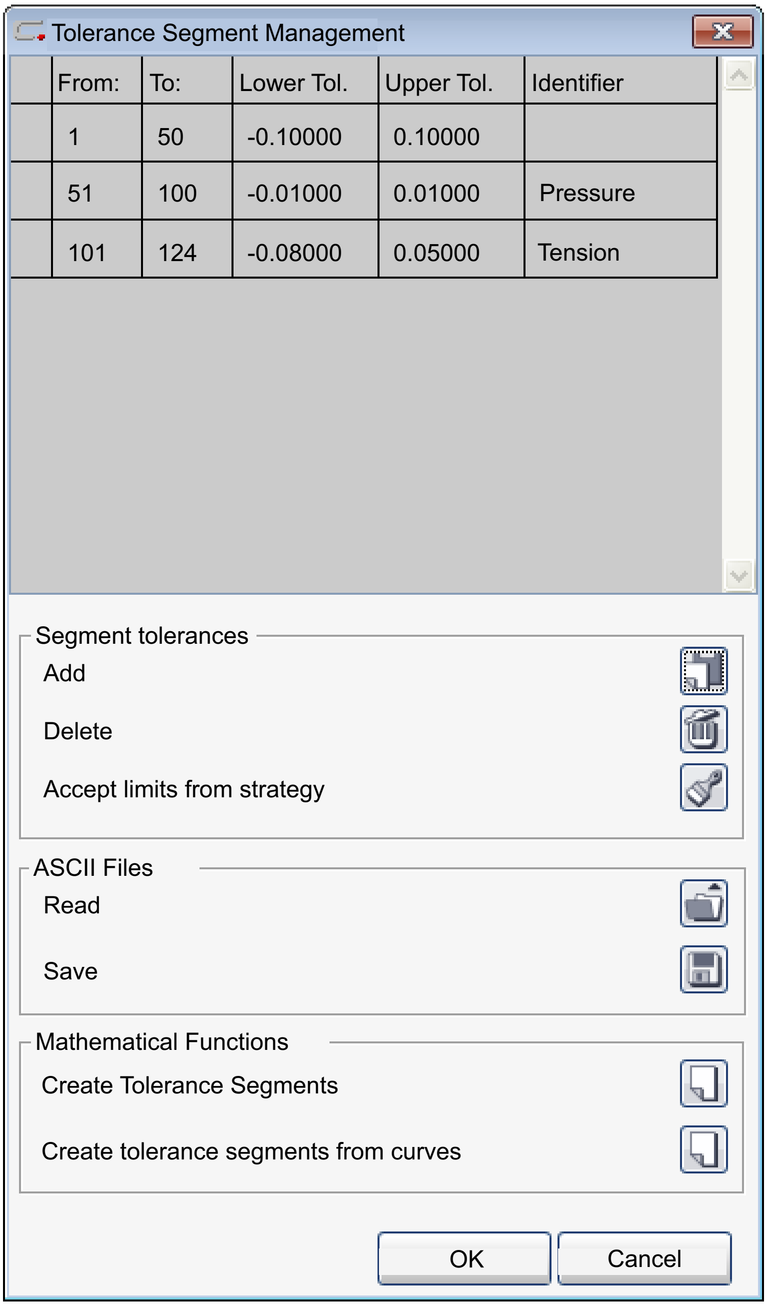


1 Open the definition template of the curve.

2 Click the button for tolerances.
The definition template of the curve is extended.

3 Activate **Segment tolerances** and then click the **Settings** button.

The **Tolerance Segment Management** dialog box appears on the screen.



4 Under **ASCII files**, click the **Read** button and select in the **Save file** window the ASCII file containing the tolerance segments.

5 Acknowledge the window with **OK** and click **OK** to close the definition template.

The tolerances you entered will apply the next time the curve is measured.

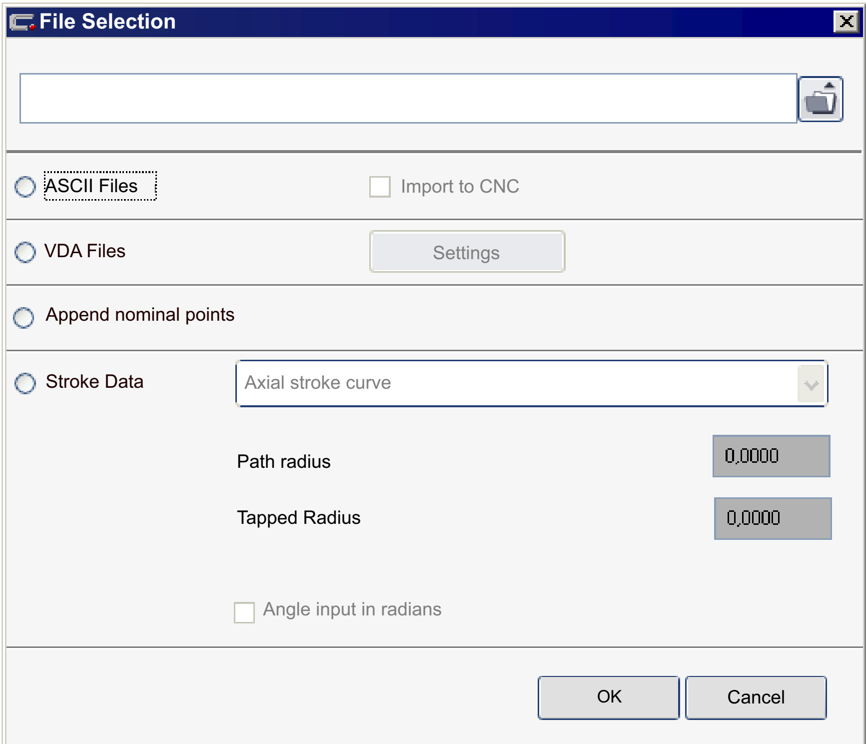
Reading tolerances with nominal values from a file

CALYPSO is able to load an ASCII file for defining the nominal values and tolerances of the curve during the automatic measurement run. The ASCII file must have a defined format (see ➤ *Format of nominal value files [➪ 1-67]*) and be available in the defined path.

To load an ASCII file during the CNC run:

1 Make sure you have the curve feature template open and displayed on your screen, and that the chosen coordinate system fits the curve to be imported.

2 Select **Nominal Data → Nominal geometry manipulations → Read nominal values**.
The **File Selection** dialog box appears on the screen.



3 Select the **ASCII Files** option and tick the **Import to CNC** check box.

4 Enter the path and name of the ASCII file or select it in the file selection dialog.

5 Click **OK** to confirm.
The nominal values of the curve and its tolerances will only be determined *during the CNC run* on the basis of the selected file.

Reference: Format of tolerance segment files

The ASCII file with the tolerance segments of the curve and associated upper and lower tolerances has the following format:

It consists of individual lines, each one defining a tolerance segment. Each line is composed of entries separated by a tab, in the following order: start point of the segment, end point of the segment, lower tolerance, upper tolerance, designation of the segment.

NOTE

The software versions preceding CALYPSO 2017 did not allow separate definition of start point and designation. Tolerance files from these versions therefore only contain 3 columns but can still be imported.

Example

The example below shows the structure of a tolerance file:

1	20	-0.1	0.1	segment_1
21	40	-0.2	0.2	segment_2
41	66	-0.3	0.3	segment_3
67	67	-0.32	0.32	segment_4
68	100	-0.3	0.3	segment_5
101	200	-0.2	0.2	segment_6

The entries in the first line of this file have the following meaning:

From point 1 to point 20, the tolerances [-0.1; 0.1] apply The name of the segment is segment_1.

Reference: Format of nominal-value files

To ensure that nominal curve values and, if desired, also tolerances and masking data can be loaded correctly by CALYPSO during the CNC run, they must be available in an ASCII file in a defined format.

File format

Every data line of the file contains at least six values, separated by tabs and blanks.

Only the first ten values are interpreted, namely as the three coordinates of the point, the three components of the nominal vector, the lower and upper tolerances, and the masking data.

If fewer than ten values are available, no masking and, if fewer than eight values are available, no tolerances will be imported.

Additionally, the file may contain one or several header lines. These lines will not be evaluated.

NOTE
The nominal vector does not need to be standardized.

Example:

XNOM	YNOM	ZNOM	UNOM	VNOM	WNOM	lTol	uTol	maskEval	maskBF
21.5926	0.5645	-2.0000	0.9946	0.1040	0.0000	-0.1	0.1	0	1
21.4906	2.1964	-2.0000	0.9949	0.1008	0.0000	-0.2	0.1	0	1
21.2688	3.7612	-2.0000	0.9846	0.1749	0.0000	-0.2	0.2	0	1
20.9286	5.3328	-2.0000	0.9688	0.2480	0.0000	-0.2	0.2	0	1
20.4721	6.8744	-2.0000	0.9475	0.3196	0.0000	-0.2	0.2	0	1
19.9015	8.3780	-2.0000	0.9210	0.3895	0.0000	-0.2	0.2	0	0
19.2201	9.8346	-2.0000	0.8893	0.4573	0.0000	-0.2	0.1	0	0
18.4322	11.2355	-2.0000	0.8525	0.5277	0.0000	-0.3	0.3	0	0
17.5409	12.5736	-2.0000	0.8111	0.5849	0.0000	-0.3	0.3	0	0
16.5523	13.8422	-2.0000	0.7654	0.6435	0.0000	-0.3	0.2	0	0
15.4728	15.0333	-2.0000	0.7152	0.6990	0.0000	-0.3	0.2	0	0
14.3064	16.1402	-2.0000	0.6606	0.7560	0.0000	-0.3	0.1	0	0
13.0604	17.1559	-2.0000	0.6026	0.7980	0.0000	-0.3	0.2	0	0
11.7418	18.0767	-2.0000	0.5417	0.8406	0.0000	-0.4	0.2	0	0
10.3589	18.8968	-2.0000	0.5442	0.8389	0.0000	-0.4	0.1	0	0
9.2574	19.6652	-2.0000	0.6607	0.7506	0.0000	-0.4	0.1	0	0

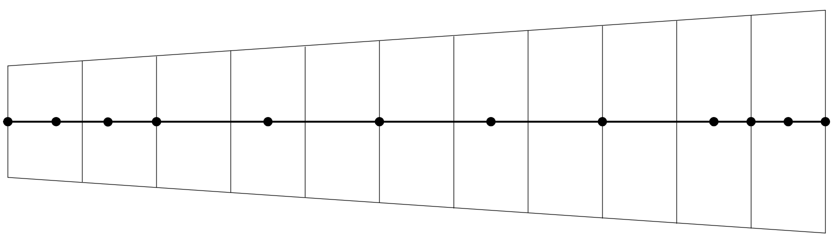
Having tolerances for curve points calculated

You do not need to enter the curve tolerances manually, but can have them calculated by CALYPSO.

Three calculation methods are available for this purpose:

– Tolerances as linear function with respect to the curve length

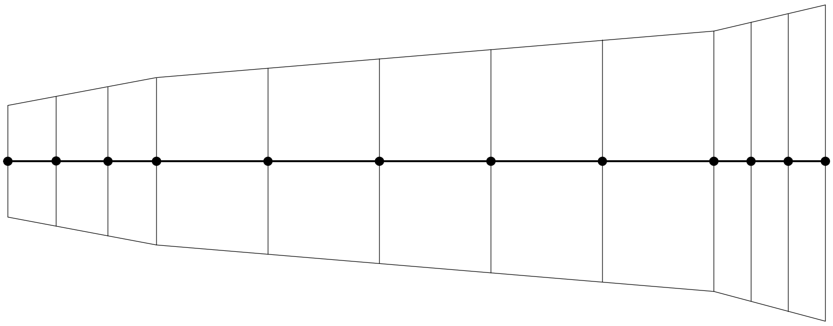
  This method produces a regular ascent of the tolerance curve over the entire curve length. Regardless of how close the points are located, the ascent will always remain the same.



– Tolerances as linear function with respect to the point number

This method produces an ascent as a function of point density. The closer the points are located, the higher is the ascent.

This calculation method is appropriate, for example, if, in the case of cams, the tolerance is to depend on the angle instead of the curve length.



– Generating tolerances from any curve of the measurement plan

The tolerances of each nominal point result from the distance to the upper and the lower tolerance curve in the nominal normal direction.

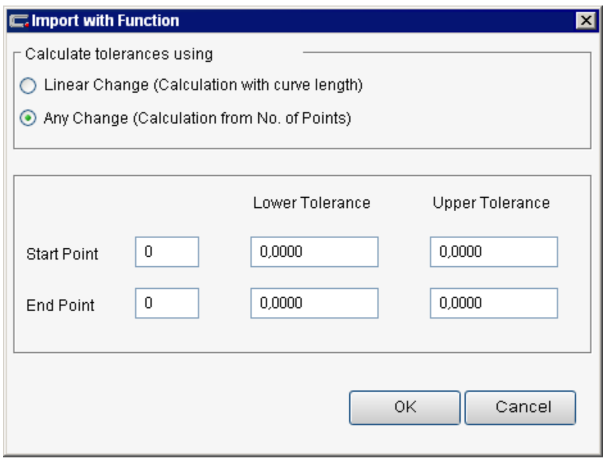
Having curve tolerances calculated

1 Open the definition template of the curve.

2 Click the button for tolerances.
The definition template of the curve is extended.

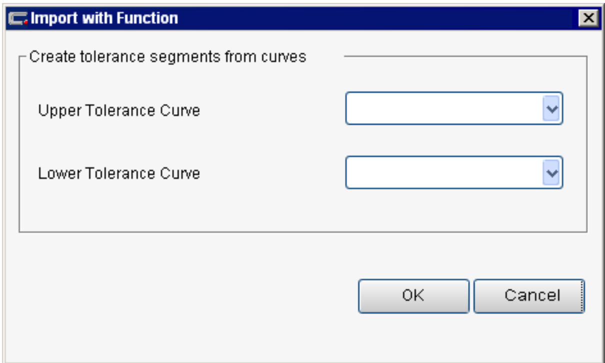
3 Activate **Segment tolerances** and then click **Settings**.

4 To generate tolerance segments from curves, click the icon next to **Create Tolerance Segments** under **Mathematical Functions** in the**Tolerance Segment Management** window.
The **Import with Function** dialog box is opened.



- Select the type of linear function.
- Enter the numbers of start and end point as well as the corresponding tolerances.
- Confirm the dialog and close the **Tolerance Segment Management**.

5 To generate tolerance segments from curves, click the icon next to **Create tolerance segments from curves** under **Mathematical Functions** in the**Tolerance Segment Management** window.
The **Import with Function** dialog box is opened.



- Select the curve for generation of the upper tolerances
- Select the curve for generation of the lower tolerances
- Confirm the dialog and close the **Tolerance Segment Management**.

The tolerances thus calculated will apply the next time the curve is measured.

Curve jump tolerance

The curve jump tolerance refers to the differences between the nominal-actual deviations of the curve points. So the curve jump tolerance indicates how much the curve may change within a certain range. It is generally independent of the curve form tolerance.

Curve jump tolerance via characteristic

To define and measure the curve jump tolerance of a curve in CALYPSO, add the **Curve Jump** characteristic to the measurement plan. You have various options to define this parameter: You can define the measuring range based on numbers of points, longitudinal sections, and angular sectors and specify different tolerance values for different curve segments.

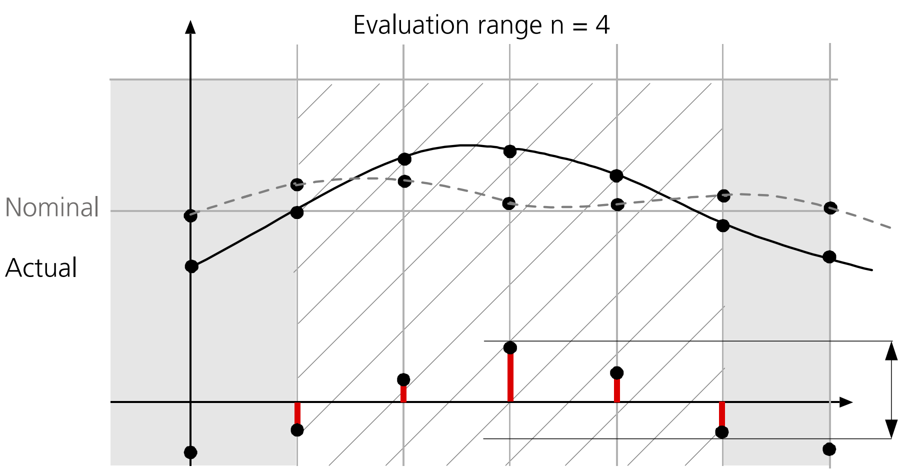
For more information, see ➤ *Defining the Curve Jump characteristic [➪ 1-124]*.

Curve jump tolerance with limited options

In measurement plans created with versions *earlier than CALYPSO 2017*, an additional option is to enable the curve jump tolerance for the entire curve in the **Curve** feature. If you select this curve as the feature for a **Curve Form** characteristic, the curve jump tolerance will be evaluated during the next measurement and indicated in the printout.

Activation of the curve jump tolerance in the Curve feature provides less options than with the Curve ump feature. To specify the size of the measuring range, enter “n” as the number of points. n + 1 neighboring points will be measured then. For tolerance evaluation, the program examines the actual-nominal deviations of the points and determines their maximum and minimum values in the respective ranges. The curve is out of tolerance in this range if the difference between the minimum and the maximum deviation is greater than the specified value.

The following figure shows the calculation of the curve jump when checking the curve jump tolerance for the entire curve with n = 4. The measurement includes the areas of n + 1 neighboring points.



The nominal-actual deviations for each point are shown in the diagram. The difference between the maximum and minimum deviation applies to points 3 and 5 in the shaded area.

Defining the curve jump tolerance for the entire curve

Only in measurement plans created with versions *earlier than CALYPSO 2017*, you can define the curve jump tolerance for the entire curve in the feature's definition template.

NOTE

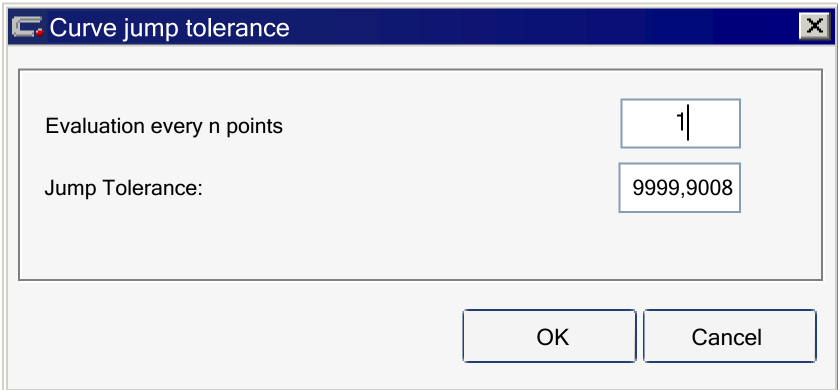
Activation of the curve jump tolerance in the Curve feature will not be effective in measurement plans created with CALYPSO 2017 or more recent versions. To measure the curve jump tolerance, add a ➤ *Curve Jump characteristic [⇨ 1-124]* to the measurement plan.

The Curve jump characteristic provides numeros possibilities: You can define the measuring ranges in different ways and divide the curve into segments with different tolerance values.

1 Open the definition template of the curve.

2 Click the button for tolerances.
The definition template of the curve is extended.

3 Tick the **Curve jump tolerance** check box and click **Settings**.



4 Enter the size of the evaluation range and the **Jump Tolerance** value and confirm by clicking **OK**.
Measurement of the curve jump tolerance is enabled. If you select this curve as the feature for a Curve Form characteristic, the curve jump tolerance will be evaluated during the next measurement and indicated in the printout.

The following example shows how the result is displayed:

```
Curve jump tolerance: 0.0125 (5)      (No: 36-40 -> 0.0043)
```

This means: The curve jump tolerance has been determined based on n = 5 and a tolerance value of 0.0125. In the range of the points 36 to 40, the curve jump tolerance was exceeded by 0.0043.

Result calculation of a curve

Basics about result calculation

CALYPSO calculates the actual curve from the measured points by interpolation with the aid of spline functions.

NOTE

CALYPSO can process a maximum of 20,000 points for a curve. More than 20,000 points may lead to errors.

The following settings are important for the definition of the results of the curve measurement:

– the selected calculation of the deviation

– the selected projection

Calculation of deviations for the curve

Overview of the calculation methods

The calculation method for the deviations is set in the definition template for the curve in the selection field under the **Comment** button.

The following methods are available:

– ➤ *Nominal Vector Direction [➪ 1-74]*

– ➤ *Act -> Nom [➪ 1-74]*

– ➤ *Nominal in plane [➪ 1-75]* (only for 3D curves)

– ➤ *Actual in plane [➪ 1-75]* (only for 3D curves)

– ➤ *in X direction [➪ 1-75]* (only for 3D curves)

– ➤ *in Y direction [➪ 1-75]* (only for 3D curves)

– ➤ *in Z direction [➪ 1-75]* (only for 3D curves)

– ➤ *Space Point Evaluation [➪ 1-76]* (2D curves only)

– ➤ *Grid coordinates [➪ 1-76]* (2D curves only)

– ➤ *Radial deviation [➪ 1-77]* (2D curves only)

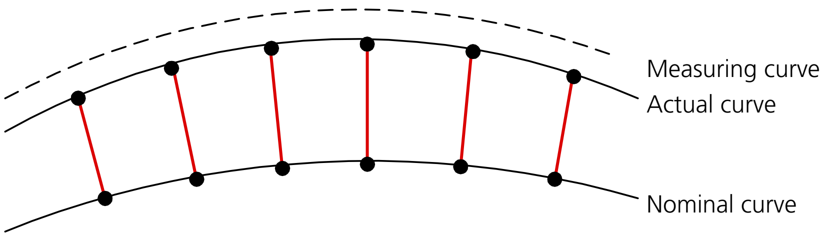
– ➤ *Space Point Evaluation (without interpolation) [➪ 1-77]* (2D curves only)

The following terms are important in order to understand the different deviation calculations:

Term	Definition
Measuring point	measured point (center of the stylus)
Measured curve	spline from the measured points
Actual curve	equidistant curve in the stylus radius distance from the measuring curve
Nominal point	point used to define the feature
Nominal curve	spline through the nominal points
Nominal vector	normal vector from the nominal point to the outside
Actual point	calculated surface point in case of deviation in actual vector direction: measured point corrected by the stylus radius if the actual curve is calculated as spline: intersection point of the nominal vector with the actual curve

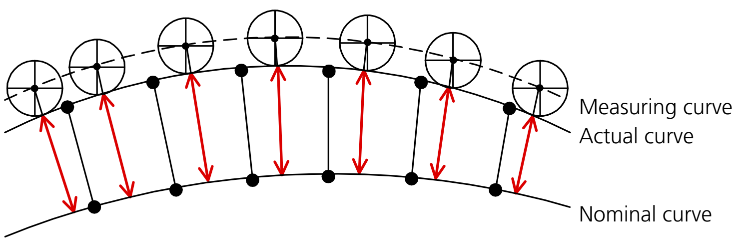
Deviation in nominal vector direction

The deviation in **nominal vector direction** is measured at each nominal point in the direction of the normal vector up to actual point (the intersection with the actual curve).



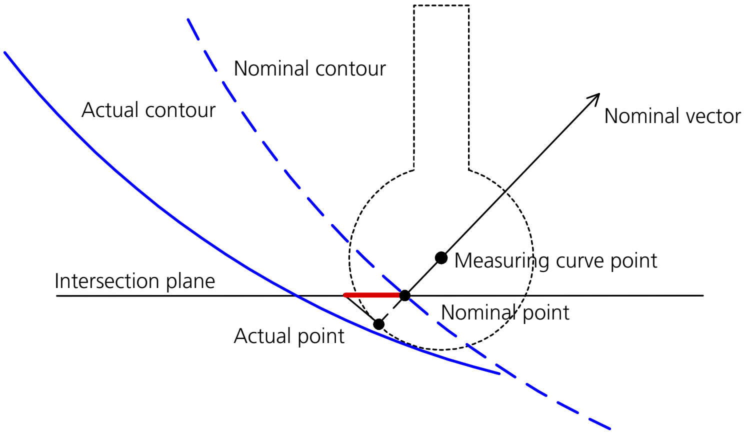
Actual -> nominal deviation

The **Actual -> Nominal** deviation means the distance between the point located on the actual curve that belongs to the measuring point and the nominal curve.



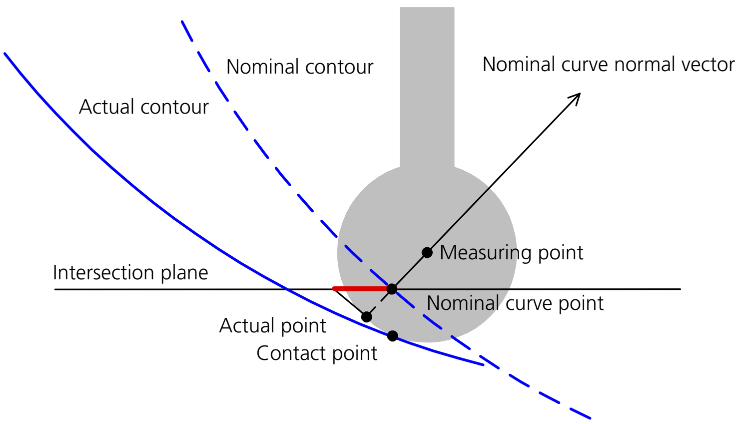
Nominal in plane deviation

The **Nominal in plane** deviation is the distance between the nominal point and the intersection with the projection of the actual point onto the intersection plane.



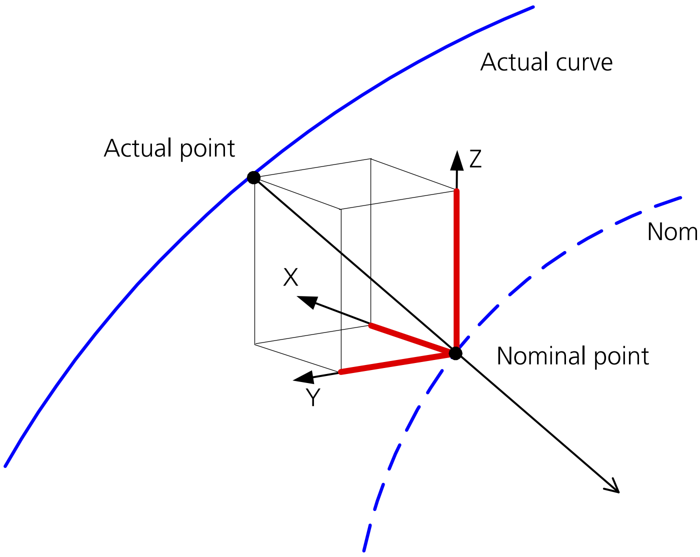
Actual in plane deviation

The **Actual in plane** deviation is the distance from the point (projected into the intersection plane) belonging to the measuring point on the actual curve to the nominal curve (located in the intersection plane).



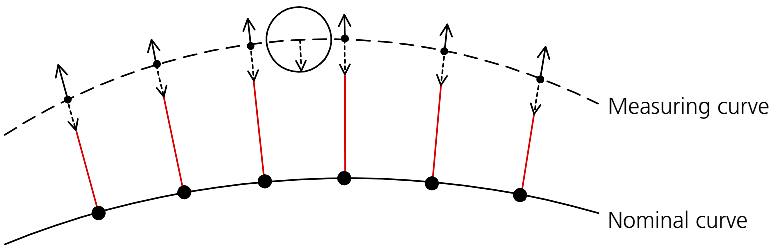
Deviation in coordinate direction

The **in X direction**, **in Y direction** and **in Z direction** deviations are the components of the distance between nominal point and actual curve in the axis directions of the base alignment.



Space point evaluation (2D curves only)

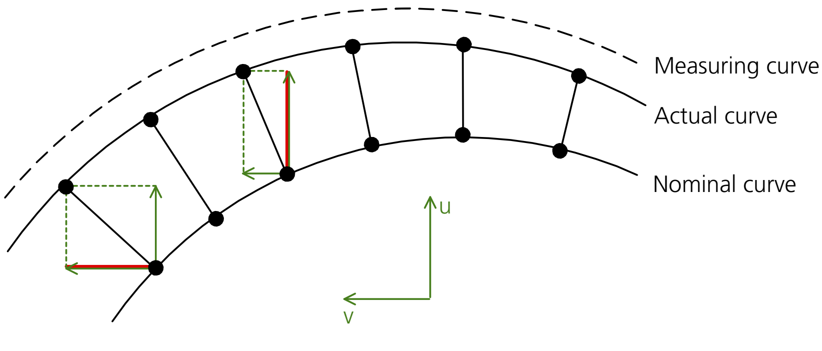
The deviation with **space point evaluation** means the distance between the nominal point and the intersection with the measuring curve, corrected by the stylus radius.



Deviation in grid coordinates (2D curves only)

To calculate the deviation in **grid coordinates**, the nominal vector from the nominal point to the intersection with the actual curve will be split into components parallel to the grid coordinate axes.

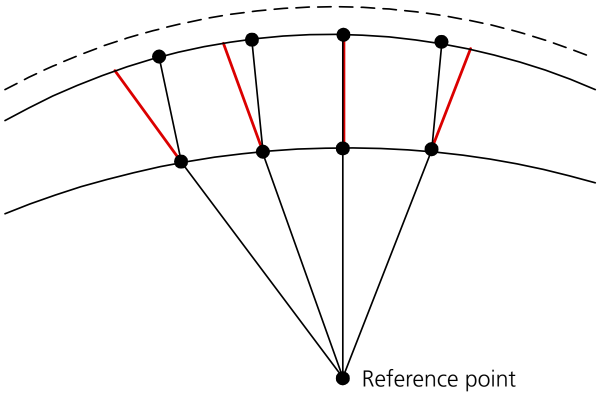
The deviation is then the length of the larger component.



Radial deviation (2D curves only)

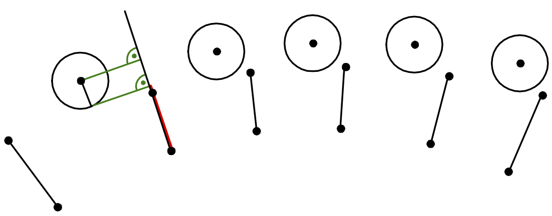
The **radial deviation** is calculated radially to a reference point of a reference feature as the distance between nominal point and actual curve along the radius beam.

This deviation calculation is required e.g. for evaluating camshafts.



Space Point Evaluation (without interpolation)

The closest measuring point is searched for each nominal point. This measuring point will then be corrected by the stylus radius in the nominal vector direction. The distance between the corrected measuring point and the curve point projected on the nominal vector is output as deviation.



Projection of the results for the curve

The selected calculation of the deviations and the set projection are crucial for the results of the curve measurement.

Projection of 2D curves

For projection of 2D curves, enter a plane onto which the measured curve points are to be projected. This results in a two-dimensional curve.

You can set projection onto one of the following planes:

- Linear projection (measuring only): Choice of several planes, the points are projected plumb onto the nominal plane.
- Circular projection (measuring only): Choice of several planes; the points are projected onto the nominal plane along the rotation face to be selected.
- Measured Planes (digitizing only): Any measured planes, e.g. to take sheet thickness values into account.
- X/Y-Plane, Y/Z-Plane, Z/X-Plane (digitizing only)
- Computed Plane (digitizing only): Plane derived from the measured values of the curve.

Projection of 3D curves

In the case of 3D curves, it is only possible to set the projection for lift curves and threaded curves.

Lift curves

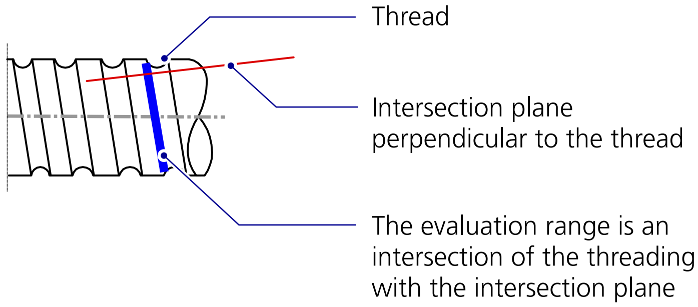
You can set the following for lift curves under **Projection**:

- **No Projection**: the deviations are evaluated in the nominal vector direction.
- **Lift curve**: the deviations are projected onto the cylinder section.

Threaded curves

In the case of threaded curves (**Thread** check box in the **Evaluation** dialog box), you can carry out the evaluation of the deviations in different planes. To do this, you must first set the deviation calculation in **Nominal Vector Direction** and then the projection for the evaluation of the measured points:

- **No Projection**: the deviations are evaluated in the nominal vector direction.
- **Vertical Projection**: the measured values are projected onto the plane perpendicular to the thread and evaluated.
- **Helix Projection**: the measured values are projected in a helical line onto the nominal plane of the profile intersection and evaluated. The helix is predefined by the thread parameters.



Using curves in the CAD window

Curve in the CAD window

The principles for the functioning and use of the CAD model in the CAD window for the curve measurement are the same as those described in the Basic Operating Instructions under Working with the CAD window.

There are, however, a number of other, useful settings and commands for working with curves. You can call these settings and commands via the ➤ *context menu of the curve in the CAD window [⇨ 1-79]*.

You can define some of the settings and commands of the context menu as well as other ➤ *additional displays [⇨ 1-80]* in the **Meas. Point Display** window.

Context menu for the curve in the CAD window

NOTE

These additional commands are available only when you have the curve definition template open.

Command	Function
Show Nominal Points	Shows the individual nominal points in yellow. The type of presentation is defined in the **Meas. Point Display** window.
Show Actual Points	Shows the actual points in green and red. The type of presentation is defined in the **Meas. Point Display** window. The points shown in red will not be considered for the evaluation. This command will only be available once the curve has been measured.
Display Measured Points	Shows the measured points in green and red. The type of presentation is defined in the **Meas. Point Display** window. The points shown in red will not be considered for the evaluation. This command will only be available once the curve has been measured.
2D View	Displays the curve's plane (2D curves only).
Magnification	Shows a magnified view of the curve. Select the magnification factor from the submenu.
Show Point Numbers	Displays the numbers of the curve's nominal points.
Show Tolerance Lines	Displays the tolerance lines of the curve. These lines are displayed along with the curve.

Command	Function
Properties	Opens the **Meas. Point Display** window for making additional settings for the presentation.

Defining the curve display

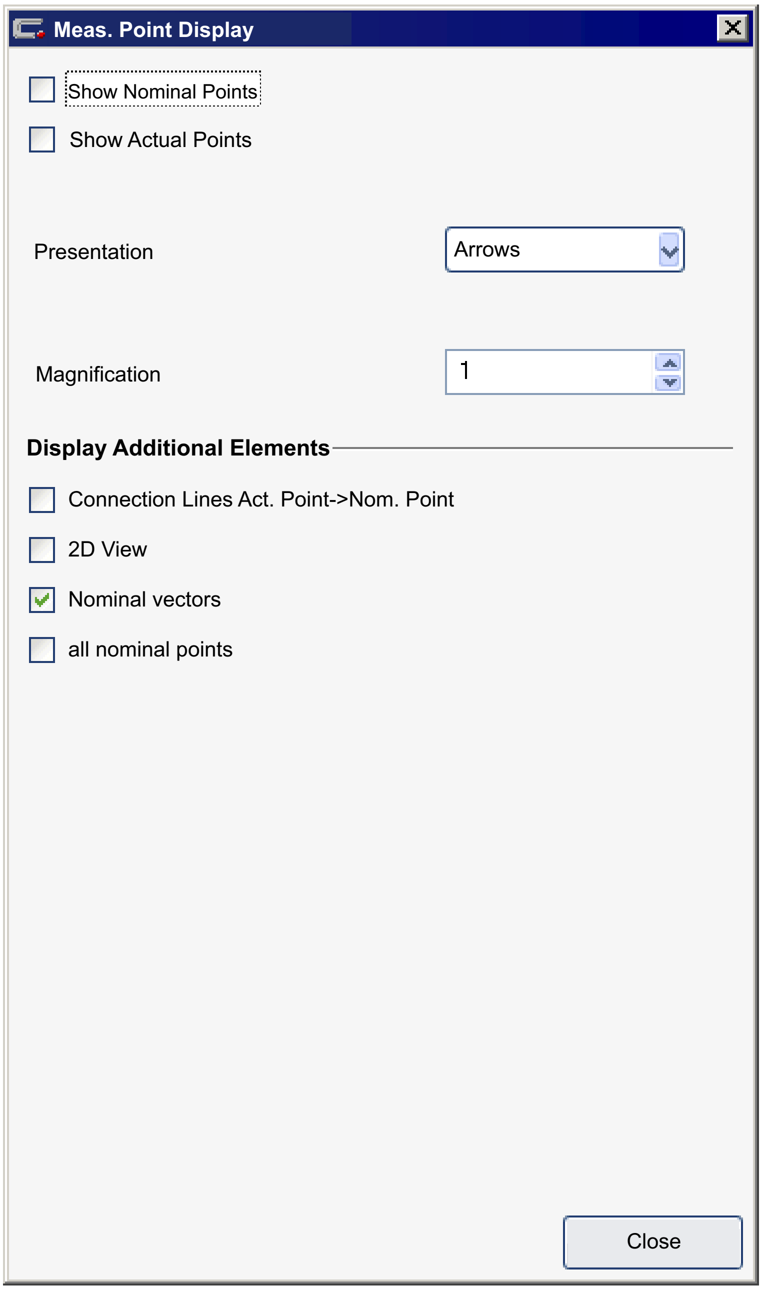
For a better overview of the measuring results, you can display the nominal points, measured points and actual points of the curve in the CAD window in different ways.

The context menu of the curve allows you to define whether the points are displayed; the type of presentation is defined in the **Meas. Point Display** window.

Conditions

– The definition template of the curve is open.

1 Select **Properties** in the context menu of the CAD window.
The **Meas. Point Display** dialog box is opened.



2 Define whether nominal points, actual points and masked points are displayed.

3 Define the type of presentation of the points.

4 Enter the magnification of the deviation if necessary.

5 If needed, activate additional settings:

- Connection Lines Act. Point->Nom. Point
- 2D View: Shows the curve in the plane of the CAD window
- Displaying nominal vectors
- Displaying all nominal points

Measuring strategy for the curve

Particularities for the curve

There is no difference in layout between the **Strategy** window for the curve and the **Strategy** window for the other features (see in the Basic Operating Instructions under Measurement strategies for features).

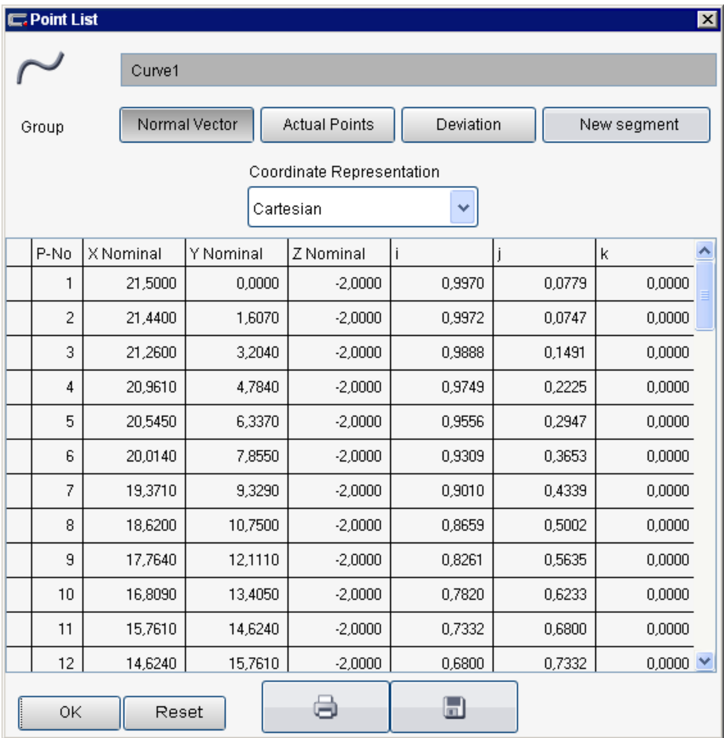
The difference is in the point list, which has an extended function in itself and in connection with creating segments. Consequently, it is described separately for the CNC Curve Measuring Software option (see ➤ *Point list for the curve [➪ 1-82]*).

Another difference is that ➤ *segments can be connected to measurement groups [➪ 1-90]* in the strategy list. Different areas of a curve can thus be measured with different parameters as well as like a segment as regards traveling.

Point list for the curve

Basics about the point list

As this illustration shows, the point list of a curve contains more functions in the **Group** section.



Each nominal point of the curve is listed with its point number and its X,Y and Z coordinates. You can use the **Normal Vector**, **Actual Points** and **Deviation** buttons to decide which additional information will be listed.

– **Normal Vector**: Each nominal point is listed with the direction components of its normal vector.
– **Actual Points**: Each nominal point is compared with the calculated actual point. If no actual points have been measured, the actual points are represented by zero.
– **Deviation**: Each nominal point is listed together with the deviation of the actual points in the direction of the normal vector and its direction components.
– **New segment**: See ➤ *How to divide a curve into segments [⇨ 1-86]*.

The other features of the point list correspond to the description in the Basic Operating Instructions under ➤ *Point list [⇨ 1-82]*.

Working with the point list

You can view and edit the points of a curve in the point list. The tasks you can undertake in the point list are as follows:

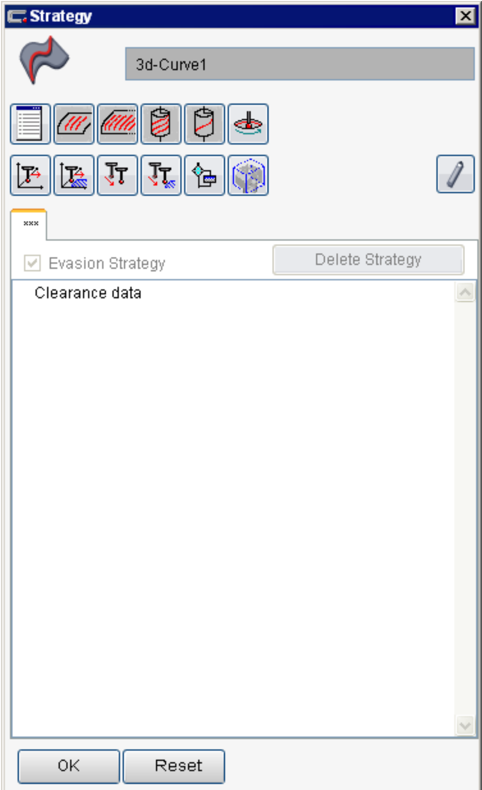
– Divide the curve into segments (see ➤ *Dividing a curve into segments [⇨ 1-86]*).
– Select display options for points (see ➤ *Point list for the curve [⇨ 1-82]*).
– Save and print the point list (see ➤ *Printing the point list or saving it as file [⇨ 1-84]*).

The point list has to be open if you want to use any of these functions.

Opening the point list

1 Open the Curve feature definition template.

2 Click the **Strategy** button.
The Strategy dialog box is opened.



3 Click the Point List button.
The list will show all points defined in the curve feature.

Printing the point list or saving it as file

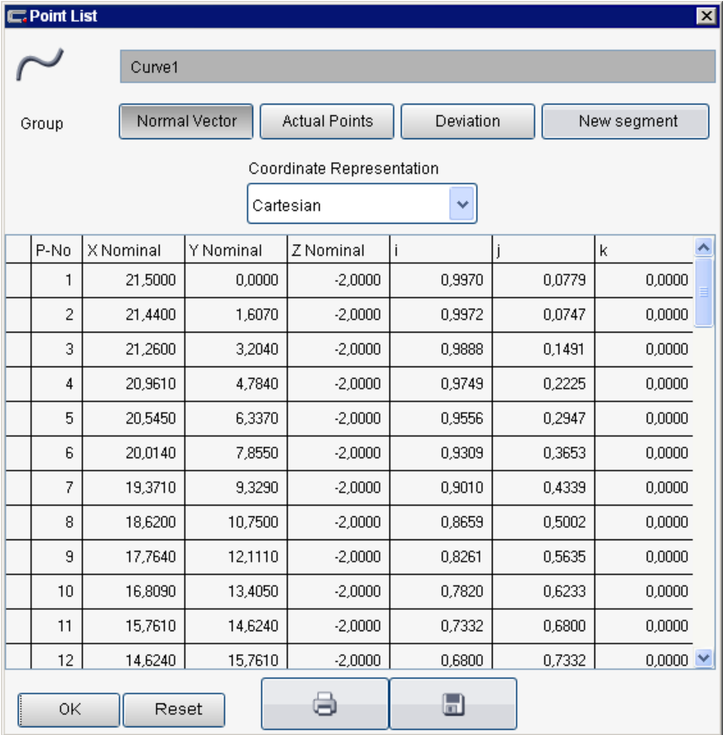
You can print the point list of the measurement strategy or save it as file. In a VDA file, you can only output either the actual values or the nominal values. In an ASCII file, you can output as desired actual values, normals and deviations either or in cartesian or in polar coordinates.

Printing the point list

1 Open the curve feature definition template.

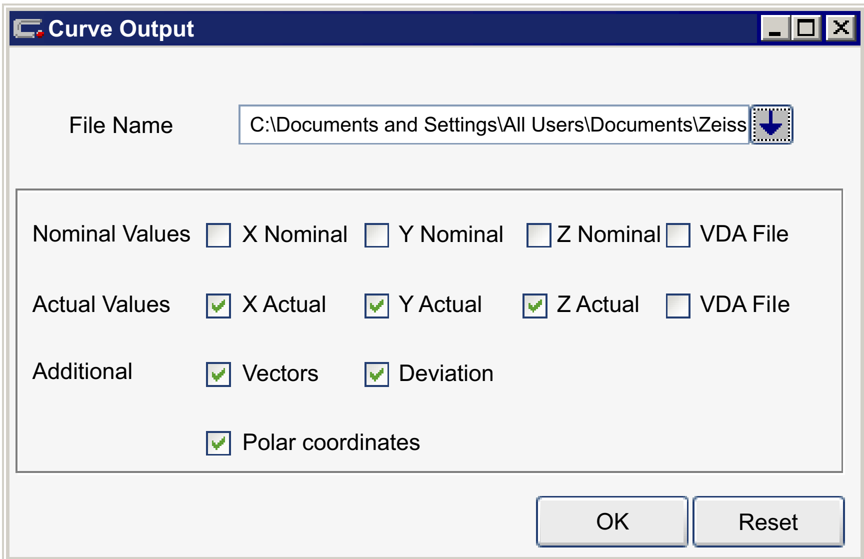
2 Click the **Strategy** button.

3 Click the **Point List** button.
The Point List window is opened.



4 Click the button with the printer icon to print the point list.
The list is sent to your printer.

5 Click the button with the diskette icon to save the point list as file.
The Curve Output window opens and you can define the parameters and format for saving the list.



- Tick the check boxes to define the data to be saved in the point list.

- To save the point list as a VDA file, tick the **VDA File** check box under *either* **Nominal Values** or **Actual Values**. The list is saved as an ASCII file if none of the check boxes is ticked.
- Click **OK** to save.

The ASCII file is stored in the specified directory.
If **VDA File** is activated, the **VDA** will be displayed.

6 Enter the **Receiving company**, **Element name** and **Element type** and confirm with **OK**.

7 Enter the directory and file name in the **Selection VDA File** window and click **Save**.

8 Click **OK**.

The point list is closed.

Scanning a contour

Steps for defining the scanning method

Curves are scanned along the segments of a curve whose points were defined beforehand in the feature.

The procedure for defining the scanning method for curves differs slightly from that of the other scans. You must begin by defining the parts (segments) of the curve you want to scan.

You can then group the segments which allows you handle them as one segment as regards traveling.

It is also possible to scan a known curve “like an unknown curve”.

Defining a scanning method is a three-step procedure:

– Define the general settings (see in the Basic Operating Instructions under General settings for the path generation method).

  These settings are the same for all scanning methods.

– Define segments (see ➤ *Dividing a curve into segments [➪ 1-86]*).

– Group segments (see ➤ *Grouping segments of a curve [➪ 1-90]*).

– Check the parameters for the scanning method (see ➤ *Scanning method for curves (known contour) [➪ 1-92]* and ➤ *Scanning method for curves (unknown contour) [➪ 1-97]*).

Dividing a curve into segments

The **Strategy** window offers two ways of defining a segment of an existing curve:

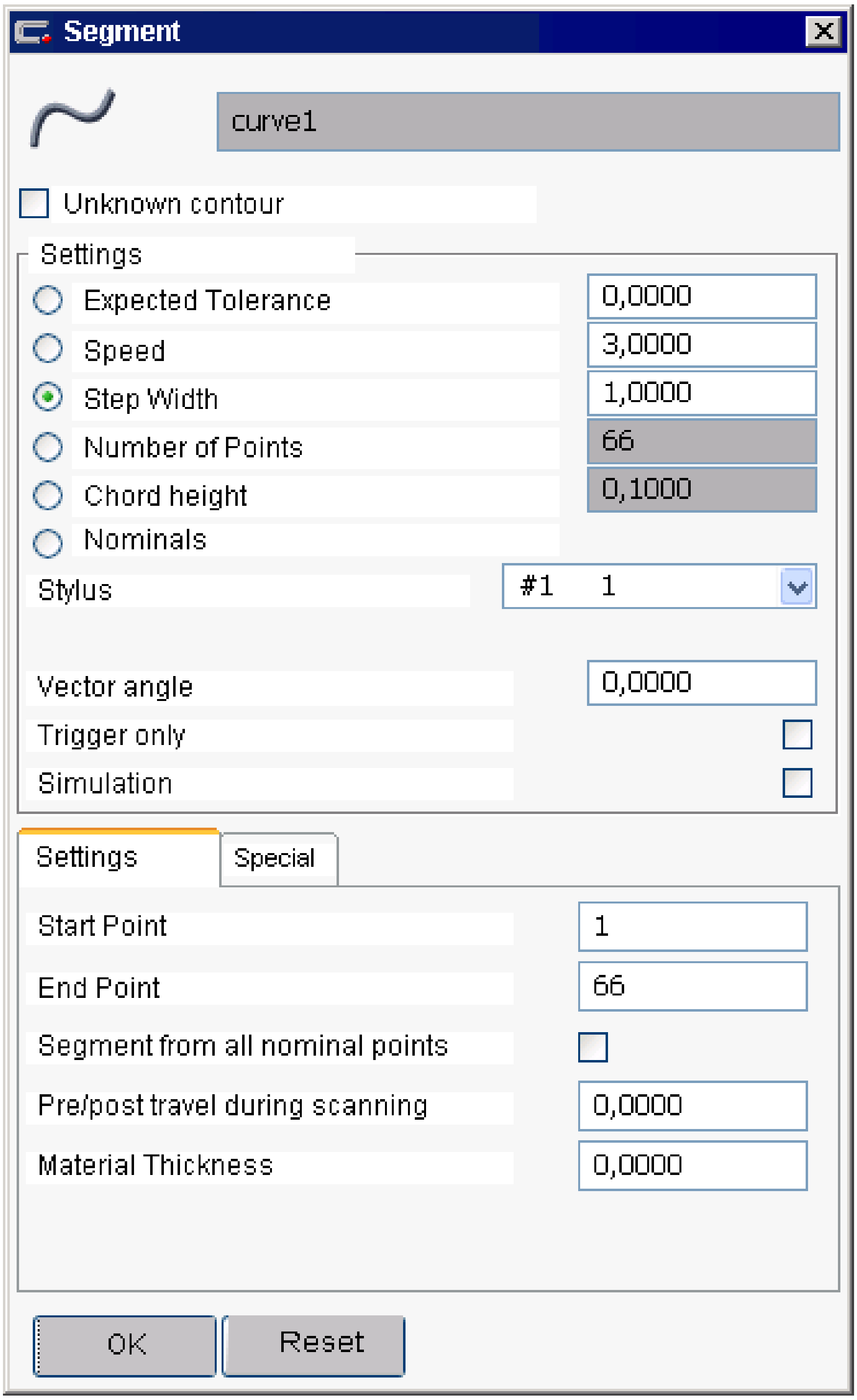
– Specification of start point and end point (consecutive points)

– Specification of individual points (free choice)

Defining a segment from consecutive points

1 Click the **New Curve Segment** button.
A new (as yet undefined) segment is added to the strategy list.

2 Mark the new segment, right-click and select **Edit** from the context menu.
The Segment window is opened.



3 Enter the start point and end point and click **OK** to confirm.
The segment appears in the strategy list.

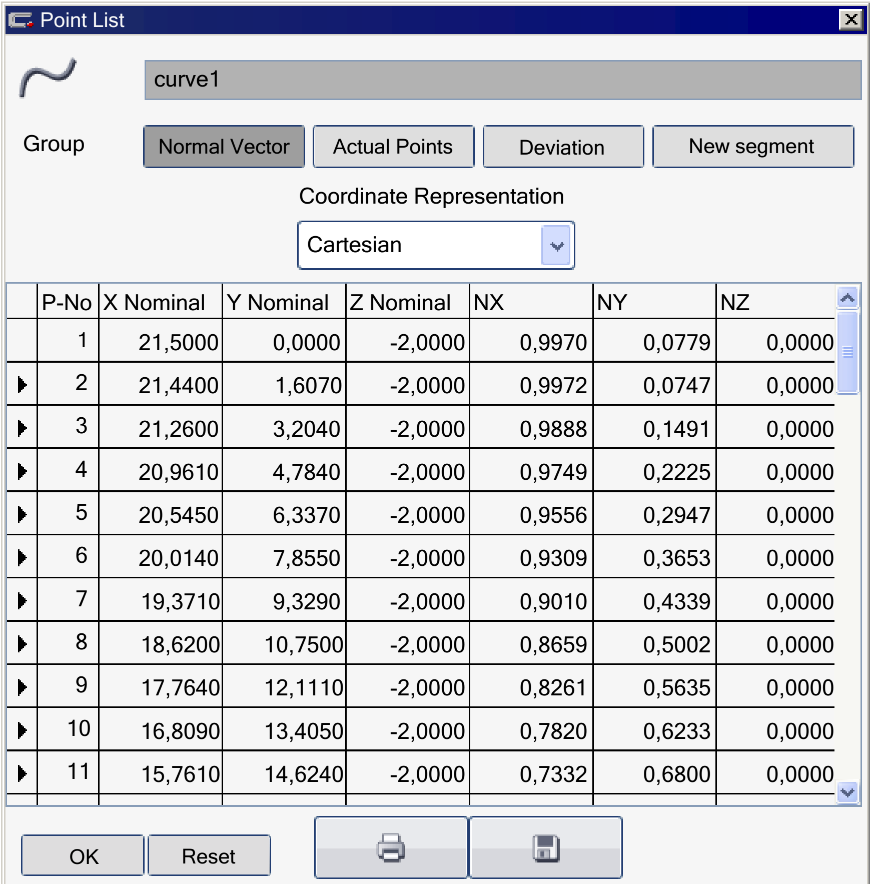
Defining a segment from freely selectable points

1 Click the **Point List** button.
You will see the point list where you define segments.

2 To select adjacent points for a segment:

- Click the point the segment should start with in the first column.
- Press and hold the shift key and click the end point.

All points between the first and the last point you have clicked are marked with an arrow.

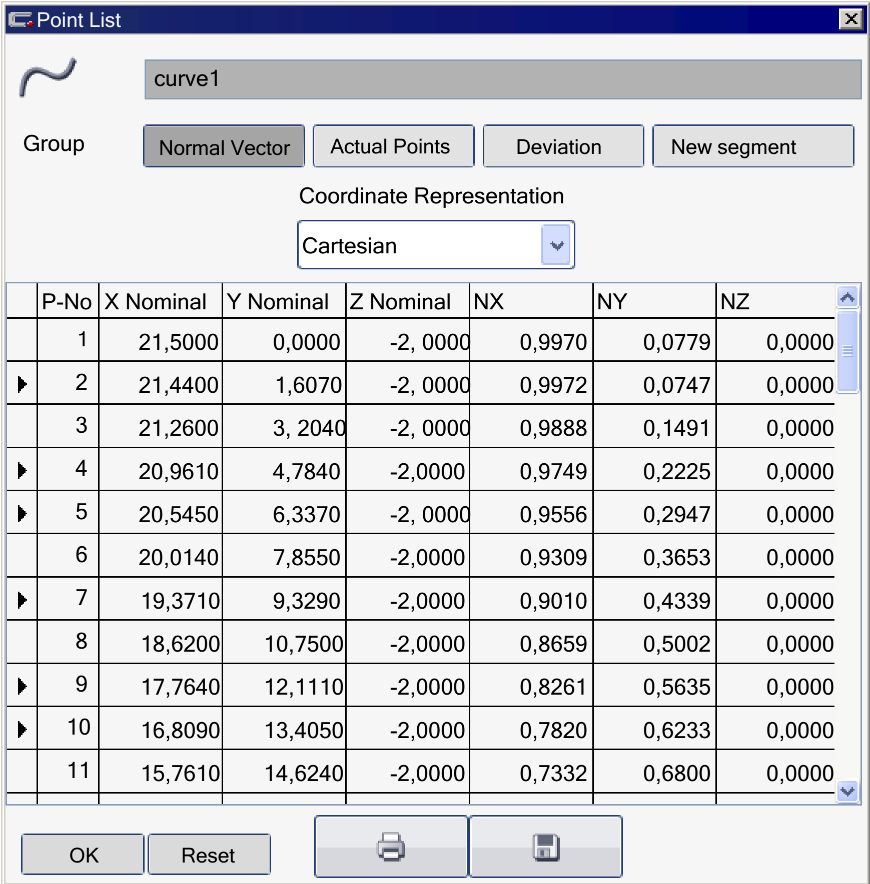


	P-No	X Nominal	Y Nominal	Z Nominal	NX	NY	NZ
	1	21,5000	0,0000	-2,0000	0,9970	0,0779	0,0000
▶	2	21,4400	1,6070	-2,0000	0,9972	0,0747	0,0000
▶	3	21,2600	3,2040	-2,0000	0,9888	0,1491	0,0000
▶	4	20,9610	4,7840	-2,0000	0,9749	0,2225	0,0000
▶	5	20,5450	6,3370	-2,0000	0,9556	0,2947	0,0000
▶	6	20,0140	7,8550	-2,0000	0,9309	0,3653	0,0000
▶	7	19,3710	9,3290	-2,0000	0,9010	0,4339	0,0000
▶	8	18,6200	10,7500	-2,0000	0,8659	0,5002	0,0000
▶	9	17,7640	12,1110	-2,0000	0,8261	0,5635	0,0000
▶	10	16,8090	13,4050	-2,0000	0,7820	0,6233	0,0000
▶	11	15,7610	14,6240	-2,0000	0,7332	0,6800	0,0000

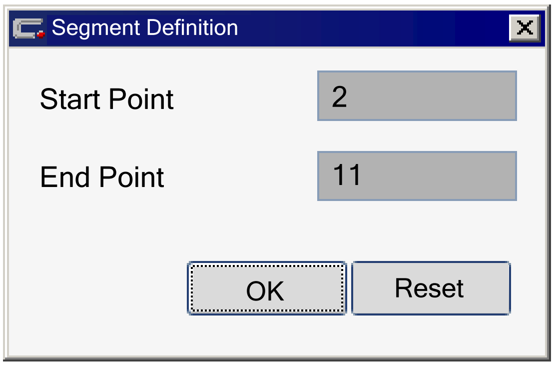
3 To select freely spaced points for a segment:

- Click the point the segment should start with in the first column.
- Press and hold the Ctrl key and click each additional point to be included in the segment.

All points you have clicked are marked with an arrow.



4 Click the **Create Segment** button.
This opens the **Segment Definition** window with the numbers of the start and end point.



5 Click **OK** to close the definition of the segment.

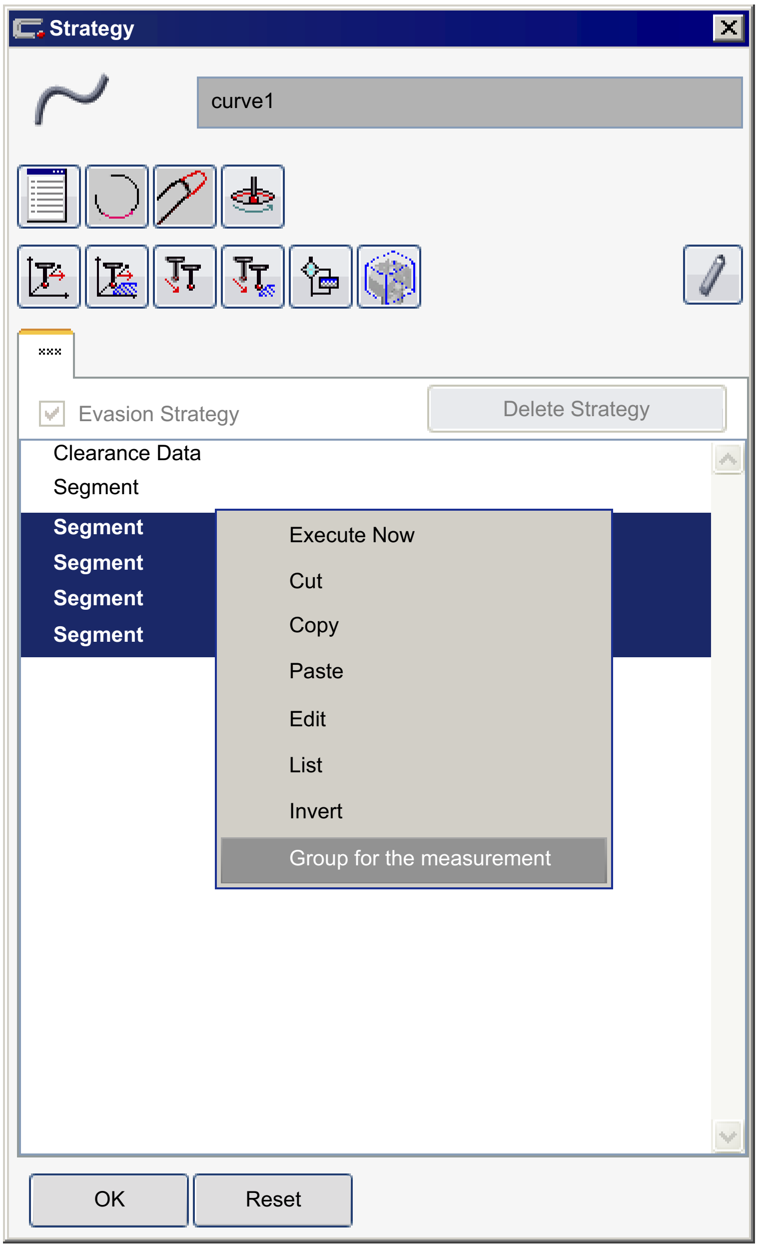
The segment is automatically added to the strategy list.

Grouping segments of a curve

You can group segments that belong together to avoid having to move the stylus to a free position and to approach the curve each time again.

In this case, the segments are considered as a measurement group. For all other segments, the stylus of the first segment will be applied, whereas the angle specifications will be applied for 4-axis scanning.

1 Insert the segments into the strategy window of the curve.



2 Select the segments that belong together and choose **Group for the measurement** in the context menu.
The segments are renamed into **Measurement Group Segment**.
You can ungroup the segments with the same command.

3 Check the specifications for the stylus and the angles in the first segment. The specifications apply to all other segments of the measurement group.

The measurement group is scanned as a single segment during the CNC run. The scanning parameters (step width, speed, etc.) are taken from the individual segments.

Scanning method for curves (known contour)

The scanning method for curves employs nominal values and segments, but points can also be measured between the nominal points. It is also possible to measure and represent the entire curve as a single segment.

Segments of a curve

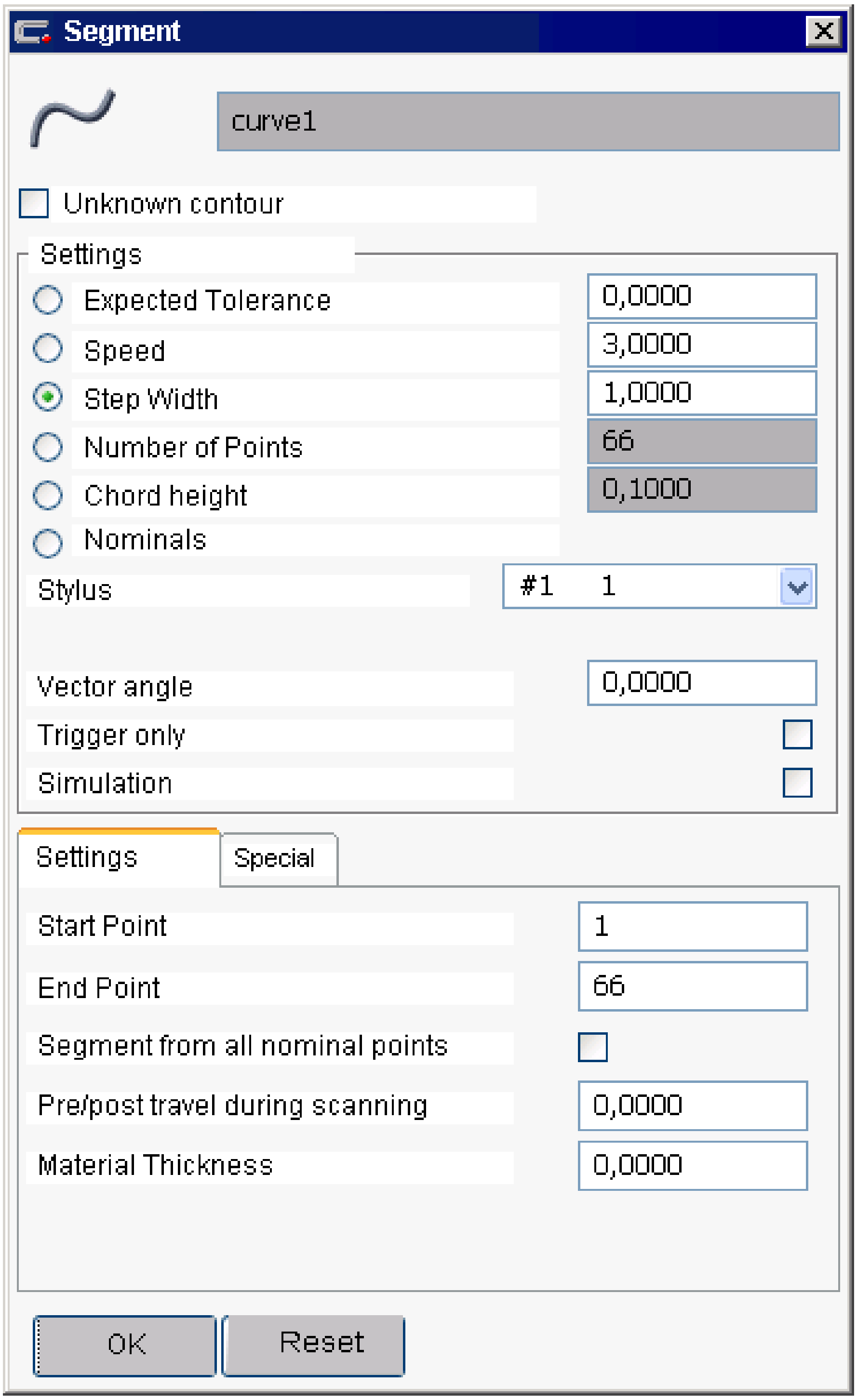
You can measure a segment automatically using a CNC capable CMM. Each curve can be divided into any number of segments, with specific tolerances assigned to the respective segments.

A segment contains any number of points of an existing curve: These points can be selected as sequential points, adjacent points, or freely selected points from the point list.

A segment always has a defined start and end point. A given point can be used in the definition of different segments.

Entry box for scanning curves

The input window for the scanning of curves is shown below.



Pretravel/posttravel during scanning

The following problems can arise at the beginning and at the end of the measuring path in the case of curve measurement and curve evaluation:

– The controller must adjust accordingly.

– The calculation of the spline functions and the corresponding vectors is difficult at the open ends of a curve.

To reduce the effects of these problems, you can define a pre/postscan, also for 4-axis scanning.

The pretravel/posttravel should not exceed 2 mm. Otherwise, the accuracy of the curve extrapolation may no longer be sufficient.

Scanning with rotary table

The curve can be scanned using the rotary table. The **Scan segment with rotary table** check box on the **Rotary Table** tab must be ticked for this purpose.

Select one of the two methods on this tab.

– **Curvature-dependent** The preconditions for this are that a known contour is scanned, the rotary table is activated for the measurement plan and the space axis of the feature on which the curve is located is in the direction of the rotary table axis.

– **Angle Preset** This method (4-axis scanning) is used if different rotary table positions are required or useful for different curve ranges (➤ *Scanning method for curves (angle preset) [⇨ 1-94]*).

Unknown contour

In order to use the movements of the CMM for unknown contours also for scanning a known curve, you can switch the strategy.

Measuring a measurement group

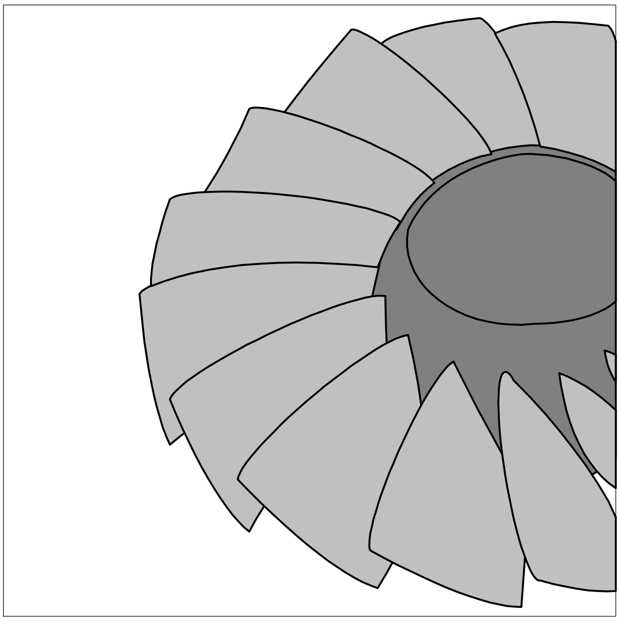
If you want to handle several segments as one segment as regards traveling, you must group them in the strategy list.

In this case, the stylus selected in the first segment applies to all other segments of the measurement group.

Further special features apply to the 4-axis scanning method.

Scanning method for curves (angle preset)

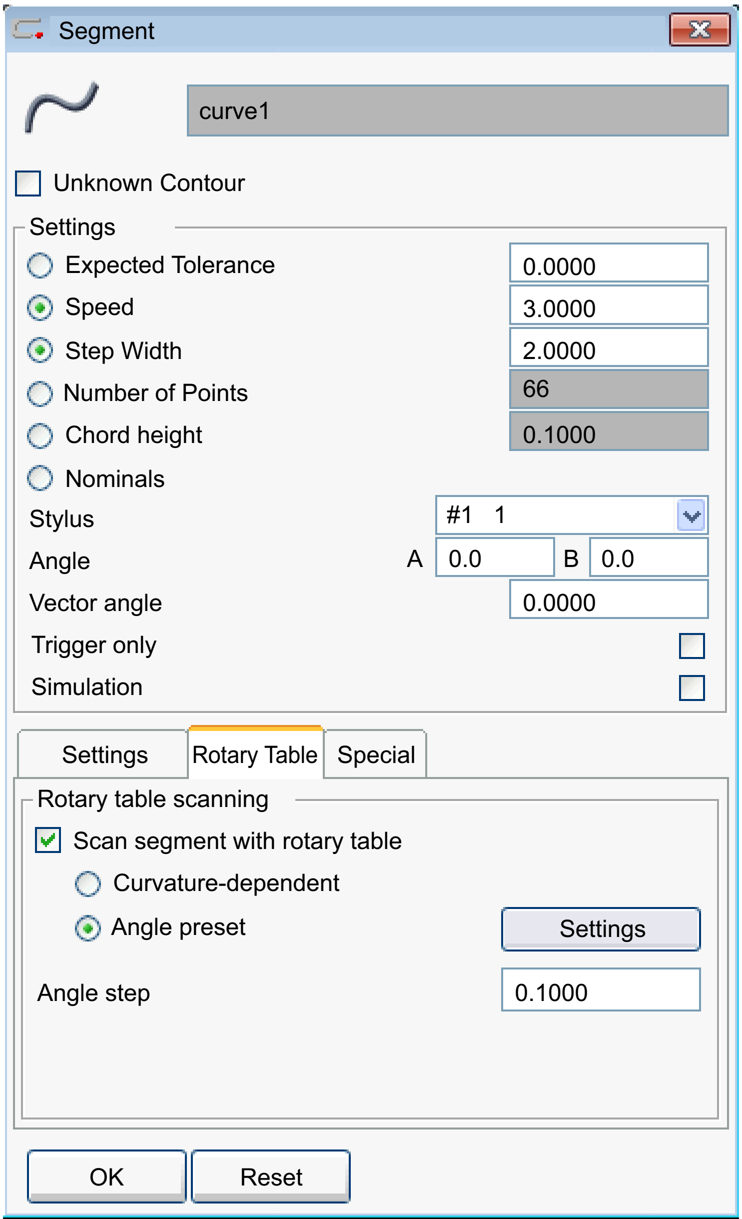
For workpieces which are difficult to access, e.g. very curved and overlapping blades on blisks (integrated blade wheels), frequent stylus changes may be necessary. This can only be avoided by means of the “4-axis scanning” method.



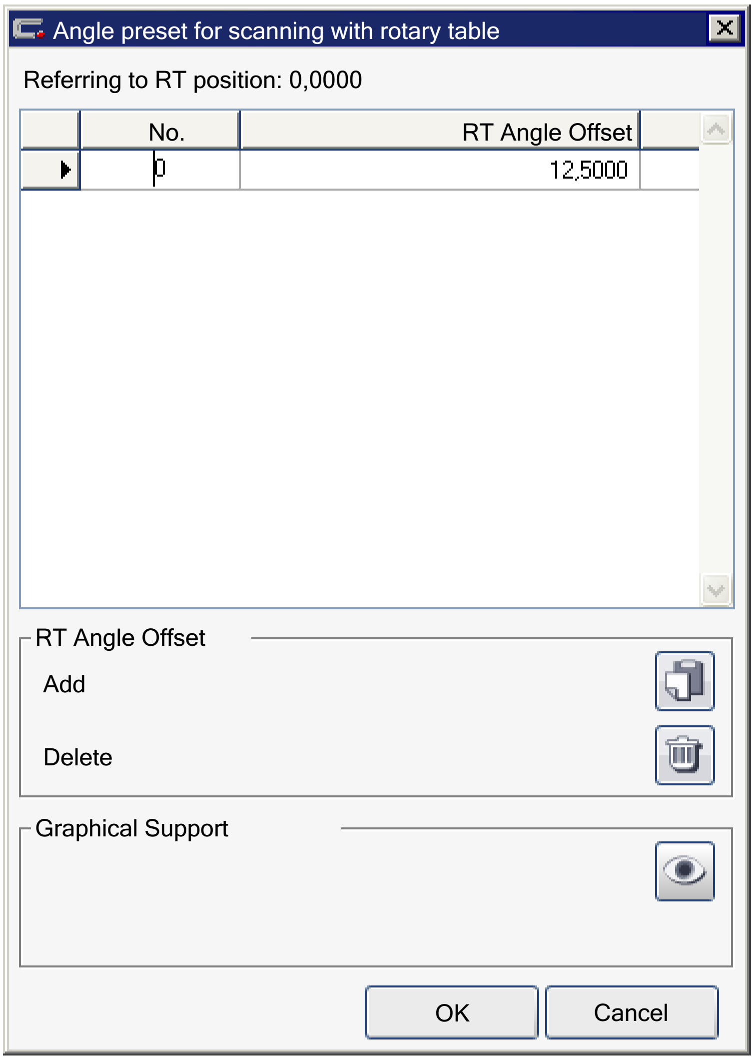
During 4-axis scanning, the rotary table angle is permanently modified during the scanning process which ensures optimum access during the entire measurement.

The prerequisite is that a certain rotary table angle is defined for each point during the segment definition. However, it is sufficient to define “support values” for certain points; CALYPSO interpolates the positions for the points in-between.

To do so, use the scanning method (known contour) and select the **Angle Preset** option for **scanning with rotary table**.



Click **Settings** to open the **Angle preset for scanning with rotary table** window.



Here, you must enter the support points and the corresponding rotary table positions in the list of point numbers. CALYPSO interpolates the positions of the points in-between.

Measuring a measurement group with the 4-axis scanning method

If you want to handle several segments as an individual segment as regards traveling, you must group them in the strategy list.

In this case, you must define all angle positions in the first segment. In the following segments, define the start and end point of the corresponding segment.

Scanning method for curves (unknown contour)

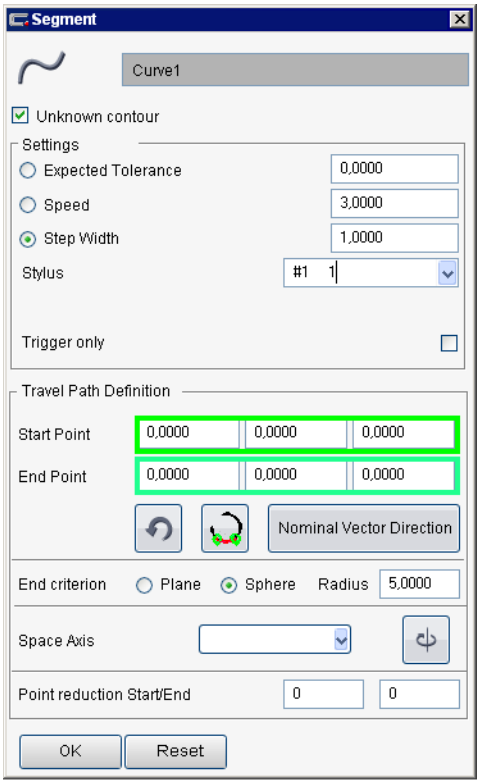
In order to use the movements of the CMM for unknown contours also for scanning a known curve, you can switch the strategy.

NOTE

The stylus used for this procedure should be as small as possible in order to keep the errors resulting from the stylus radius correction and the path inaccuracies to a minimum.

Switching to unknown contour

In the **Segment** window you can switch the strategy to the measurement of an unknown contour by ticking the **Unknown contour** check box. The window changes accordingly:



As the contour is now "unknown" to CALYPSO, the definition of the travel path and an end criterion are required.

To this end, you can use the **Accept points** icon to adopt the start and end points of the segment into the travel path definition and, if required, overwrite them.

The end criterion used is usually the plane whose normal is formed by the line between the start and end points and which runs through the end point.

If the start and end points are identical, no line and thus no plane can be formed. A certain course of a curve can also lead in some cases to a rapid end of the measurement.

With the "Sphere with radius around the end point" end criterion, you can avoid cases of this kind.

Scanning method with nominal contour extension

With turbine blades, the blade lengths may vary by up to 2 mm. The CMM control is generally not able to follow such important changes when scanning according to nominal data.

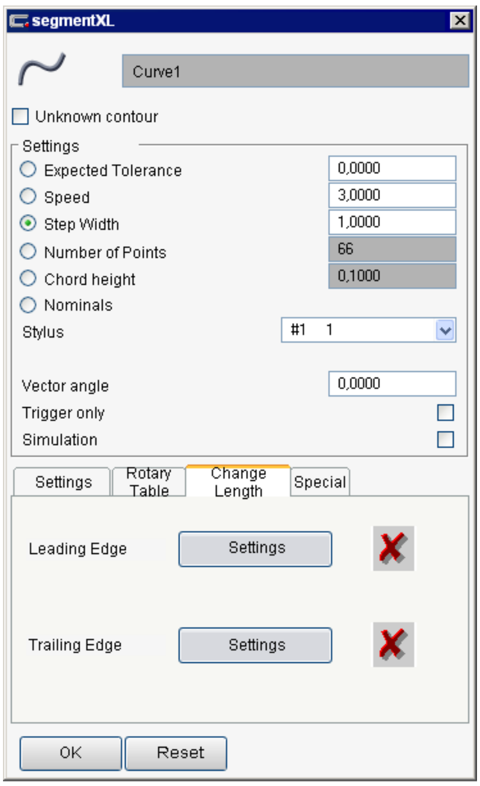
To nevertheless scan the contour as known contour in order to achieve an increased scanning speed, you can modify the curve's nominal values *only for the CMM control* and adapt them to the actual blade length. This is done by stretching or compressing the unchanged number of nominal points along the newly calculated nominal spline

NOTE

As usual, the evaluation only considers the unchanged nominal values. The changed nominal values are only used for controlling the CMM.

Defining the nominal contour extension

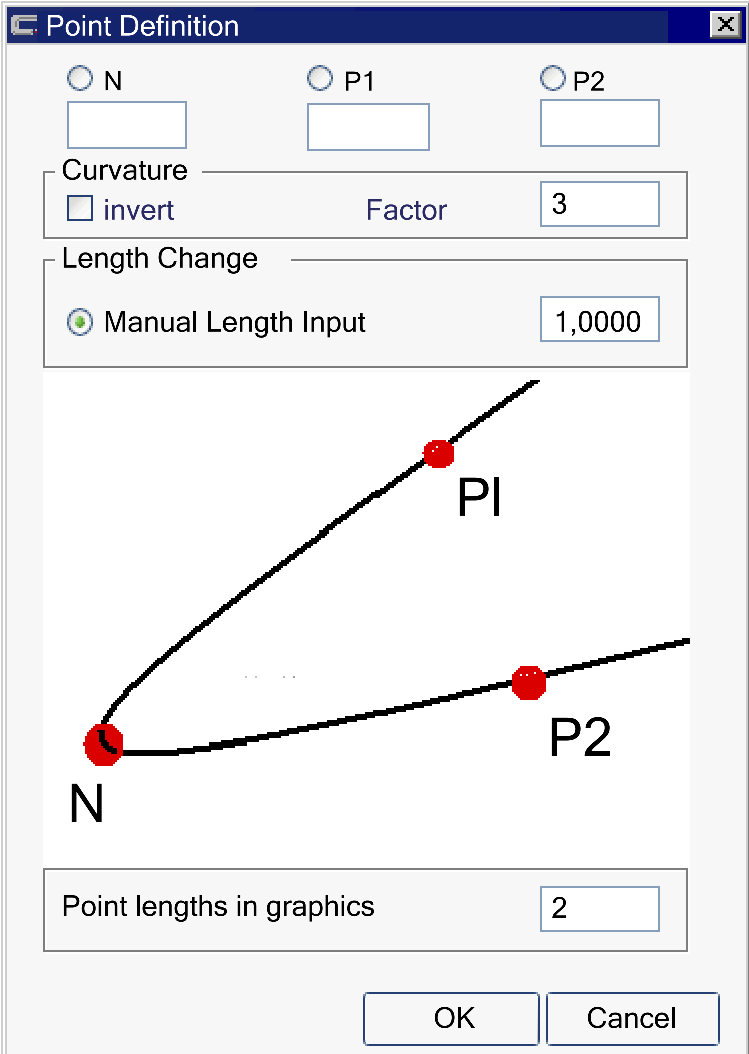
To define the curve's stretching or compression, create a “SegmentXL” strategy in the curve's strategy.



Select the spline extension parameters separately for both sides of the segment on the **Change Length** tab. An icon indicates whether the point definition is complete:

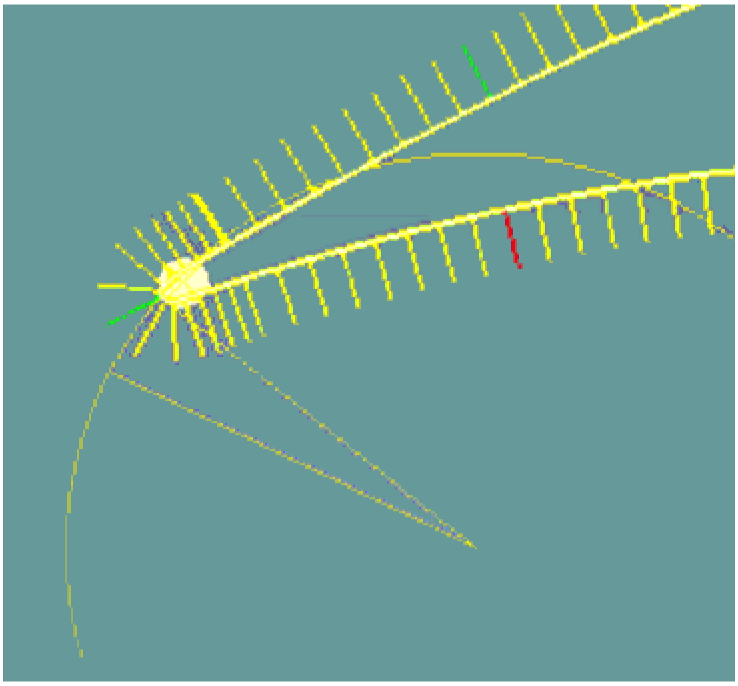
✔	Definition complete
✘	Definition incomplete

Click **Settings** to define the spline modification. Define the required extension in the **Point Definition** dialog box.



The three points N, P1 and P2 can be entered using their point numbers or by clicking them on the CAD model. The current point is highlighted in red in the CAD window, the others are shown in green.

P1 and P2 are used to compute a symmetry point S. The points N and S as well as the radius defined in the **Factor** input field are used to compute a circle. The contour is then extended or reduced along the circular arc by the value entered in the **Length Change** field.

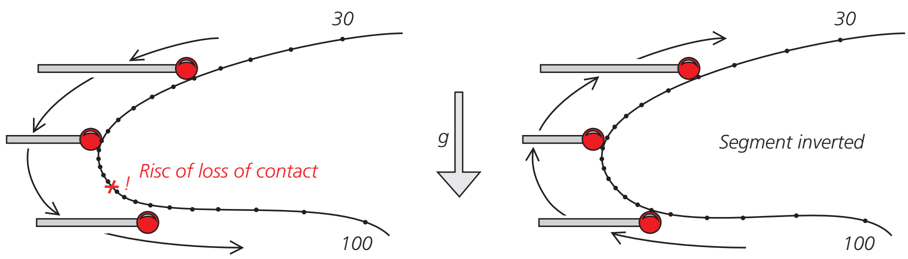


The circle along which the nominal values are to be shifted is drawn in the CAD window. A clever selection of the points and the radius allows you to adjust this circle to the real contour.

Segment measured in reverse direction

If needed, you can reverse the measuring direction for an individual curve segment in order to reduce measuring times and achieve higher accuracy when scanning the contour.

This may be useful for turbine blades and other sharp-edged workpieces. Due to the form of leading edge and trailing edge, the stylus may be more likely to loose contact to the surface in a certain direction, which would lead to measurement errors.



Scanning in the opposite direction prevents the stylus from lifting off at the edges: in this case, the mass of the stylus does not need to be held to the workpiece against the force of gravity.

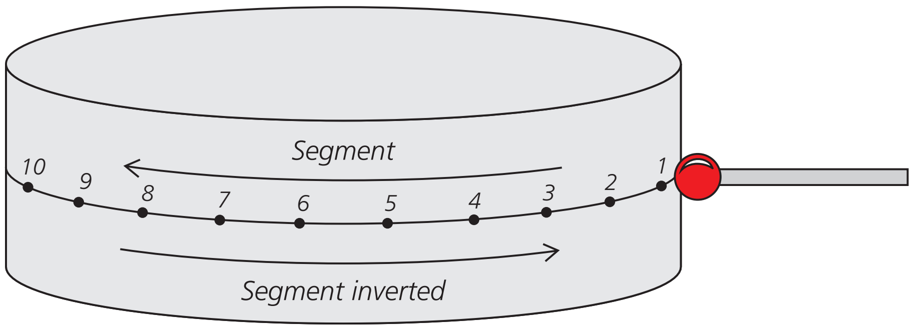
CAUTION

Enter clearance data with intermediate positions before and after an inverted segment to make sure that the stylus can move between the segments without any risk of collision.

There are two options to reverse the measuring direction of a segment: either in the strategy window of the curve or in the definition template of the “Segment” strategy.

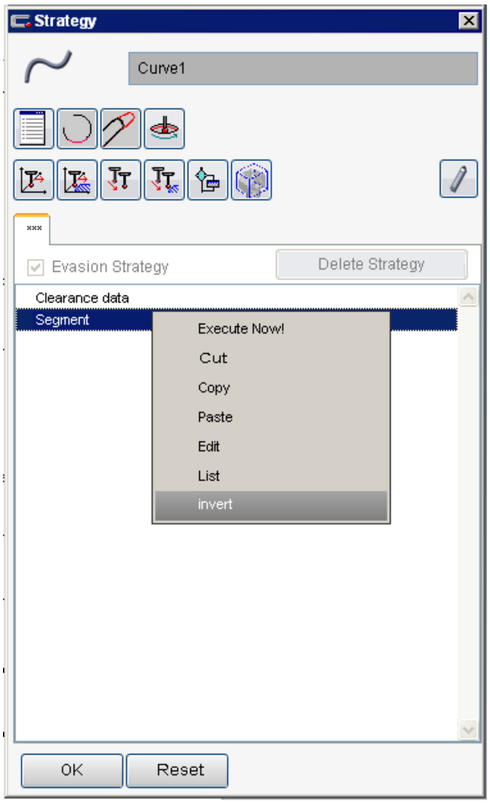
NOTE

Reversing only refers to the measurement. In the evaluation of the measuring results, the points are treated in their normal order.



Inverting a segment

1 Open the strategy window of the curve.



2 Highlight the desired segment and select **Invert** from the segment's context menu.
- or -

Open the strategy window of the desired segment and click the icon for **Reversing the order of the measuring points** under **Settings**.
The entries **Start Point** and **End Point** exchange places.
In the strategy list, the segment is labeled **Segment inverted**.

In the CNC run, the segment is measured in the opposite direction – in the opposite order of the point numbers.

NOTE

Inversion of the segment can be undone in the same way.

Measuring a contour using single points on the rotary table

You can record the nominal data of a contour (curve) as single points using a rotary table.

Conditions

– The curve is a 2D curve.

– The base alignment of the workpiece to be measured is located inside the workpiece.

– During probing, the probe clearing path is guaranteed (collision prevention during rotary table movement).

1 Open the 2D curve definition template.
2 Open the **Strategy** dialog box.
3 Select **New Curve Segment** or **New curve segment with modified length**.
4 If you want to measure nominal points, go to the **Segment** dialog box and activate the **Nominals** option and tick **Trigger only**.
You may also activate the **Step Width**, **Number of Points** or **Chord height** option.
5 On the **Rotary Table** tab, tick the **Scan segment with rotary table** check box.
6 Activate the **Curvature-dependent** option.
7 Accept the settings with **OK**.

Characteristics for the curve

Overview of curve characteristics

Both general characteristics and special curve-specific characteristics can be applied to curves.

The basics of defining special characteristics for curves are the same as for the other characteristics (see in the Basic Operating Instructions under Defining characteristics).

General characteristics

The following characteristics can be used as general characteristics for the curve:

Characteristic	Menu command	Description
X Value	**Size → Standards**	Defines the position of the curve's center of gravity in the X axis.
Y Value	**Size → Standards**	Defines the position of the curve's center of gravity in the Y axis.
Z Value	**Size → Standards**	Defines the position of the curve's center of gravity in the Z axis.
Space Point Distance	**Size → Distance** and **Form and Location → Distance**	Determines the ➤ *distance of a space point or net point [➪ 1-107]* referenced to its nominal value.
Form	**Form and Location**	From the extreme values of features, determines form deviation as the difference between the maximum and minimum measured values perpendicular to the feature.

For curves, too, you can define the characteristics for tolerance in the definition template of the curve feature (see ➤ *Defining tolerances for a curve [➪ 1-59]*).

Special characteristics for the curve

The following characteristics can be used as special characteristics for the curve:

Characteristic	Menu command	Description
Line Profile	**Form and Location**	The ➤ *"Line Profile" characteristic [➪ 1-108]* is used to check the form deviation of a curve.
Curve Slope	**Size → More**	The ➤ *"Curve Slope" characteristic [➪ 1-111]* is used to check the height difference between two defined points of a curve or the difference between the predefined and the achieved height.
Curve Stroke	**Size → More**	The ➤ *"Curve Stroke" characteristic [➪ 1-113]* is used to check the axial and radial deviations of a lift curve.
Curve Distance	**Size → More**	The ➤ *"Curve Distance" characteristic [➪ 1-115]* is used to check the distance between two curves.
Curve Expansion	**Size → More**	The ➤ *"Curve Expansion" characteristic [➪ 1-119]* is used to check the expansion of a curve in a predefined direction.
Curve Length	**Size → More**	The ➤ *"Curve Length" characteristic [➪ 1-120]* is used to check the length of a curve.
Surface Area	**Size → More**	The ➤ *"Surface Area" characteristic [➪ 1-121]* is used to check the surface area of a closed 2D curve.
Curve Form	**Form and Location**	The ➤ *"Curve Form" characteristic [➪ 1-122]* is used to check the compliance with the form of the complete curve or of individual segments.
Curve jump	**Form and Location**	The ➤ *"Curve jump" characteristic [➪ 1-124]* is used to check the importance of the deviation changes in differently definable areas.

Characteristics of cam evaluation

The following characteristics for cam evaluation are available:

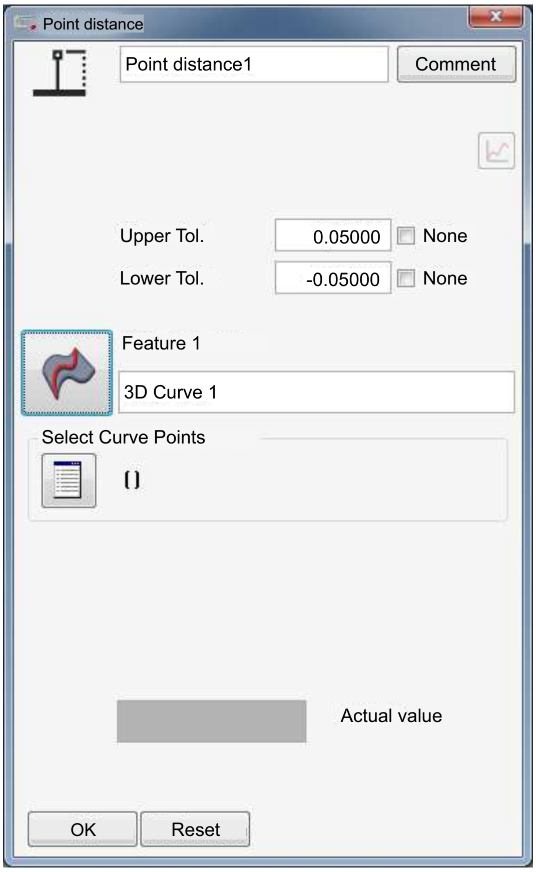
Characteristic	Menu command	Description
Cam lift	**Size → More → Cams**	The ➤ *"Cam lift" characteristic [➪ 1-127]* is used to check the radial lift of a cam curve.
Cam velocity	**Size → More → Cams**	The ➤ *"Cam velocity" characteristic [➪ 1-128]* is used to check the radial lifting speed of a cam curve.

Characteristic		Menu command	Description
Cam acceleration		**Size → More → Cams**	The ➤ *"Cam acceleration" characteristic [⇨ 1-129]* is used to check the radial lift acceleration of a cam curve.

Defining the Distance Between Points characteristic

The "Dist. btw. points" characteristic is used to check the distance between the nominal curve points and the actual curve spline.

You can measure one or several defined points of the curve – the arithmetic average of the deviations will then be calculated.



For this purpose, enter the numbers of the desired points in the **Select Curve Points** dialog, either directly or as a coherent range. The range limits can be parameterized.

Defining the Line Profile characteristic

You can add the Line Profile characteristic to the measurement plan via **Form and Location → Line Profile**.

The characteristic is defined via the definition template. You select a 2D or a 3D curve as the feature.

Direction of deviations

The deviations between the actual contour and the nominal contour are required for the determination of the “Line Profile” characteristic. It is assumed that the values increase in outward direction (away from the material) and decrease in inward direction.

Further considerations are based on the assumption that the deviations increase in outward direction (away from the material) and decrease in inward direction (towards the material).

Tolerance zone shapes

When defining the Line Profile, you can choose from nine Tolerance zone shapes:

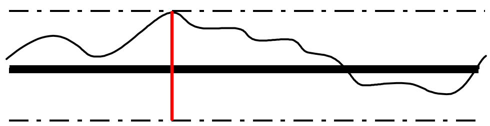
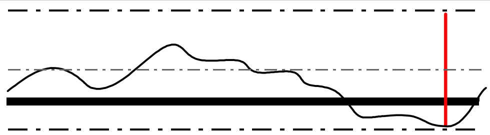
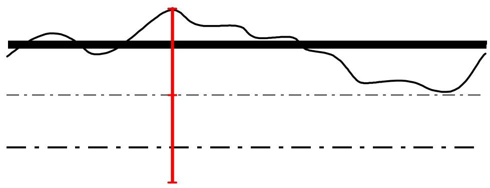
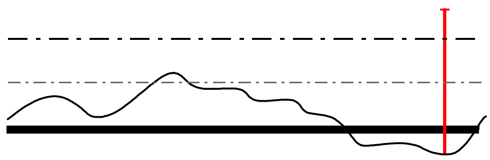
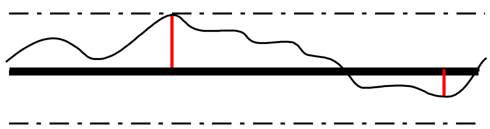
Shape of tolerance zone	The tolerance band is defined by ...
Bilateral - one result	Identical distances from the nominal contour to the inside and outside
Bilateral (unequal distribution) - one result	Unequal distances from the nominal contour to the inside and outside
Unilateral (nominal contour inside)	Nominal contour and distance to the inside
Unilateral (nominal contour outside)	Nominal contour and distance to the outside
Bilateral - two results	Identical distances from the nominal contour to the inside and outside
Bilateral (unequal distribution) - two results	Unequal distances from the nominal contour to the inside and outside
Open outwards	Distance from the nominal contour to the inside
Open inwards	Distance from the nominal contour to the outside
Adopting tolerances from curve	The tolerances of the feature. This allows you to use different tolerances for each point. The tolerances need to be specified in the definition template of the curve. The tolerances of the curve are displayed (except segment tolerances and curve jump tolerances).

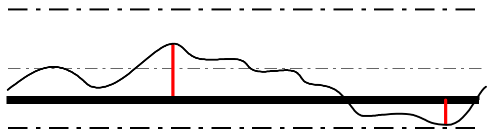
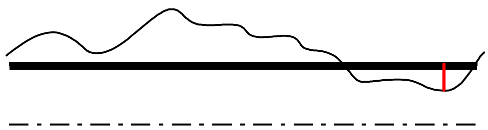
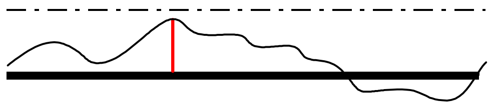
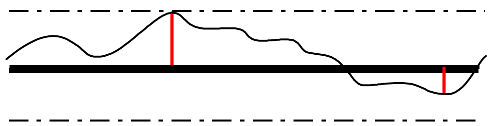
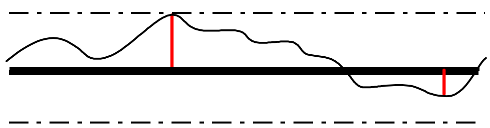
Shape of tolerance zone	The tolerance band is defined by ...
Evaluating tolerance segments individually	The tolerances defined in the feature for the tolerance segments. If several tolerance segments exist in the curve, they will be evaluated individually and output in the printout individually.


For the bilateral tolerance with unequal distribution, a further input field is activated for the **Tolerance (one side)** where you additionally specify the side to which the tolerance applies using the **Inside / Outside Switch** button.

Result of the line profile

The result of the line profile depends on the selected shape of zone.

Shape of tolerance zone	Will be output:	Example
Bilateral - one result	Double the largest deviation (inside and outside)	
Bilateral with unequal distribution - one result	Double the largest deviation (inside and outside) from one of the calculated theoretical center lines	
Unilateral (nominal contour inside)	Double the largest deviation from the tolerance average to the inside or outside	
Unilateral (nominal contour outside)	Double the largest deviation from the tolerance average to the inside or outside	
Bilateral - two results	The largest deviation inside (minimum) and the largest deviation outside (maximum) the workpiece	

Shape of tolerance zone	Will be output:	Example
Bilateral with unequal distribution - two results	The largest deviation inside (minimum) and the largest deviation outside (maximum) the workpiece	
Open outwards	The largest deviation inside the workpiece	
Open inwards	The largest deviation outside the workpiece	
Adopting tolerances from curve	The largest deviation inside (minimum) and the largest deviation outside (maximum) the workpiece, applying the tolerances from the curve.	
Evaluating tolerance segments individually	The largest deviation inside (minimum) and the largest deviation outside (maximum) the workpiece, applying the tolerance segments from the curve and evaluating them individually.	

Limitations

The following restrictions apply to the line profile:

– Negative tolerances are not permitted.

MMC/LMC condition for datums

For the line profile of 2D curves, you can apply the most-material condition or the least-material condition to the datums (exception: **Outwards into infinity** and **Inwards into infinity** shapes of zone).

Additional Printout

By activating **Additional Printout** in the Measurement Plan Editor Characteristics, not only the extreme values but all results will be included in the printouts. Each of these results consists of the nominal and actual value, upper and lower tolerance, error and histogram of the error.

Dependency on the evaluation settings

CALYPSO uses the Gaussian Best Fit method for determining the line profile. Best fit into the tolerance band will only be used for 2D curves with MMC/LMC.

The evaluation settings (outlier, filter, offset, evaluation direction, stylus correction, etc.) valid for the corresponding curve are used for the best fit alignment. For this reason, the result of the line profile will change if you change the parameters for curve evaluation.

NOTE
As the spline filter is only used for the measuring points and not for the deviations of the measured points, larger deviations may result from the distance evaluation. This especially refers to the spline ends with open contours and areas that are subject to a high degree of curvature changes. Do not use the spline filter in such cases.

Defining the Curve Slope characteristic

The “Curve Slope” characteristic is used to check a 3D lift curve or a 2D spiral curve for one of the two following criteria:

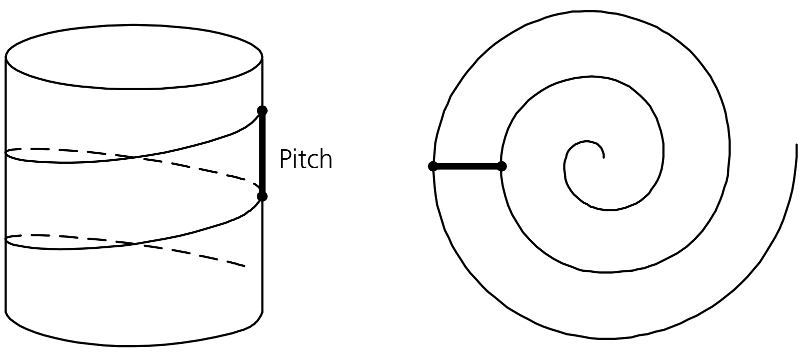
– *Pitch*

  The pitch is the difference in height or radius between two defined points of the curve. It can be specified as absolute value or relative to the angle of rotation.

– *Pitch Error*

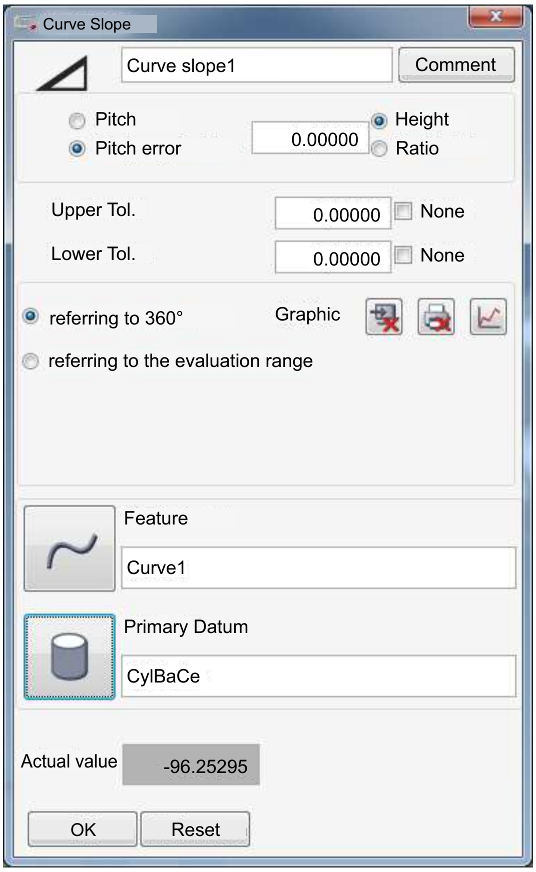
  The pitch error is the deviation (in mm) of the slope from a defined height or radius difference.

For lift curves, the heights are calculated in the polar coordinate system of the lift curve (height parallel to rotation axis). For spiral curves, the “heights” are calculated as radius to the given angle of rotation.



Lift curve Spiral curve

Add the “Curve Slope” characteristic to the measurement plan via **Size → More → Curve Slope**. Use the definition template to define it.



The following table describes the buttons and fields that are not common to other characteristics:

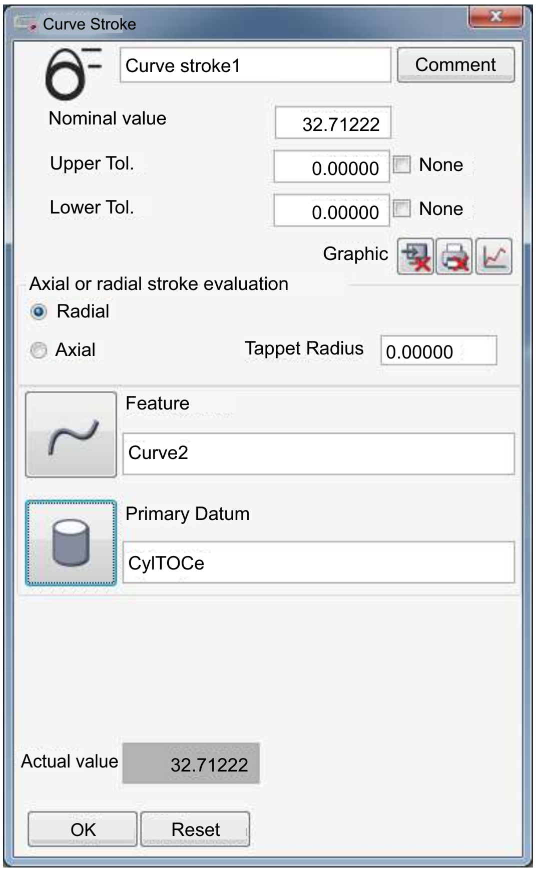
Dialog element	Function
Pitch	The characteristic compares the slope of the curve with respect to the nominal value which can be specified as absolute **height** or as **ratio** (height/path).
Pitch Error	The characteristic checks the deviation of the curve slope from the nominal value.
Upper Tol. **Lower Tol.**	When checking the pitch, input of the upper and lower tolerance is possible.
Tolerance	When checking the pitch error, only one tolerance can be specified. The pitch error may be positive or negative.

Dialog element	Function
Referenced to ...	**360°**: The curve slope is calculated for the entire scope. **Evaluation Range**: The curve slope is calculated for a certain range. There are three ways to specify the two points between which the slope is determined: – by specifying two point numbers – by specifying the start and end angle (only lift curve) – by specifying a start and end height (only lift curve) If the angle or height specification does not meet with a point exactly, the next point will be used. By clicking **Entire Curve**, the evaluation from the first to the last curve point is performed. The corresponding angles and heights will also be entered.
Feature	Select the curve to be checked.
Primary Datum	Select here the datum that defines the rotation axis (and the center) of the lift curve (in general a circle).

Defining the Curve Stroke characteristic

The “Curve Stroke” characteristic is used to check the axial and radial deviations of a lift curve.

Add the “Curve Stroke” characteristic to the measurement plan via **Size → More → Curve Stroke**. Use the definition template to define it.



The following table describes the buttons and fields that are not common to other characteristics:

Dialog element	Function
Axial or radial stroke evaluation	For stroke evaluation, select here the direction in which the deviations are to be determined: – **Radial**: perpendicular to the rotation axis – **Axial**: parallel to the rotation axis Enter the **Tappet Radius** if the results should refer to the tappet center and not to the surface.
Feature	Select the curve to be checked: – with radial stroke evaluation, the 2D curve to be checked (lift curve) – with axial stroke evaluation, the 3D curve to be checked (lift curve)

Dialog element	Function
Primary Datum	Select the datum here: – With radial stroke evaluation, the base circle. *Notice*: From CALYPSO 2017, the calculated actual value of the base circle radius is used by default. If you want to use the nominal value of the base circle radius, as was done in previous versions, disable **Cam evaluation: lift calculation with calculated base circle radius** in the Compatibility settings. – with axial stroke evaluation, the plane perpendicular to the rotation axis to which the nominal lift data refer (if specification is omitted, the corresponding coordinate plane of the base alignment is used).
Deviation	Shows the extreme deviations and their difference: **Upper**: The maximum deviation in the positive direction of the normal vector (“too much material”). **Range**: Shows the difference range between upper and lower deviations.. **Lower**: The maximum deviation in the negative direction of the normal vector (“too little material”).

NOTE

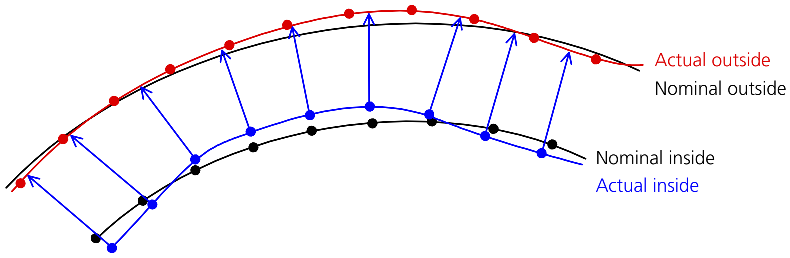
For radial evaluation of 2D curves, the **Radial Deviation** deviation calculation must be entered in the Curve feature.

For axial evaluation of 3D curves, the **Nominal Vector Direction** deviation calculation must be entered in the Curve feature.

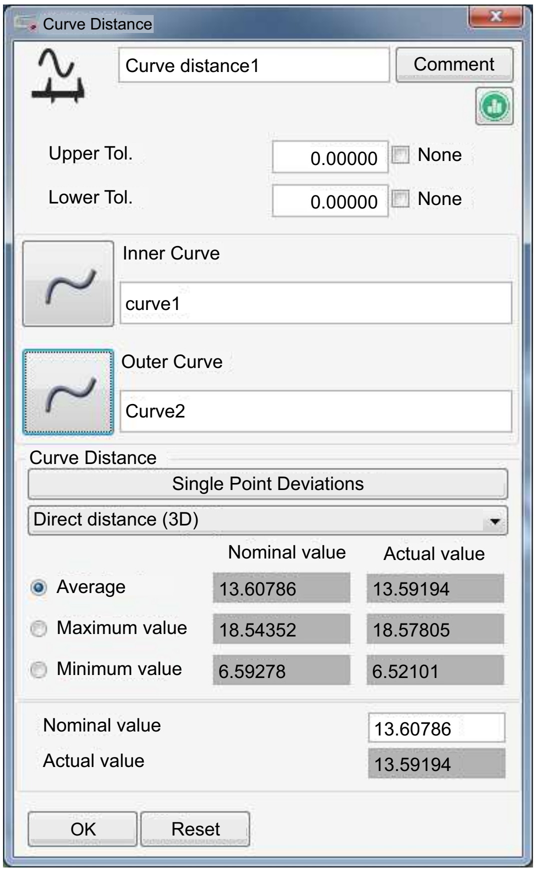
Defining the Curve Distance characteristic

The “Curve Distance” characteristic is used to check the distance between two curves, e.g. for the determination of the brake disk coarse of thickness.

- The nominal distance is constant in the case of equidistant curves. The characteristic allows checking the minimum, maximum or the average distance.
- In the case of different curve pairs, CALYPSO checks for each point of the inner curve the distance to the outer curve, comparing nominal and actual distance.



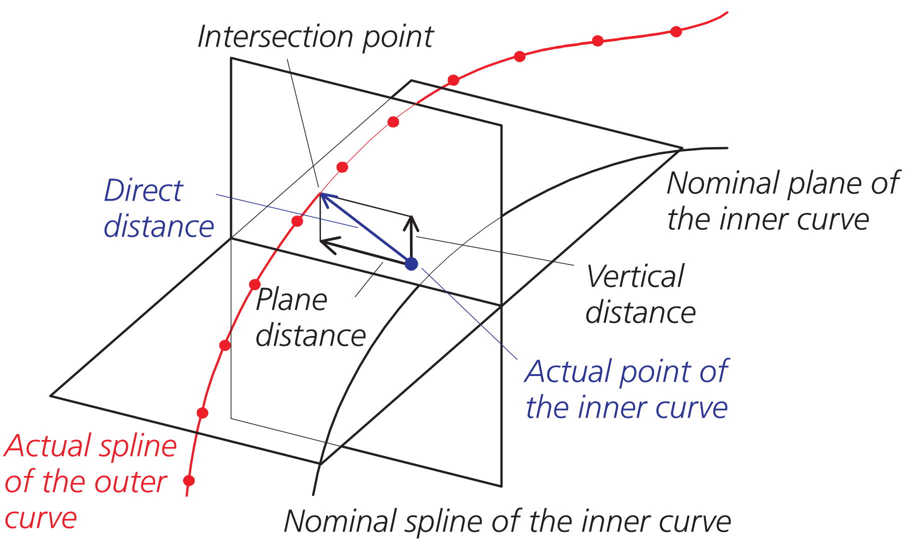
Add the “Curve Distance” characteristic to the measurement plan via **Size → More → Curve Distance**. Use the definition template to define it.



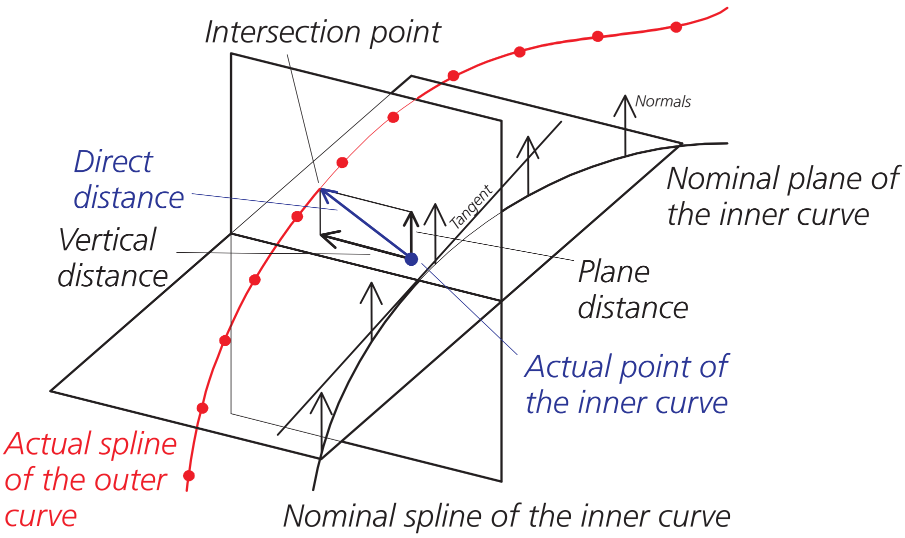
The following table describes the buttons and fields that are not common to other characteristics:

Dialog element	Function
Inner Curve	Select the curve to be checked.
Outer Curve	Enter the curve for which the distance should be checked.
Curve Distance	
Single Point Deviations	Opens the **Single Point Deviations** window, listing all deviations between the actual and nominal distance.
Calculation method	Select here the *type of calculation* of the distance: – **Direct Distance (3D)**: spatial distance between an actual point of the inner curve and the intersection point of the plane that is perpendicular to the tangent of the inner curve with the outer curve – **Plane Distance (in direction of nominal normal**: direct distance (3D), projected onto the nominal normal of the inner curve – **Distance vertical to normals and tangents**: direct distance (3D), projected perpendicularly to the nominal normal direction and perpendicularly to the tangent of the inner curve
Type of inspection	Select the *distance to be checked*: – **Average** (the arithmetic average resulting from all distances to the reference curve) – **Maximum Value** (the largest distance to the reference curve) – **Minimum Value** (the smallest distance to the reference curve)

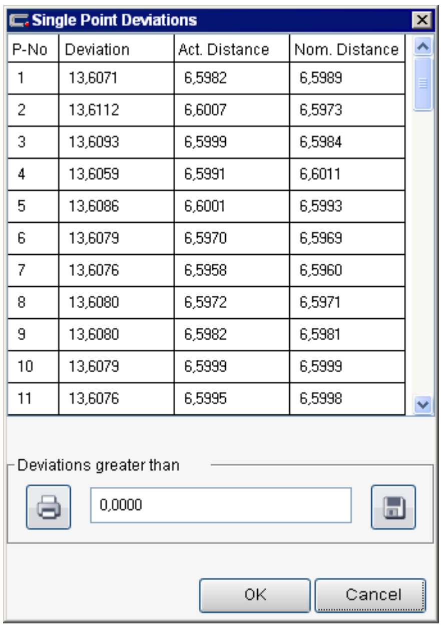
This illustration shows the methods for calculating the curve distance with nominal normals in the nominal plane:



This illustration shows the methods for calculating the curve distance with nominal normals perpendicular to the nominal plane:



Single Point Deviations After the measurement, you can find the distance of each point of the inner curve in the Single Point Deviations window.



P-No	Deviation	Act. Distance	Nom. Distance
1	13,6071	6,5982	6,5989
2	13,6112	6,6007	6,5973
3	13,6093	6,5999	6,5984
4	13,6059	6,5991	6,6011
5	13,6086	6,6001	6,5993
6	13,6079	6,5970	6,5969
7	13,6076	6,5958	6,5960
8	13,6080	6,5972	6,5971
9	13,6080	6,5982	6,5981
10	13,6079	6,5999	6,5999
11	13,6076	6,5995	6,5998

Calculation and output Regardless of the criterion you wish to check, calculation will always be done for all three values (maximum value, minimum value, average). For the maximum and minimum value, the coordinates of the corresponding measurement points will also be included in the printout.

Access via formula The Formula window allows to access the following results of the characteristic:

– **actual**: actual value of the criterion to be checked

– **x**, **y**, **z**: coordinates of the corresponding measurement point (not for average)

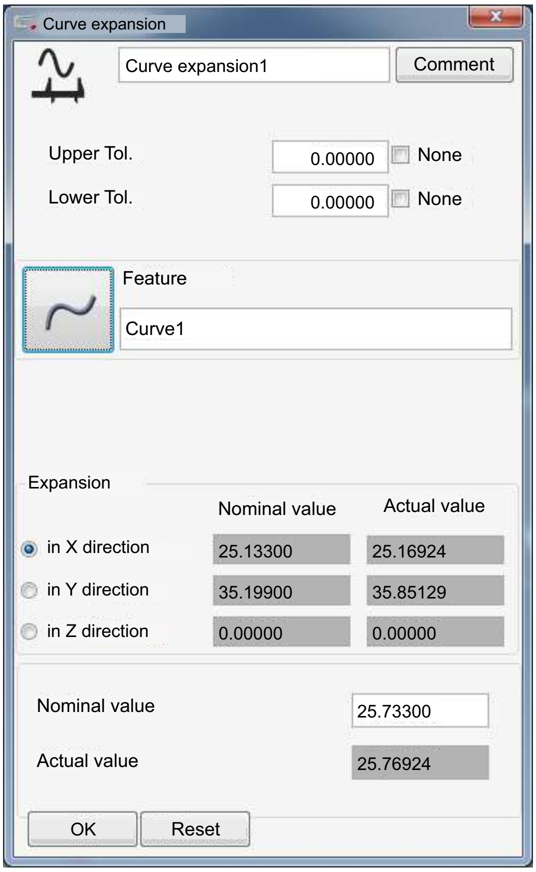
Form plots for the curve distance

The **Graphics Element** utility allows you to output various form plots for the curve distance. For details, see the Basic Operating Instructions Outputting form and location plots with the graphics elements. Illustrative graphics and explanations can be found in the subchapter Curve distance plots.

Defining the Curve Expansion characteristic

The “Curve Expansion” characteristic is used to check the expansion of a curve in a predefined direction in the same way as with a caliper gage.

Add the “Curve Expansion” characteristic to the measurement plan via **Size → More → Curve Expansion**. Use the definition template to define it.

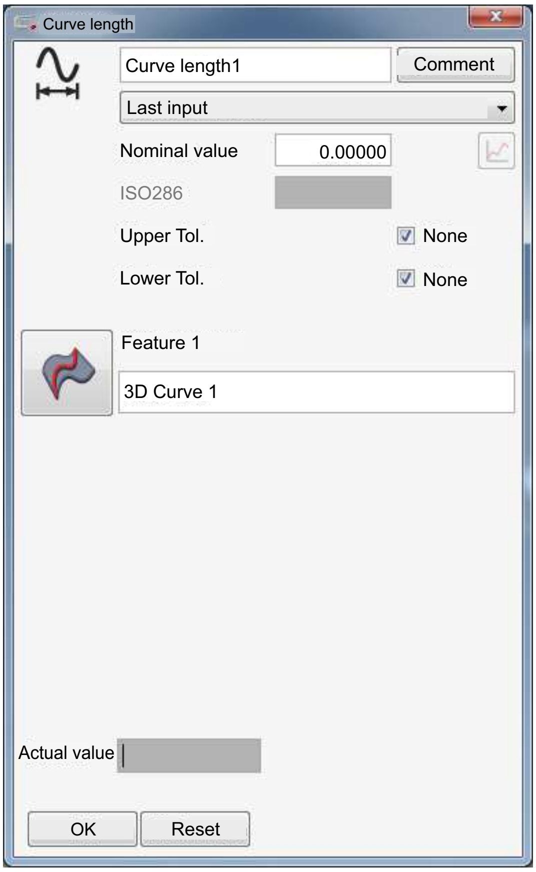


The following table describes the buttons and fields that are not common to other characteristics:

Dialog element	Function
Feature	Select the curve to be checked.
Expansion	Choose the axis direction in which the maximum expansion is to be calculated. The nominal and actual values of the expansion referenced to the current coordinate system are shown on the right-hand side.
Nominal Value / Actual Value	The nominal and actual values of the expansion referenced to the current alignment.

Defining the Curve Length characteristic

Add the “Curve Length” characteristic to the measurement plan via **Size → More → Curve Length**. Use the definition template to define it.



In the definition template there are no features deviating from the usual ones. You select the feature and define the tolerances.

Calculation mode

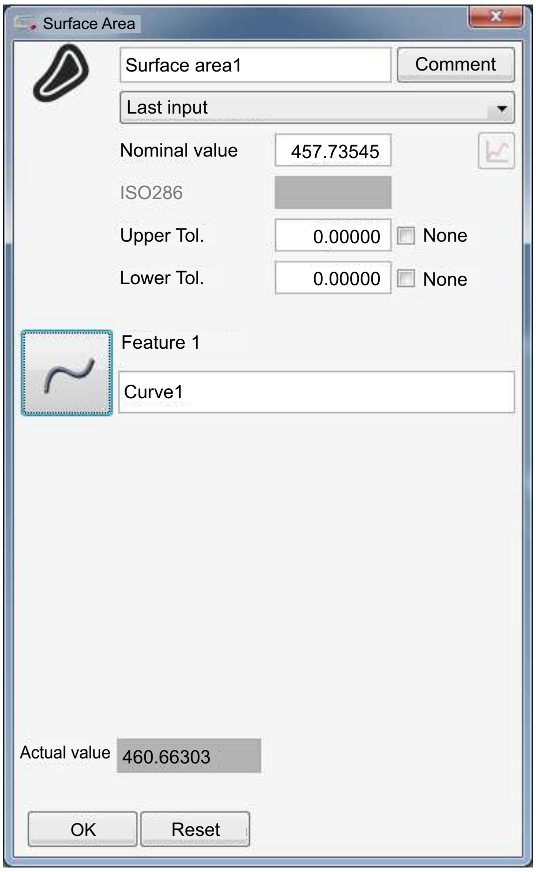
Based on the relevant measured points, the curve length is calculated as follows:

– for distance evaluation “Act – Nom”: Length of the spline that is defined by the relevant (being included in the evaluation), corrected actual points.

– for all other distance evaluations: Length of the spline that is defined by the intersection points of the actual spline (by the radius-adjusted actual points) with the vectors of the nominal points.

Defining the Surface Area characteristic

Add the “Surface area” characteristic to the measurement plan via **Size → More → Surface Area**. Use the definition template to define it.

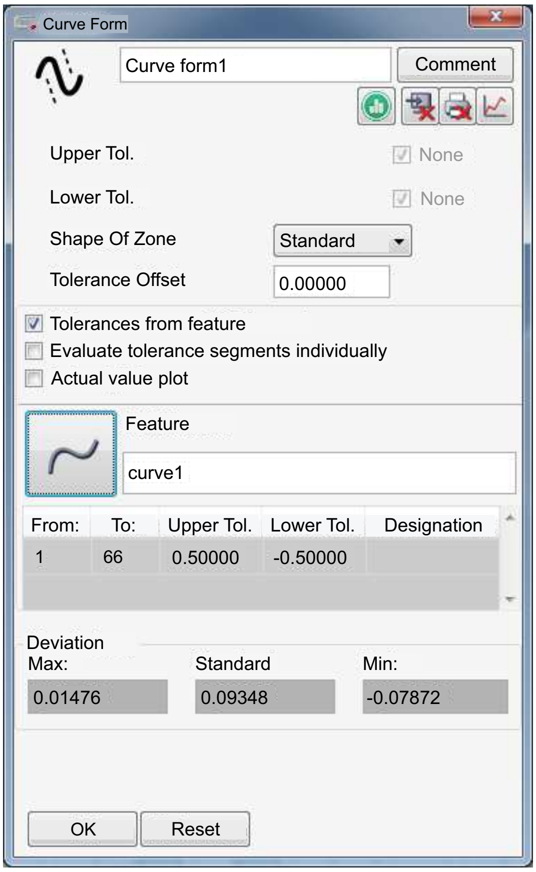


In the definition template there are no features deviating from the usual ones. You select the feature and define the tolerances.

The Surface Area characteristic calculates the surface area of a closed 2D curve.

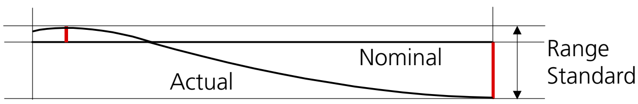
Defining the Curve Form characteristic

You can add the “Curve Form” characteristic to the measurement plan via **Form and Location → Curve Form**. Use the definition template to define it.

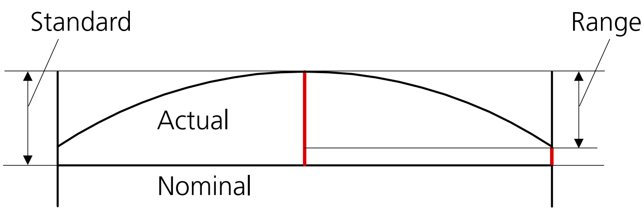


Standard and range

There are two types of deviation calculation – standard and range – for the “Curve Form” characteristic.



The results of both calculation methods are only different if both, the maximum and the minimum nominal-actual difference lie on one side of the nominal curve.



The following table describes the buttons and fields that are not common to other characteristics:

Dialog element	Function
Upper Tol.	Input box for the upper tolerance. Formula input is possible.
Lower Tol.	Input box for the lower tolerance. Formula input is possible.
None	Suppresses consideration of upper and lower tolerances for measurement evaluation.
Tolerance form	Defines the type of form tolerance: **Standard**: The curve is within the tolerance if the curve points lie in a range between the outer and inner equidistants and the nominal curve. **Range**: The curve is within the tolerance if the difference between the largest and the smallest deviation does not exceed the tolerance dimension.
Tolerance Offset	The value entered here is added to the upper and lower tolerance prior to the evaluation. This makes it possible to measure several parallel curves with one single characteristic.
Tolerances from feature	Instead of the tolerances specified above, the values from the assigned Curve feature are used.
Evaluating tolerance segments individually	The tolerances defined in the Curve feature for the individual tolerance segments are used. The tolerance segments are evaluated individually and represented in the printout. *Notice*: Only available if **Segment tolerances** has been enabled in the feature.
Actual Value Plot	Activates the settings for the actual value plot: **Default Actual Value Plot**: The measured points are output with a value corrected by the stylus radius. **Projected + corrected points**: For the plot, the measured points are projected into the projection plane of the curve and corrected by the stylus radius along the normal vectors turned into the projection plane. **Projected + BLADE PRO Export**: For the plot, the measured points are projected into the projection plane of the curve and corrected by the stylus radius along the normal vectors turned into the projection plane. Subsequently, the XML data is generated in BLADE-PRO export format. **With masked points**: For better recognition of the transitions at the gaps, the plot also includes the points that were masked for the evaluation. These points will not be taken into account for the calculation of the measurement result.

Dialog element	Function	
Feature	Shows the feature for which the characteristic is defined or assigns the feature to a characteristic. A feature defined before the characteristic was called is entered on the button and in the input field. By clicking the button, you can call the **Selection (Feature)** dialog box to accept, redefine or edit a feature. You can enter the name of an already existing feature and confirm it by pressing Tab, Return or by clicking  or reject it with ESC or by clicking .	
Table	Displays the tolerance segments defined in the Curve feature with their tolerances and designations.	
Deviation	**Top**	The maximum deviation in the positive direction of the normal vector ("too much material").
	Bottom	The maximum deviation in the negative direction of the normal vector ("too little material").
	Standard	(only if **Standard** is selected as the **Shape Of Zone**) The maximum from the difference between the greatest and smallest deviation and the maximum absolute nominal-actual deviation.
	Range	(only if **Range** is selected as the **Shape of Zone**) Difference between upper and lower deviations.

Defining the Curve Jump characteristic

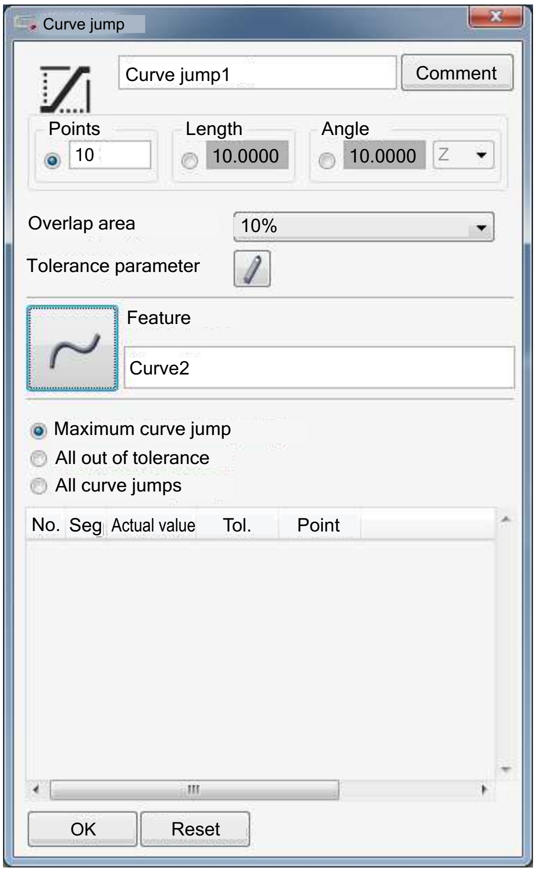
The "Curve jump" characteristic allows you to measure the maximum differences between the nominal-actual deviations within defined curve sections. You can define these sections in different ways. You may also vary the sections' degree of overlapping. The tolerance can be specified as one value for the entire curve or differently depending on the curve section.

NOTE

Only in measurement plans created with versions earlier than CALYPSO 2017, you can define the curve jump tolerance also in the definition template of the Curve feature. However, in this case, the measuring ranges can only be defined as ranges consisting of n+1 neighboring points.

Definition template

You can add the “Curve Jump” characteristic to the measurement plan via **Form and Location → Curve Jump**. Use the definition template to define it.



The following table describes the buttons and fields that are not common to other characteristics:

Dialog element	Function
Measuring range	Select here how to define the measuring range and specify its size. – **Points**: Enter the number of points per measuring range. – **Angle**: Specify the measuring range as an angle range. The curve's local feature alignment is the datum. It is displayed in the CAD window. – **Length**: Specify the length of the measuring range.

Dialog element	Function
Overlap area	Define here the degree of overlapping of the measuring ranges in %. – 0% means *no* overlapping, thus smooth transition between the ranges. – 100% means *complete* overlapping *with the exception of* one point or 0.5° or 0.1 mm.
Tolerance parameter	Opens the **Create Tolerance Segments** window, allowing you to specify the curve jump tolerance value. This is where you can divide the curve into segments and define different tolerances for each segment.
Result Selection	Select here the result output mode: – **Maximum curve jump**: displays only the maximum curve jump. – **All out of tolerance**: displays all curve jumps out of tolerance. – **All curve jumps**: displays all curve jumps for all measuring ranges. *Notice*: Bear in mind that this list may become very long in case of strong overlapping.
List	Displays the curve jumps determined according to the selection made (see above). The maximum value always appears in the first line. The currently selected segment is highlighted in the CAD window. The columns have the following meanings: – **No.** : serial number of the curve jump. – **Seg**: number of the tolerance segment., – **Actual**: curve jump value. – **Tol**: tolerance value of the segment. – **Start (No.)**: start number, start angle, or start length of the segment. – **Status**: curve jump status.

Special aspects for ranges based on angles

When specifying measuring ranges based on angles, you need to consider the direction of the curve points. The curve's coordinate system is displayed in the CAD window to assist you. The angles and the direction of the curve refer to this coordinate system.

If the curve points are numbered in mathematical positive direction, specify the angles in positive direction. In the other case, specify them in negative direction.

Special aspects for ranges based on lengths

If you define the measuring ranges based on length values, computation in CALYPSO will take longer, since the exact arc length needs to be calculated for the curve length. An evaluation based on length segments is therefore not recommended for curves with more than 500 nominal points!

Result output

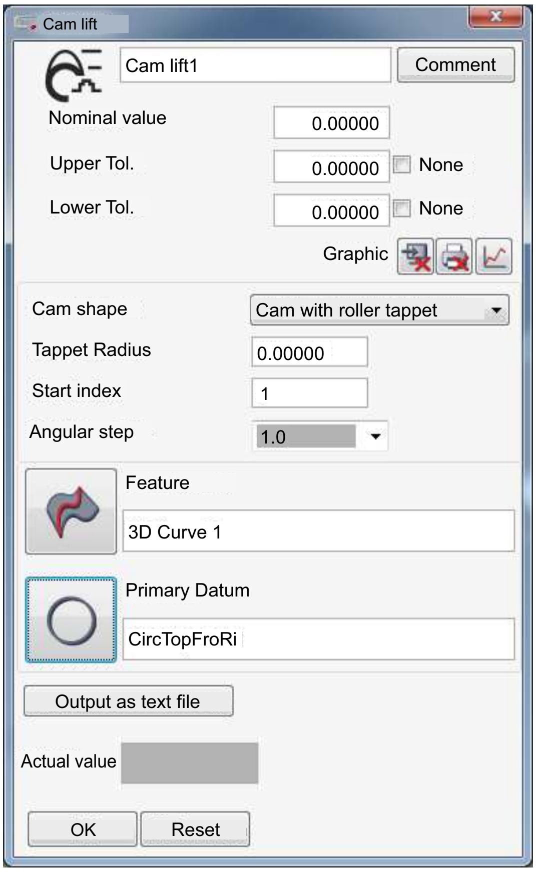
Results will be output in the custom printout and the compact printout according to the settings made in the definition template.

The maximum curve jump value will be transferred to PiWeb reporting.

Defining the Cam Lift characteristic

The “Cam lift” characteristic is used to measure the lift of a cam curve (radial closed 2D curve) in a predefined direction.

Add the “Cam lift” characteristic to the measurement plan via **Size → More → Cams → Cam lift**. Use the definition template to define it.



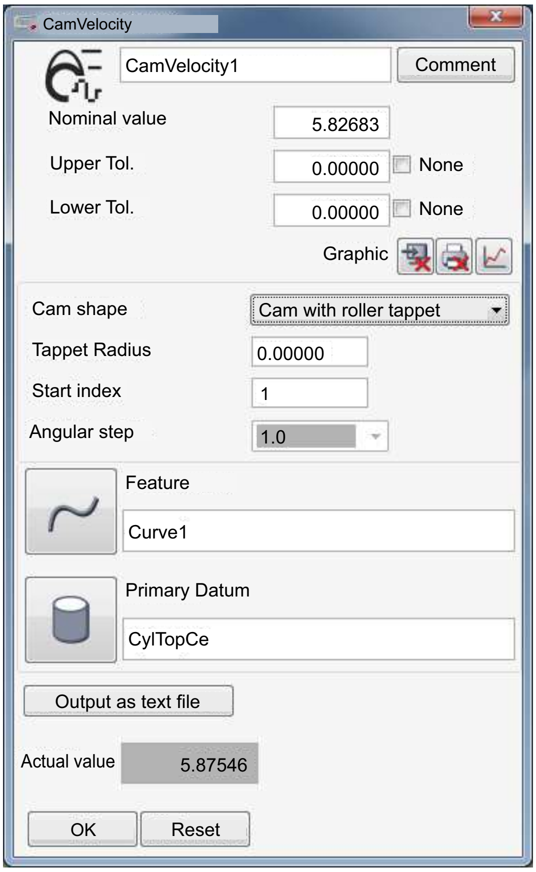
The following table describes the buttons and fields that are not common to other characteristics:

Dialog element	Function
Cam shape	Select between roller tappet and barrel tappet. Specify the tappet radius for the roller tappet.
Feature	Select the curve to be checked.
Primary Datum	Enter the base circle of the cam as reference feature. The calculations refer to the center point of this circle. *Notice*: From CALYPSO 2017, the calculated actual value of the base circle radius is used by default. If you want to use the nominal value of the base circle radius, as was done in previous versions, disable **Cam evaluation: lift calculation with calculated base circle radius** in the Compatibility settings.
Output as text file	Outputs the measurement results together with angle, nominal value, actual value and deviation in a TXT file.

Defining the Cam Velocity characteristic

The “Cam velocity” characteristic is used to check the angular speed of a cam curve (radial closed 2D curve) in a predefined direction.

Add the “Cam velocity” characteristic to the measurement plan via **Size → More → Cams → Cam velocity**. Use the definition template to define it.



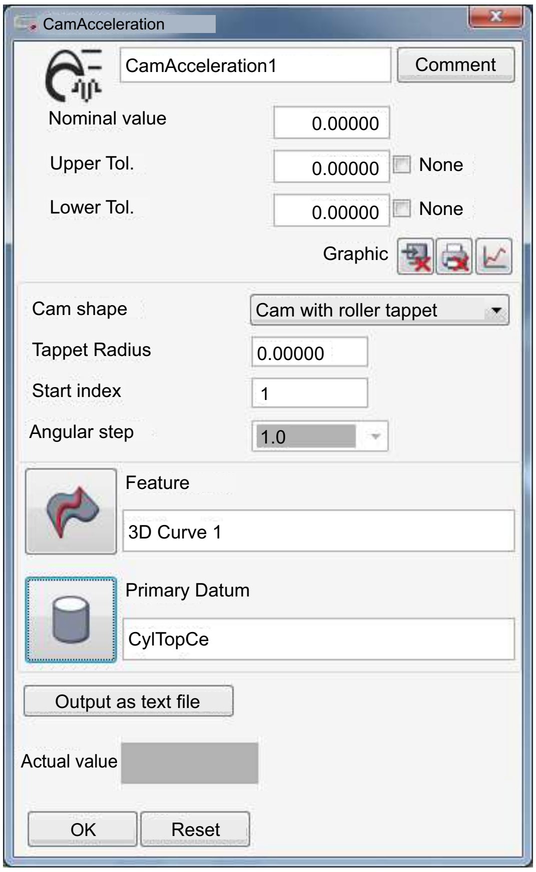
The following table describes the buttons and fields that are not common to other characteristics:

Dialog element	Function
Cam shape	Select between roller tappet and barrel tappet. Specify tappet radius for the roller tappet.
Feature	Select the curve to be checked.
Primary Datum	Enter the base circle of the cam as reference feature. The calculations refer to the center point of this circle.
Output as text file	Outputs the measuring results together with angle, nominal value, actual value and deviation in a TXT file.

Defining the Cam Acceleration characteristic

The “Cam acceleration” characteristic is used to check the angular acceleration of a cam curve (radial closed 2D curve) in a predefined direction.

Add the “Cam acceleration” characteristic to the measurement plan via **Size → More → Cams → Cam acceleration**. Use the definition template to define it.



The following table describes the buttons and fields that are not common to other characteristics:

Dialog element	Function
Cam shape	Select between roller tappet and barrel tappet. Specify the tappet radius for the roller tappet.
Feature	Select the curve to be checked.
Primary Datum	Enter the base circle of the cam as reference feature. The calculations refer to the center point of this circle.
Output as text file	Outputs the measuring results together with angle, nominal value, actual value and deviation in a TXT file.

Using the curve measurement results

Overview of the use of measurement results

After measurement, the actual values are displayed in the right half of the curve definition template. In contrast to most other definition templates, the curve template enables you to perform additional operations with the results.

You have the following options for evaluating results:

– ➤ *Calculation and display of deviations [➪ 1-131]*

– ➤ *Optimization of coordinate system with best fit alignment [➪ 1-132]*

– ➤ *Fitting actual values to nominal values [➪ 1-135]*

– ➤ *Defining or restricting the alignment [➪ 1-137]*

– ➤ *Specifying search distances [➪ 1-140]*

– ➤ *Smoothing the curve display [➪ 1-141]*

– ➤ *Sorting the measured points [➪ 1-143]*

– ➤ *Excluding measured points from the evaluation [➪ 1-144]*

– ➤ *Eliminating outliers [➪ 1-147]*

– ➤ *Excluding apparent segment overlaps [➪ 1-148]*

– ➤ *Adding an offset to results [➪ 1-149]*

– ➤ *Defining the evaluation of the 3d curve [➪ 1-153]*

– ➤ *Setting the deviation calculation for threads [➪ 1-150]*

– ➤ *Determining coordinate system with best fit alignment of several curves [➪ 1-151]*

Calculating and displaying the deviations of a curve

The deviation between the measured and specified values for a curve can be calculated in a number of ways (see ➤ *Calculation of deviations for the curve [➪ 1-73]*).

1 Open the definition template of the curve.

2 Select the desired calculation mode from the selection list under the **Comment** button.

Calculation will be carried out immediately if there are already actual values. If not, calculation will commence as soon as actual values are available.

Displaying deviations

The actual values refer to the workpiece coordinate system. When dealing with a curve, however, the deviation between the nominal and the actual values in the X, Y and Z coordinates can be of greater interest.

1 Open the definition template of the curve.

2 Tick the **Deviation** check box.

The actual values on the right side of the definition template now refer to the nominal data of the curve.

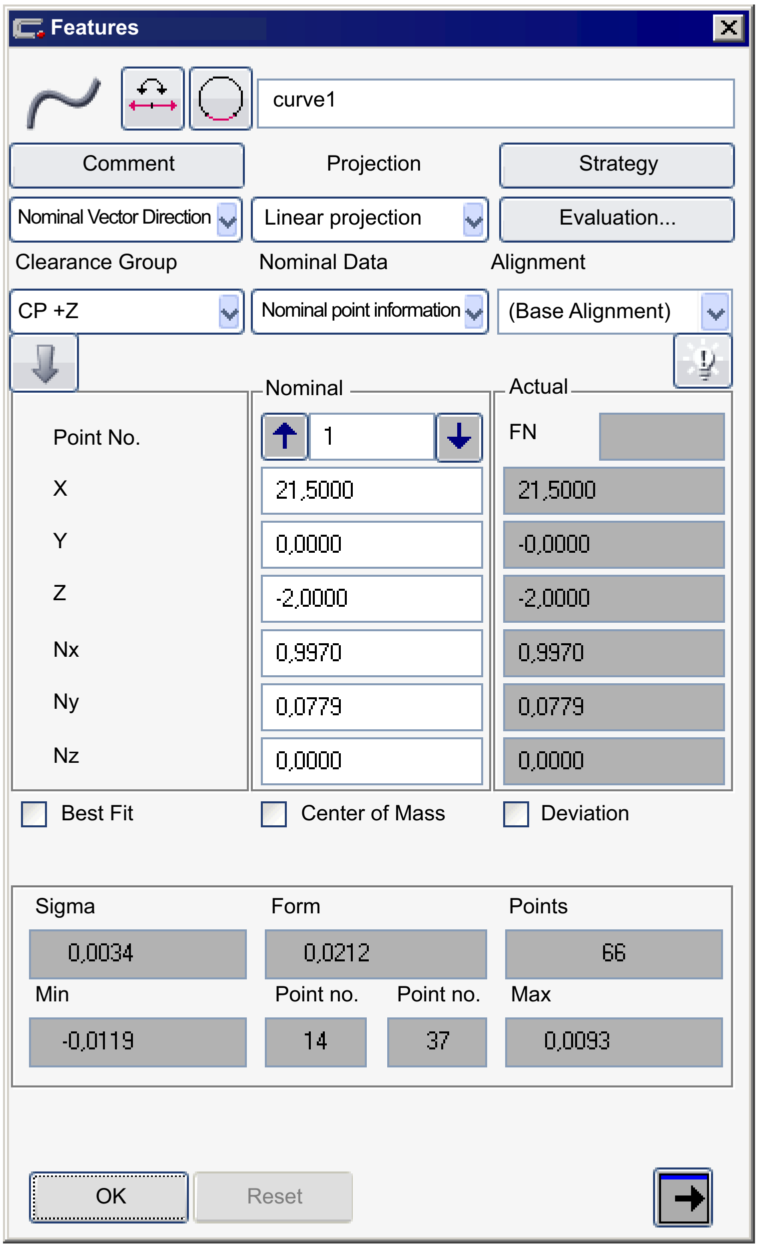
Optimization of coordinate system with best fit alignment

Inaccurate coordinate systems produce inaccurate measured values. This, in turn, means incorrect form errors following a nominal/actual comparison. To eliminate this positional offset, CALYPSO automatically performs best fit for standard geometric features when it measures form characteristics.

You have the option of defining automatic best fit in CALYPSO following every measuring run. CALYPSO can also correct the current coordinate system by applying the rotational and translational components of the best fit result.

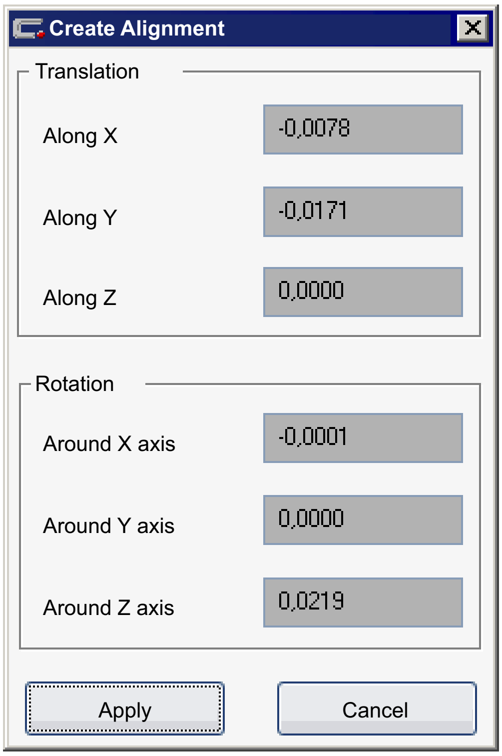
Optimizing form characteristics

1 Open the definition template of the curve.



2 Click the **Evaluation** button.

3 Tick the check box under **Best Fit** and click **Alignment**.
CALYPSO will fit an alignment. You can see the **Create Alignment** window in which CALYPSO shows the translation and rotation of the feature alignment with reference to the part alignment.



4 Click **Apply** to accept the local feature alignment.
The **Enter Name** dialog box appears on the screen.

5 Enter a name for the local feature alignment.

6 Click **OK** to close the best fit.

Calculating the curve's center of gravity

The location of the curve is calculated using the center of gravity. The coordinates of this point can be displayed.

Showing the center-of-gravity coordinates

1 Make sure you have the definition template open and displayed on your screen.

2 Tick the **Center of Mass** check box.

The coordinates of the center of gravity are displayed in the left half of the template.

The center of gravity is also displayed in the CAD window.

Best fit of the curve

Performing a curve best fit

"Best fit" refers to the mathematical separation of form deviations and location deviations. You may use best fit to make a mathematical correction of the positive deviation referring to the applicable nominal curve.

The curve generated from the measured values is translated and/or rotated mathematically until it is closest to the nominal curve according to the selected method. The position error results from these translations and rotations; the remaining "distance" shows the form error of the curve.

Defining the best fit

1 Make sure you have the definition template open and displayed on your screen.

2 Tick the **Best Fit** check box.
- or -
Click **Evaluation** and tick the check box under **Best Fit**.

CALYPSO performs the fit according the best fit settings without changing the curve form.

To choose the best fit method and the transformation restrictions, select the **Best Fit** window (see ➤ *How to define a best fit alignment of a curve [➪ 1-137]*).

Parameters for the best fit of the curve

When you activate the **Best Fit** check box to have the curve aligned, CALYPSO separates form deviations from positional deviations by computation.

You have several options to influence this best fit alignment:

– You can select the best fit method and (except for Gauss) define for it the number of iterations:
  – Best Fit according to Gauss
  – Best fit in the tolerance band
  – Best fit according to Chebyshev (minimum feature)
  – Best fit according to the L1 method

– You have the option of restricting the best fit to exclude certain movements: you can forbid the translation in the direction of any axes or the rotation around any axes.

  This restriction applies to best fit of the measured curve to the nominal curve and to best fit of a coordinate system.

– You can specify that certain points are not to be taken into account during the best fit by masking them (see ➤ *Defining the best fit alignment of a curve [⇨ 1-137]*).

  In this case, the masked points will not be shown in the CAD window.

– For the alignment, the average deviation between actual and nominal is minimized. Here, every curve point is compared with a calculated curve section (a section connects two neighboring points). This can take a long time if the curve has a lot of sections.

  Usually, it is quite sufficient to compare some sections near the point. You can enter the size of the area that is to be considered.

Methods for best fit of curves

CALYPSO uses four best fit methods for the curve measurement, only one method being available for the measurement of 3D curves:

– *Best fit according to Gauss (LSQ feature)* (2D and 3D curves)

  With the best fit according to Gauss (LSQ feature), the measured values are translated and/or rotated until the *sum of the error squares* reaches a minimum (certain degrees of freedom may be restricted here). This operation leaves only the curve's form deviation.

  Note: If the *degrees of freedom* are not restricted, the curve will be rotated around the curve center of gravity. This usually corresponds to a rotation around all coordinate axes. With a best fit *with restricted degrees of freedom*, the result normally deviates from a best fit around all axes as the curve is generally not located in a main plane of the coordinate system. The greater the distance, the farther away the curve center of gravity from the curve origin.

– *Tolerance band* (2D curves)

  With the best fit in the tolerance band, the nominal points define tolerance circles whose center points are located in the center of the tolerance band. The associated actual values are fitted into these tolerance circles until the maximum of the sum resulting from the difference between nominal point and actual point and tolerance becomes the minimum (min (max | | act - nom | - tol |)).

– *Chebyshov (Minimum Feature)* (2D curves)

  The Chebyshov best fit consists in minimizing the *maximum of the deviations* between the nominal and actual contour.

  As the extreme values of the probing have an impact on the result of the best fit, this best fit method is very susceptible to outliers.

– *L1* (2D curves)

  With the L1 best fit (as L1 feature), the geometric element is determined in a way to minimize the *sum of the deviation values*.

  This Best Fit method is insensitive against outliers and leads to a clear result with low computational effort.

Best fit procedure

The three purely two-dimensional best fit procedures run iteratively; with the best fit in the tolerance band, you can define the number of iterations.

A rough best fit according to Gauss is performed before starting the best fit in the tolerance band.

Iteration step

The further iterative procedure is identical for the three methods: The result (rotation and translation) of an iteration step is used to transform all the actual points and to create a new actual spline.

On the newly fitted actual spline, an actual point is calculated for each nominal point. These actual points are used for the next iteration step.

An iteration step ends when the rounding precision (number of decimal places) set in CALYPSO is reached.

Cancelation criteria

CALYPSO automatically stops iteration if one of the following conditions is met:

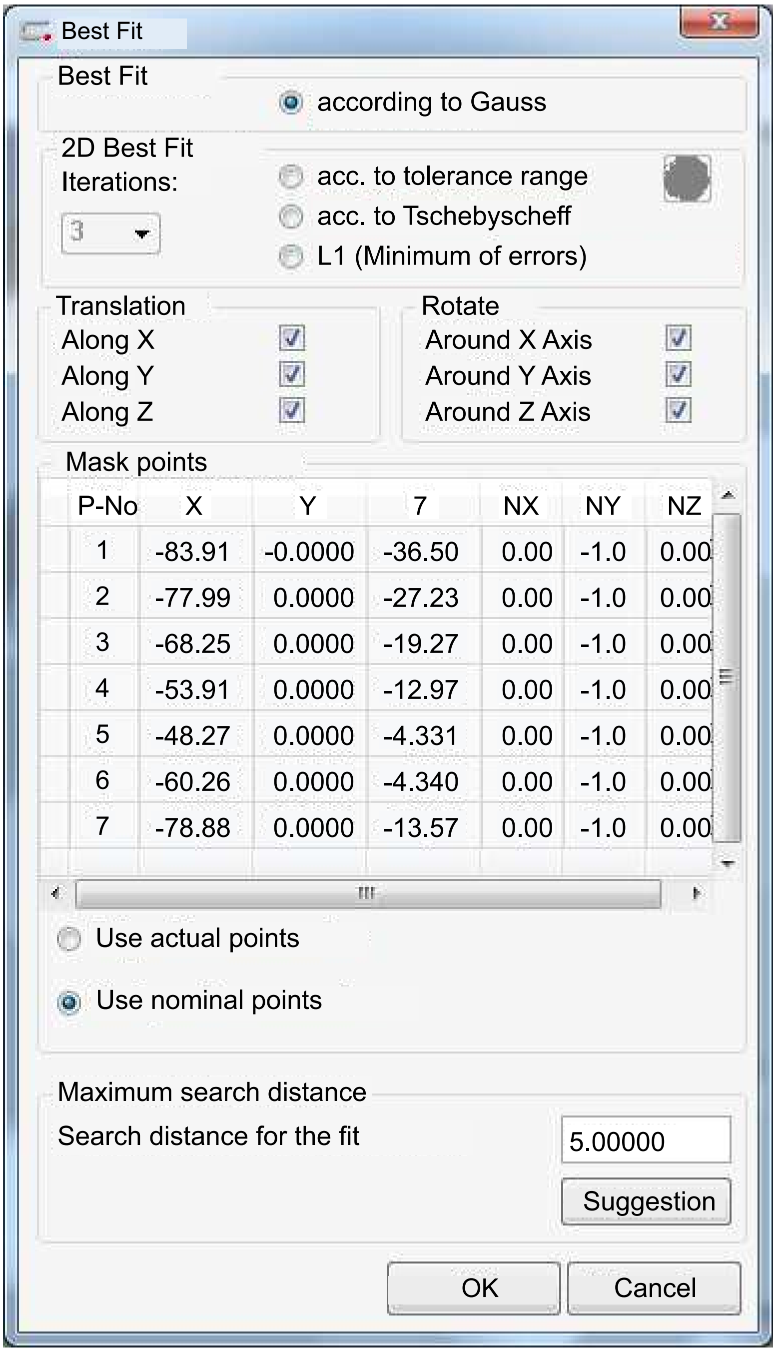
– The value achieved by the iteration falls below the cancelation criterion (A value). The delta value is the sum of the relevant components of the rotational matrix and the translation vector.
– The A value is smaller than the value 0.000 000 01.
– The maximum number of iteration steps has been reached.
– The set number of iteration steps has been reached (tolerance band).
– You have selected “inTol” under **No of Iterations** and the actual points are located within the tolerance circles.

Defining the best fit alignment of a curve

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box is opened.

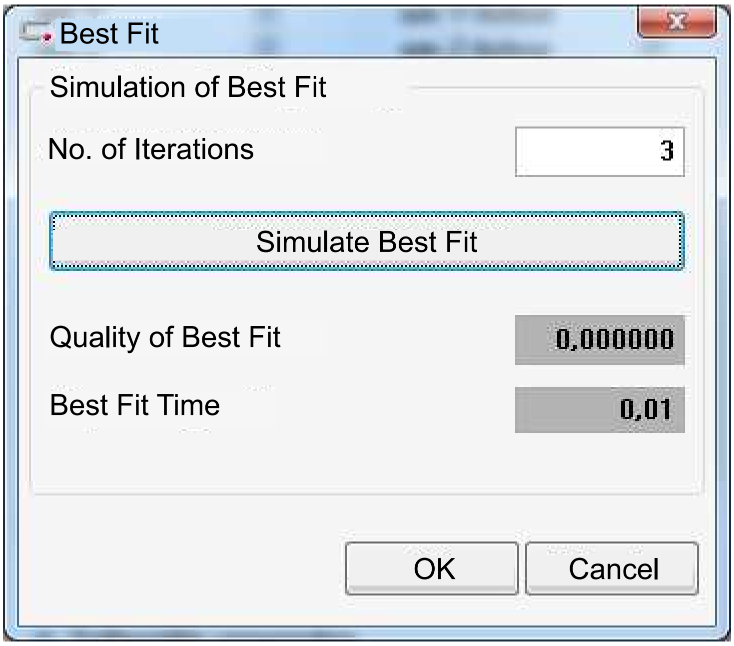
2 Tick the check box under **Best Fit** and click **Settings**.

The **Best Fit** dialog box appears on the screen.



3 Select the desired best fit method and enter the number of iterations for the best fit in the tolerance band.

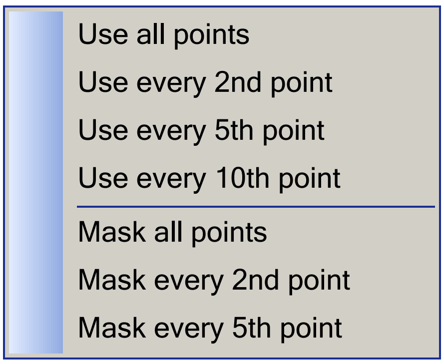
By clicking the clock, you open the **Best Fit** window, allowing you to determine, via simulation, the optimal number iterations.



4 Under **Translation** and **Rotation**, uncheck the check boxes where you *do not want to permit* the respective movement for the best fit. All the check boxes are ticked by default.
Check boxes that are not relevant for the respective 2D best fit will be ignored.

5 To fill the point list under **Mask points** with data: Select **Use nominal points** or **Use actual points** (below the point list).

6 Under **Mask points**, click the points you wish to mask and not to be taken into account for the best fit. Another click while holding down CTRL depressed will cancel the selection.
You can also select a rule for the use of points in the context menu:



Note: If you define the curve via an ASCII file, you can mask nominal points already in the ASCII file for the best fit.

7 Under **Max. Search Distance**, enter the area to be considered in the field **Search distance for the best fit** in millimeters or click **Default** if you wish to use the CALYPSO default.

This default is derived from the doubled sum of tolerance and stylus radius.

8 Click **OK** to apply the definition.

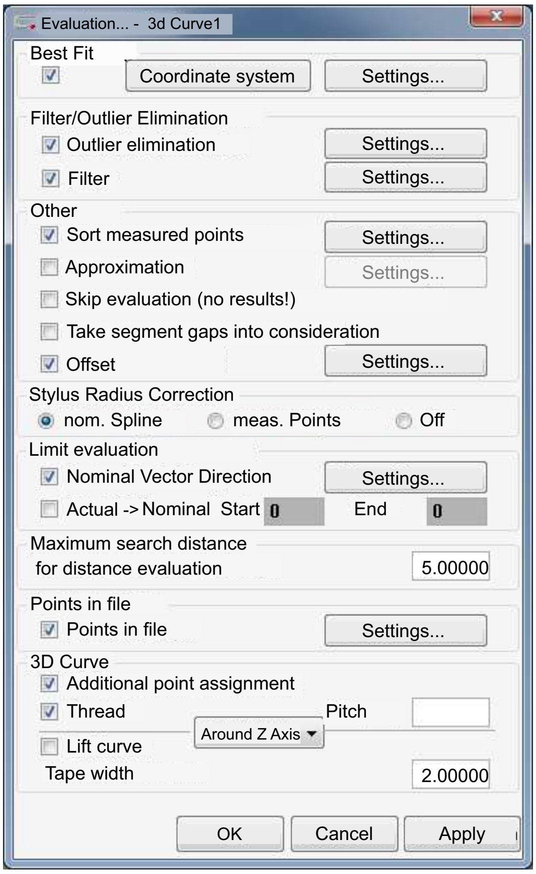
The alignment of the coordinate system or of the curve feature into the nominal feature is then only possible in the permitted directions, with the specified points and the entered search distance.

Restricting the search distances during curve evaluation

Depending on the form of the curve, there may be several intersection points between the spline and normal in the case of distance evaluation. This may affect the computing time.

This may affect the computing time. To prevent this, you can define the maximum permissible distance from the actual point to the curve.

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box will open.



2 In the **for distance evaluation** field under **Max. Search Distance**, enter the maximum distance which will presumably suffice in millimeters.

3 Click **OK** to save your entry and close the dialog box.

The search distances are taken into account the next time the curve is calculated.

Smoothing a curve

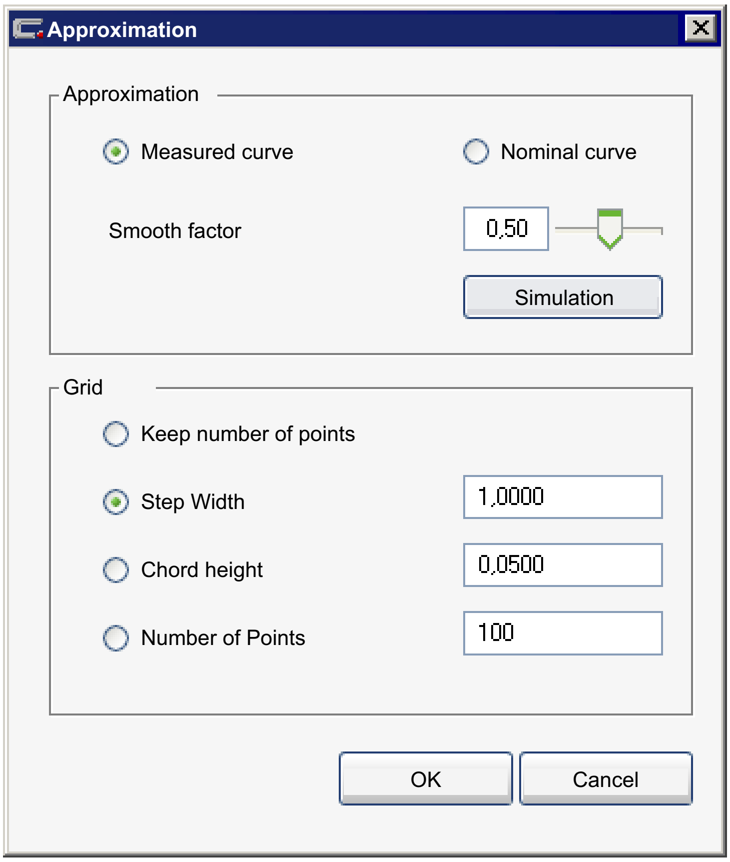
In order to display a curve in a CAD window, CALYPSO lays spline functions through the nominal points of the curve. As a result, all nominal points will lie on the curve that is calculated in this manner.

In the case of some initial values (e.g. when measured actual values are used as nominal values), the presentation of the curve may well be relatively “rough”. This can, if necessary, be smoothed.

While doing so, the spline functions are only set in the close proximity of the points and do not actually pass through each individual point. The degree of approximation or smoothing can be defined by a number between 0 and 1: If 0 is selected, the splines nestle up to all points so that no distinction can be made to the usual method. 1, on the other hand, will produce the maximum smoothing of the curve.

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box will open.

2 Under **Additional**, tick the **Approximation** check box and click **Settings**.
The **Approximation** window for entering the approximation parameters will be displayed.



3 Select whether you wish to smooth the presentation of the measured curve or the nominal curve.

4 Enter a **Smooth factor** between 0 and 1 by dragging the slider with the mouse.
To check the result, click the **Simulation** button – the result will immediately be displayed in the CAD window.

5 If necessary, select a method for redefining the curve points under **Grid**.
If you select **Keep number of points**, the number of points of the initial curve will also apply to the newly calculated curve.

6 Click **OK** to save your entry and close the dialog box.

The curve will be recalculated in accordance with your entries. The new nominal curve will be determined on the basis of the calculated values and displayed in the CAD window.

NOTE

As soon as you confirm with **OK**, you will regenerate the nominal points of the curve. The original curve cannot be restored afterwards. For this reason, it is important that you use the Simulation function to check the result beforehand.

Sorting the points in a curve

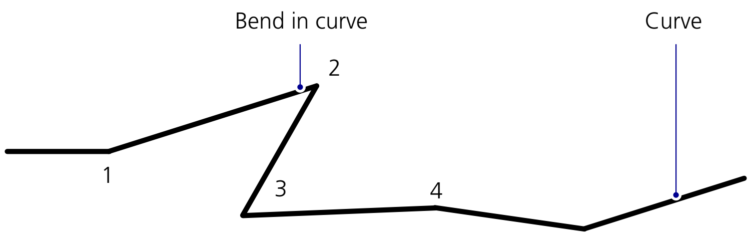
When scanning with a high point density or in positions which display a high degree of curvature, it may well be that measured points are not transferred in the right sequence. Normally, this is of no great significance.

This is, however, significant when you are measuring curves, as the sequence of the points influences the form of the curve. CALYPSO therefore sorts the points in a meaningful manner.

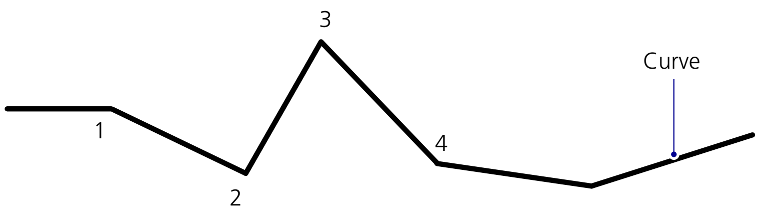
On the other hand, there may also be curves that actually contain a sharp “bend” and, consequently, should not be sorted: Sorting curves such as these would result in an undesirable alteration in the form of the curve (see example).

For this reason, you can control sorting using an angle limit. Here, an angle is determined on the basis of the last three points that were calculated (Points 1 to 3 in the example). The points will only be sorted if the calculated angle is smaller than the angle limit.

Example: The run of a curve contains a bend.



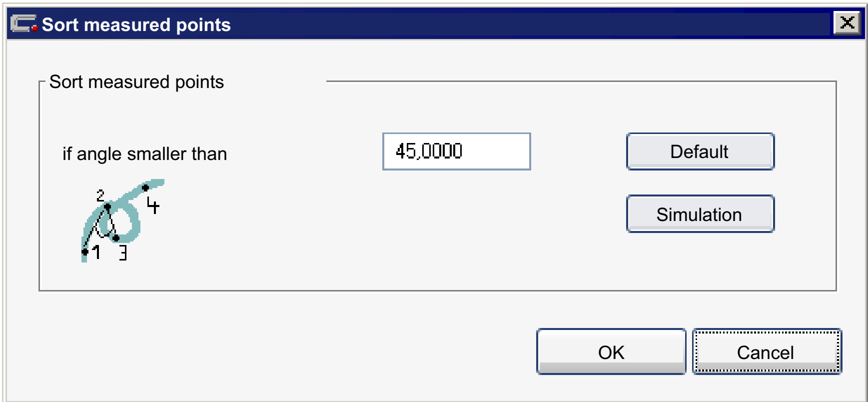
The angle of this “bend” is slightly less than 50°. If you set the limit to “50”, point 2 will automatically be interchanged with point 3 although this is not desired here. The curve would then look as follows:



In this case, you will have to enter a limit that is less than the angle of the bend, i.e. approx. 45°.

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box will open.

2 Under **Additional**, tick the **Sort measured points** check box and click **Settings**.
You see the **Sort measured points** window for input of the angle limit.



3 Enter the maximum angle that should be accepted or click the **Default** button to enter the CALYPSO default value.
If larger angles occur in the curve, the appropriate points will be sorted.

4 To check the result, click the **Simulation** button – the result will immediately be displayed in the CAD window.

5 Click **OK** to save your entry and close the dialog box.
The curve will be sorted in accordance with your entries. The new nominal curve will be determined on the basis of the new sequence and displayed in the CAD window.

6 Close the **Evaluation** dialog box with **OK**.

Restricting the evaluation of the curve values

Reason for restriction

The following problems can arise at the beginning and at the end of the measuring path in the case of curve measurement and curve evaluation:

– The controller will have to readjust to the correct nominal path.

– The calculation of the spline function and the corresponding vectors is problematic at the end of a curve: a minor deviation has a stronger impact here than at other locations

To reduce the effects of these problems, you restrict the number of points used for evaluation.

For other reasons, too, it may be useful if some curve ranges are not considered for the evaluation.

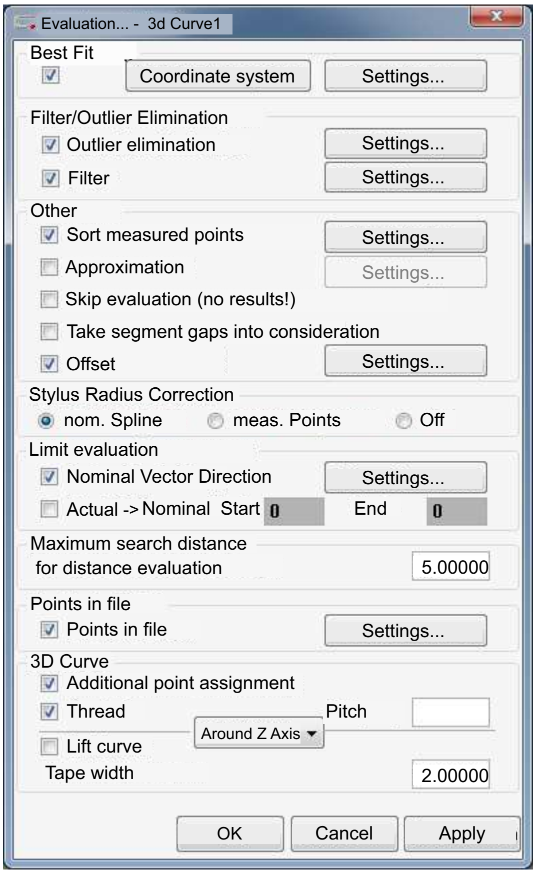
Two methods of restriction

A distinction must be made here between basing the calculation on the nominal points on the measuring spline or on the measured points on the nominal spline:

– When evaluating in the *nominal vector direction*, *all* measured points will be considered. The restriction will then *apply to the nominal points only*.

– When evaluating in the actual vector direction (*Act -> Nom*), all nominal points will always be used. Here, the restriction only applies to the actual points.

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box will open.



2 Tick the corresponding check box under **Restrict evaluation**.

3 For restriction in **Nominal vector direction**, click **Settings** and specify in **The selected points are not calculated** window the nominal points that should not be considered for evaluation.

4 For the **Act -> Nom** restriction, enter the number of actual points that should not be considered at the start and at the end of the curve.

5 Click **OK** to save your entry and close the dialog box.

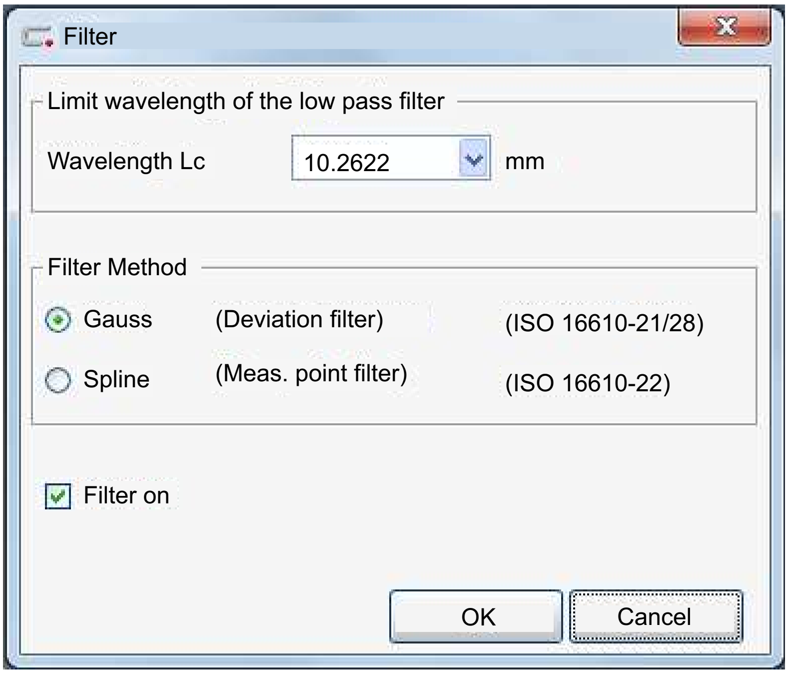
During the evaluation, a correspondingly fewer number of points will be considered at the start and at the end of the curve.

Filtering a curve

You can filter the measuring points prior to calculating the computed feature to avoid systematic distortions. This is especially important for scanned features.

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box will open.

2 Under **Filter/Outlier**, tick the **Filter** check box and click **Settings**.
The **Filter (Curve)** dialog box for entering the parameters will be displayed.



3 Enter the **Wavelength Lc** for the low-pass filter.
Note: The wavelength may not exceed half the curve length.

4 Select the **Filter Method**.
Note: As the spline filter is only used for the measuring points and not for the nominal points, larger deviations may result from the distance evaluation. This especially refers to the spline ends with open contours and areas that are subject to a high degree of curvature changes. Do not use the spline filter in such cases.

5 Tick **Filter on** to activate the filter from the **Datum Features** dialog box.

6 Click **OK** to save your entry and close the **Filter** window.

7 Close the **Evaluation** window with **OK**.

Only the filtered measuring values will be used for calculating the computed feature.

Eliminating outliers from a curve

Outliers are measured points that differ significantly from the geometric form yielded by the other measured points and as such, they can produce a large error when the computed feature is calculated. An error of this nature easily propagates through the actual-value determination of the assigned characteristic.

There are several different points at which you can set and activate outlier elimination for curves:

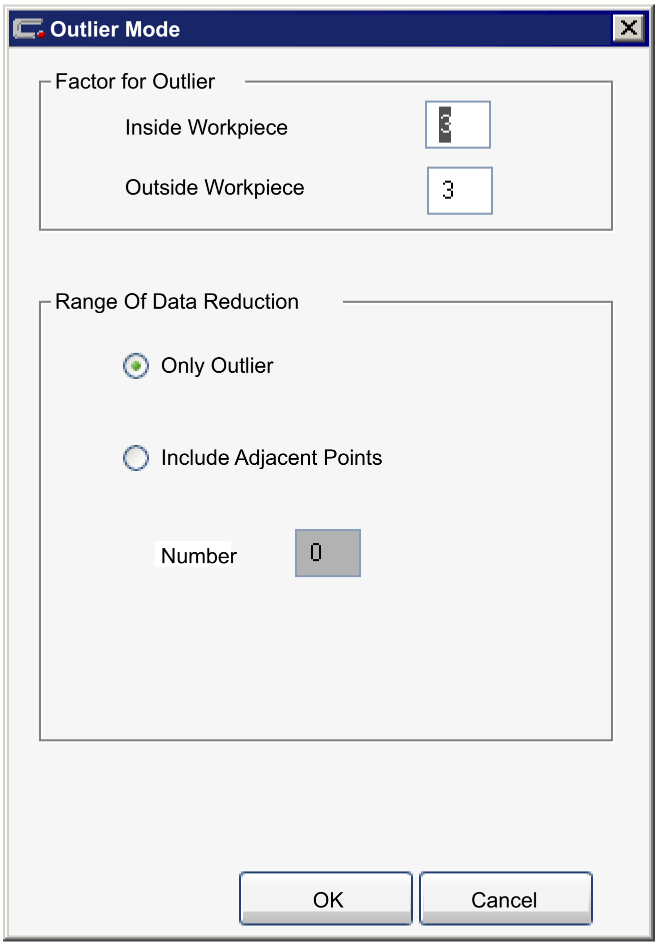
– As defaults for the characteristic groups and the references and alignment features of the coordinate systems

– For an individual characteristic

– For an individual curve feature

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box will open.

2 Under **Filter/Outlier**, tick the **Outlier Elimination** check box and click **Settings**.
The **Outlier Mode** window for entering the parameters will be displayed.



3 Enter the **Factor for Outlier** as well as the **Range Of Data Reduction** and confirm with **OK**.

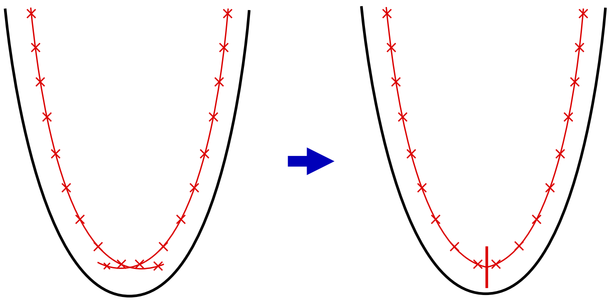
4 Click **OK** to save your entry and close the **Outlier Mode** dialog box.

5 Close the **Evaluation** window with **OK**.

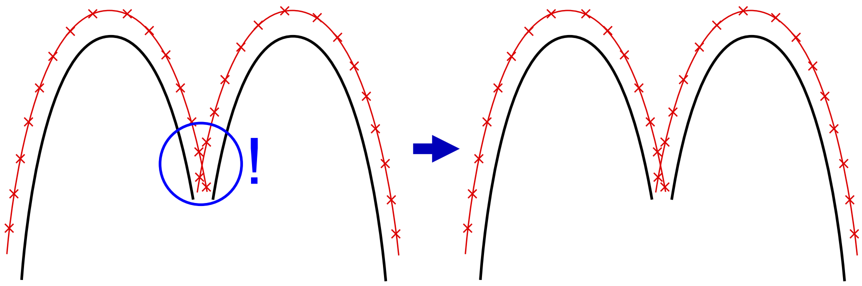
During the calculation, the measured outlier values that fall under the specified criteria are not taken into account.

Excluding apparent segment overlaps

If a curve to be measured is divided into several overlapping segments, CALYPSO will check the overlapping areas, filtering out possible superfluous actual values. This is to ensure that the calculated actual spline optimally corresponds to the real contour and does not contain any superfluous loops, for example.



With some contours, however, the segments may only seem to overlap, although gaps exist between the segments. This happens, for example, in the case of narrow and acute recesses where the stylus cannot probe the contour continuously, but with interruptions.



For such a case, you can define to consider segment gaps in order to avoid incorrect computation of the actual contour.

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box appears on the screen.

2 Select **Miscellaneous** and tick the **Take segment gaps into consideration** check box.

3 Close the **Evaluation** window with **OK**.

The segments will be treated as non-overlapping segments.

Adding an offset to a curve

You can add an offset calculated from the curve values to the measured points of a curve. The same offset is added to each measured curve value.

You have a choice of the following offsets:

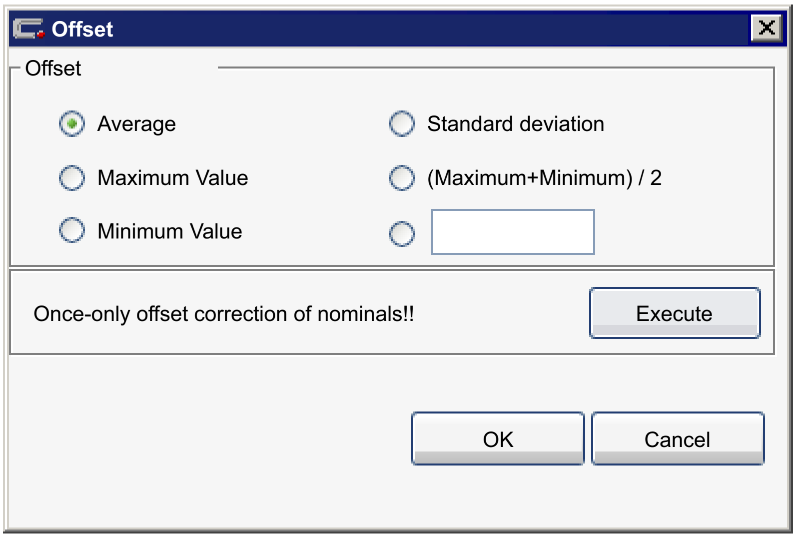
– Average
– Maximum Value
– Minimum Value
– Standard deviation

– Arithmetic average calculated from the largest and shortest distance

– Any entry

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box is opened.

2 Under **Additional**, tick the **Offset** check box and click the **Settings** button.
The **Offset** window for selecting the offset calculation will be displayed.



3 Select the mode of offset calculation and click **OK**.

4 Close the **Evaluation** window with **OK**.

The selected offset is now added to all measured curve values.

Setting the deviation calculation for threads

For the measurement of thread profile intersections (e.g. recirculating ball screws), it may be necessary to calculate the deviations in the profile intersection plane of the thread and not in the nominal vector direction.

If the slopes prove to be slight, there is no important difference between these evaluation modes. If the slopes are significant, however, the differences may exceed the measuring uncertainty.

Note: If nothing else is defined for the measurement, use measurement in nominal vector direction and without projection. These results supply the best indication as to whether the spheres “get stuck” or not.

Defining evaluation methods for thread measurements

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box is opened.

2 Under **3D curve**, tick the **Thread** check box.

3 Select the feature that defines the thread axis and enter the **Pattern** of the thread (lead).

4 Confirm with **OK** and select in the definition template for the curve the **Nominal Vector Direction** deviation calculation and the desired projection:

- **No Projection**: the deviations are evaluated in the nominal vector direction.
- **Vertical Projection**: the measured values are projected onto the plane perpendicular to the thread and evaluated.
- **Helix Projection**: the measured values are projected onto a helicoid that is predefined by the thread parameters and then valuated.

5 Press **OK** to confirm.

Coordinate system from best fit alignment of several curves

Target

The best fit alignments of several individual curves on a workpiece supply in general a different result for each curve. If several curves belong together, the “common” best fit of curves is required; i.e. the transformation that minimizes the deviations for all viewed curves.

Example

The common best fit is required, for example,in connection with turbine blades which normally require the measurement of several intersections.

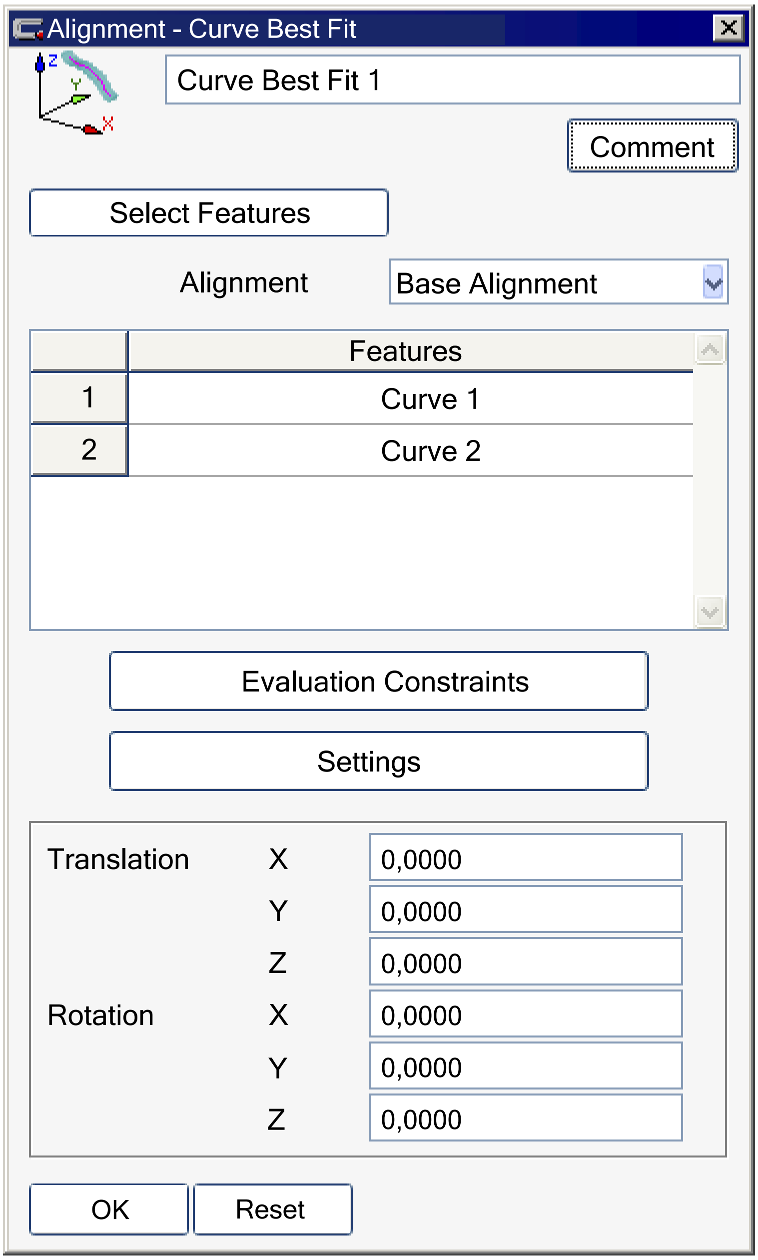
Determining best fit

Use the **Alignment - Curve Best Fit** window for the best fit of several curves.

1. Select **Resources → Utilities → Alignment from Several Curves**.

   A new “Curve Best Fit” feature is included in the list of characteristics.

2. Open the new feature.



3. Select the curves for the best fit via **Select Features**.
4. Select the coordinate system for the best fit.
5. If necessary, restrict the constraints for the best fit in the **Best Fit** window. The **X**, **Y**, **Z** check boxes refer to the axes of the above selected coordinate system.

   The best fit will then be limited for all curves together. All points are used for the best fit.
6. If needed, change the search distance for the best fit under **Settings**.

During the CNC run, CALYPSO creates a new alignment whose displacement and rotation with respect to the initial alignment result from the common best fit of the curves.

Using the alignment

You can use the new alignment for all features, except for the curves used for the best fit. Otherwise, CALYPSO would get stuck in an endless loop during the evaluation of the curves.

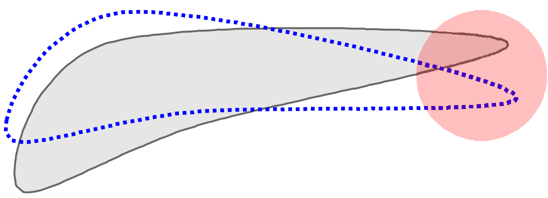
However, you can copy each curve used for the common best fit and evaluate the copied curve.

Defining the evaluation of the 3d curve

For the 3d curve, there are further methods of influencing the evaluation of the measured points.

Additional point assignment

For 3d curves with large form deviations and with very small radius or edge ranges, the default curve evaluation may result in wrong results. This occurs especially with evaluations of leading and trailing edges on turbine blades.



Here the assignment of measured data to the nominal geometry may become faulty. In the area of edges, it may happen that measured points are assigned to the upper side of the blade instead of the lower side and vice versa. You can avoid this effect by means of additional point assignment.

If the measured points of the curve are not measured directly, but have been defined via point recalls, the stylus tip radii of the original measurements must be the same. Curves with own measurement strategy (included segmented ones) can have been measured with different stylus tip radii.

3d curve as thread

If you want to use the 3d curve for evaluating a thread, you can activate **Thread** and specify the thread axis and the nominal lead.

Lift curve

To evaluate a 3d curve as a lift curve, activate **Lift curve**.

Defining the tape width

A 3d curve is displayed in the CAD window as a tape of a certain width. This makes the orientation of the normal and thus the probing direction visible. You can define the width of this tape.

Output of the results of curve measurement

Overview of the output of the results

The measured and possibly corrected and edited curve measurement results can be output in different ways for further processing.

- ➤ *Output of curve points in table files [➪ 1-155]*
- ➤ *Output of all curve results in files [➪ 1-156]*
- ➤ *Output of curve points and tolerances in text files [➪ 1-158]*
- ➤ *Output of points and deviations of a cam curve in text files [➪ 1-160]*
- ➤ *Output of curve deviations in a form plot [➪ 1-161]*
- ➤ *Printing the point list or saving it as file [➪ 1-84]*

Output of curve points in table files

If "Output to table file" is set in the **Results to File** window, CALYPSO will output with each run the following three text files in the *<user directory>\workarea\results* directory:

File name	Contents
*planid_partnb*_hdr.txt	Header data for measurement plan and measurement
*planid_partnb*_chr.txt	Measurement results for characteristics
*planid_partnb*_fet.txt	Measurement results for features

In this case, "planid" represents the measurement plan name and "partnb" the part number.

The measurement results are available in these files for internal and external processing (e.g. in spreadsheet programs).

Curve results

The results of the curve measurement are output as table files only if the **Curve Points** check box is ticked.

If the **Masked curve points** check box is ticked in addition, the table file also includes the masked points which are not used for the evaluation. These lines contain in each column the entry "99999" instead of the measuring values.

Number of decimal places

You can set the number of decimal places for table files in the Measurement Plan Editor Features. If you do not make this setting, the values output in table files will automatically have one digit more than those in the printout.

Format of the files

All three files have the same format: The first line contains the column headers of the table, the following lines contain the measured or calculated values for the corresponding column and there is an "END" at the end of the file.

– The *_hdr.txt header file contains the general data for the measurement plan and the measurement.

– The *_chr.txt characteristic file contains all values defined and measured or calculated in the characteristics.

– The feature file contains all values (nominal and actual values) defined and measured in the features.

The same identifiers as in the printout format editor are used for designation of the values.

Interface to DML

The table files represent the interface to various other output formats, e.g. also to the DML files.

In addition to the direct measurement results, the table files contain further information:

– Names of the datums for all characteristics.

– Coordinate system of the True Position as a matrix and vector.

– Tolerance zone

Output of all curve results in files

You can output the measurement results for the curves of a measurement plan in ASCII files. The following types and file formats are available:

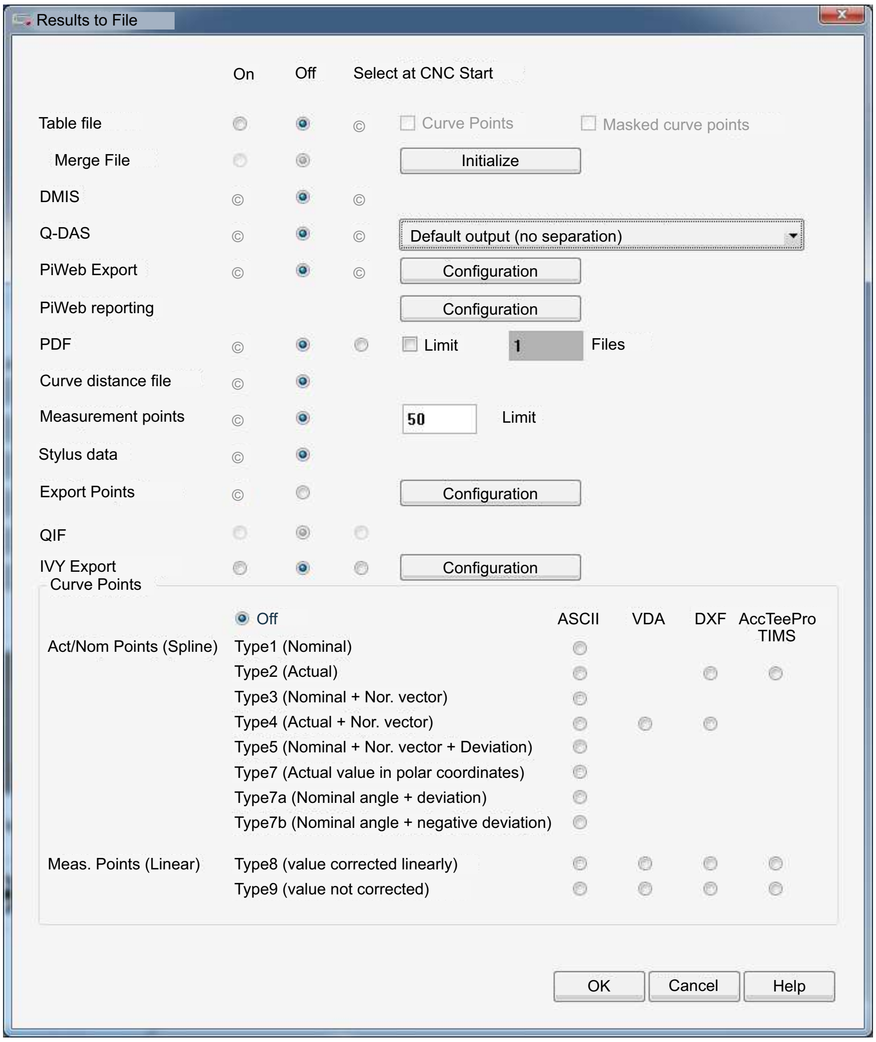
Type	Content	Format
Type 1	Nominal values	ASCII
Type 2	Actual values	ASCII / DXF / TIMS
Type 3	Nominal values and normals	ASCII
Type 4	Actual values and normals	ASCII / VDA / DXF
Type 5	Nominal values, normals and deviations	ASCII
Type 7	Actual values in polar coordinates	ASCII
Type 7a	Nominal angles of polar coordinates and deviations	ASCII
Type 7b	Nominal angles of polar coordinates and inverted deviations	ASCII

Type	Content	Format
Type 8	Not interpolated measured values, linearly corrected	ASCII / VDA / DXF / TIMS
Type 9	Non-interpolated measured values, not corrected	ASCII / VDA / DXF / TIMS

A distinct file is created for each curve and stored under <user_directory>\workarea\results\ASCII\<measurement_plan_name>\<feature name>.txt.

Note: You can also have CALYPSO overwrite the file created during each CNC run (see Exporting points during CNC run).

The output of curve results in files is defined related to the measurement plan via **Resources → Results to File**.



Select the desired content and format of the output files under **Curve Points** in the **Result To File** window.

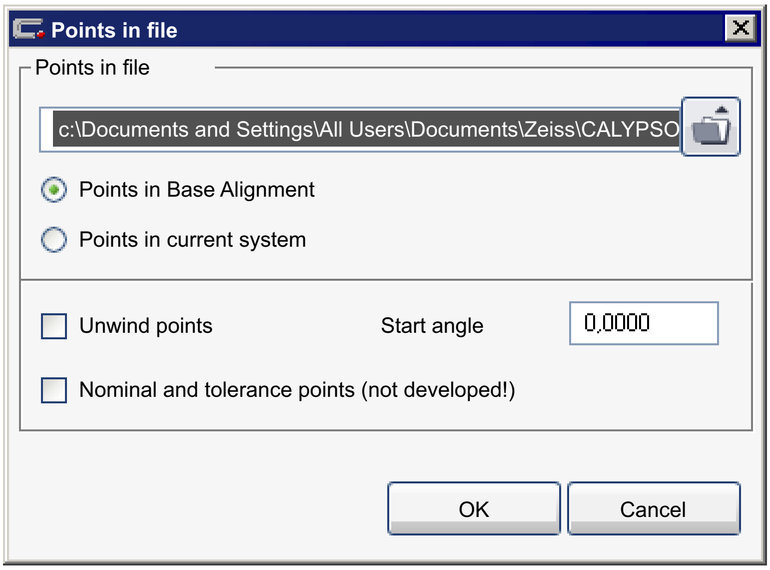
Output of curve points and tolerances in text files

After each measurement, you may have the coordinates of the curve points output to several text files; these file will be overwritten like log files during the next measurement.

The points of a lift curve can be unwound and projected onto the plane.

1 Open the definition template of the curve and click the **Evaluation** button.
The **Evaluation** dialog box is opened.

2 Under **Points in file**, tick the **Points in file** check box and click **Settings**.
You will see the **Points in file** window with the settings for the output to file.



The default path is the measurement plan directory and the feature name is the default file name. The file name extension is “txt”.

3 If required, enter a different path and file name or click the button and select them in the **Save file** dialog box.

4 Select the coordinate system for specification of the points. The base alignment is set by default.

5 Tick the **Nominal and tolerance points (not developed!)** check box to generate the text files.

6 With stroke data: If required, activate unwinding of the curve points and define the start angle (default: the angle of the first curve point).

Unwinding is a projection of the three-dimensional lift curve onto the plane: The curve points are projected onto the lateral surface of the cylinder; this surface will then be “unwound” from the cylinder. The result is a curve on the plane (z = 0).

7 Press **OK** to confirm.

8 Close the **Evaluation** window with **OK**.

Reference: Format of the text file with curve points

After each measurement, you may have the coordinates of the curve points output to a text file. In the text file, the points are represented in Cartesian coordinates as follows:

- In the first line, you will find the variable names x, y, z, u, v, w (for the coordinates of the point and its normal vector) and r (for the stylus radius).
- The other lines show the values for each individual point below the variables. The unit for the values is “mm”.
- In case of unwound lift curves, you will find zeros in the third column.
- r = 0 means that no correction of the stylus radius is required.

The following shows an example of the format of such a text file.

```
    x              y             z             u             v             w
           r
-23.0707348835 -32.0739616041 -0.9213020337  0.0019417548  0.9188948219 -0.3944978274
0.0
-21.5829215676 -32.0760668737 -0.9198508453  0.0001264637 -0.9093540976  0.4160229671
0.0
-20.0751808348 -32.0742300542 -0.9203910801  0.0001018995  0.9418390797 -0.3360641866
0.0
-18.5754535891 -32.0759142286 -0.9194448817  0.0005215434 -0.9841751775  0.1771974828
0.0
-17.0740001869 -32.0725757351 -0.9194892888 -0.0006841894  0.9999996467 -0.0004883545
0.0
-15.5591963058 -32.0762768604 -0.9200407405 -0.0030894740 -0.8653831066  0.5011013210
0.0
-14.0713513121 -32.0789392544 -0.9205921658  0.0020224195 -0.9924604729 -0.1225484378
0.0
-12.5698426332 -32.0726308300 -0.9201344234 -0.0027245345  0.9929397400  0.1185885726
0.0
-11.0521915216 -32.0743066146 -0.9201852439  0.0029758511  0.8023852166 -0.5967990520
0.0
-9.5618831389  -32.0774705126 -0.9197375737  0.0016869369 -0.9774580500  0.2111229847
0.0
-8.0600024197  -32.0716499506 -0.9207801273 -0.0019823247  0.9623648355 -0.2717535535
0.0
-6.5492508541  -32.0728412410 -0.9198281411 -0.0006327384 -0.9273548406  0.3741825749
0.0
-5.0510986398  -32.0715213582 -0.9203771783 -0.0007064220  0.9655644195 -0.2601631270
0.0
-3.5491471593  -32.0701556948 -0.9204217208  0.0033960346 -0.9992305329 -0.0390744047
0.0
-2.0219519625  -32.0728254374 -0.9199832673  0.0205454752  0.9997206636  0.0116823907
0.0
```

Output of points and deviations of a cam curve in text files

For some characteristics, you may output the curve points and deviations in a text file (*.TXT).

Export is possible for the following characteristics:

– Cam lift
– Cam velocity
– Cam acceleration

To do so, click **Output as text file** in the definition template of the characteristic.

Output format

The output comprises a text file with several lines containing four values each:

– Angle
– Nominal
– Actual
– Deviation

Graphical evaluation of curve deviations

Options for graphic evaluation

There are two options available for the graphic evaluation of the curve measurement just as for other features:

– Output of **form plots** via characteristics
– Output via the **Graphics Element** utility

Output of form plots via characteristics

You call form plots and display them as described in the Basic Operating Instructions under Outputting form and location plots for characteristics.

Curve Form

The form plots available for the Curve Form characteristic are as follows:

– Linear curve form
– Curve form 2D
– Multi-Curve form linear
– Multi-Curve form 2D

A special aspect of the form plot for curves is the option of selecting different scales in X and Y direction.

Curve Slope

The form plots available for the Curve Slope characteristic are as follows:

– Slope Type 1 (portrait and landscape)
– Slope Type 2 (portrait and landscape)
– Slope Type 3 (portrait and landscape)

Five parameters are additionally displayed in the form plots for the curve slope:

– Pitch Error
– Form Error
– Total Deviation

- Minimum Deviation f_{min}
- Maximum Deviation f_{max}

In addition to the graphical output, the measuring results can also be output in tabular form as a point list.

Cam evaluation

The following form plots are available for the characteristics of the cam evaluation:

- Cam lift type 1 and type 2
- Cam velocity type 1 and type 2
- Cam acceleration type 1 and type 2

Point table in the form plot

In addition to the graphical output, the measuring results can also be output in tabular form as a point list.

Output of the point list in the form plot is activated in the selection list of the **Form and location plot** window by selecting the **Point List** entry.

The following data is output in the point list:

- Actual and nominal values
- Upper and lower tolerances
- Deviation

Output of form plots via Graphics Element

The output via the **Graphics Element** utility is described under in the Basic Operating Instructions under Defining graphics elements.

Graphic forms

Graphic forms and single templates are available for the following measuring results:

- Curve Distance
- Curve Form
- Curve Best Fit

The forms show all table values which are important for the curve; in addition, the best fit forms contain the best fit result.

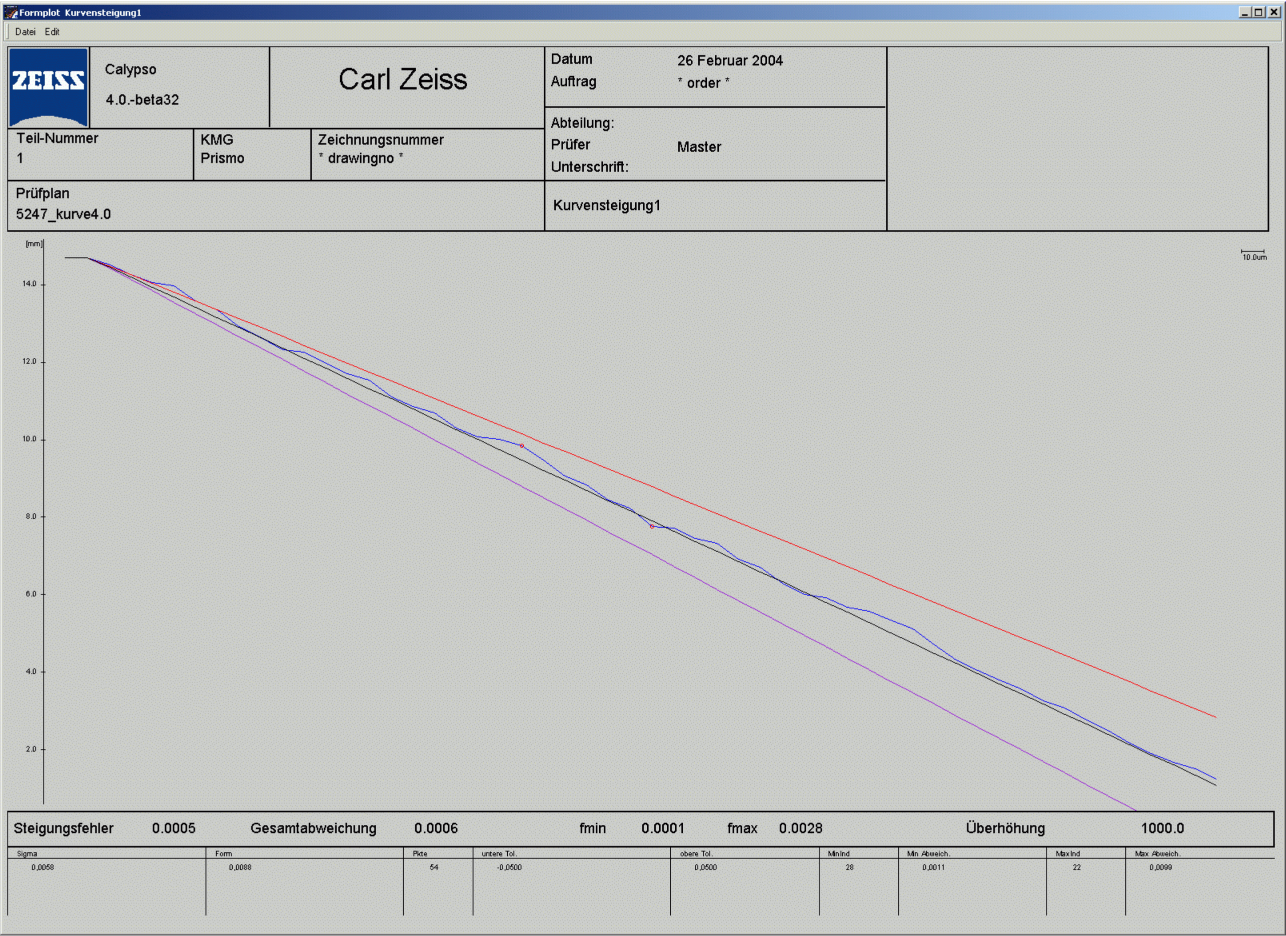
Multiple Curve Plots

If curve plots are assigned to the same characteristic type (e.g. curve form), you can group them in the graphics element and output them all together in a multiple plot. This allows you to compare, for example, different curves.

Example: Slope Type 1 form plot

The illustration shows the **Slope Type 1** form plot (landscape) by way of example.

It is derived from the 2D curve form. In addition, the regression line is shown.



Example: Slope Type 2 form plot

The illustration shows the **Slope Type 2** form plot (landscape) by way of example.

It is derived from the 2D curve form. In addition, the regression line is shown. The distorted coordinate system is shown; the angle is selected so that the slope line is shown horizontally.

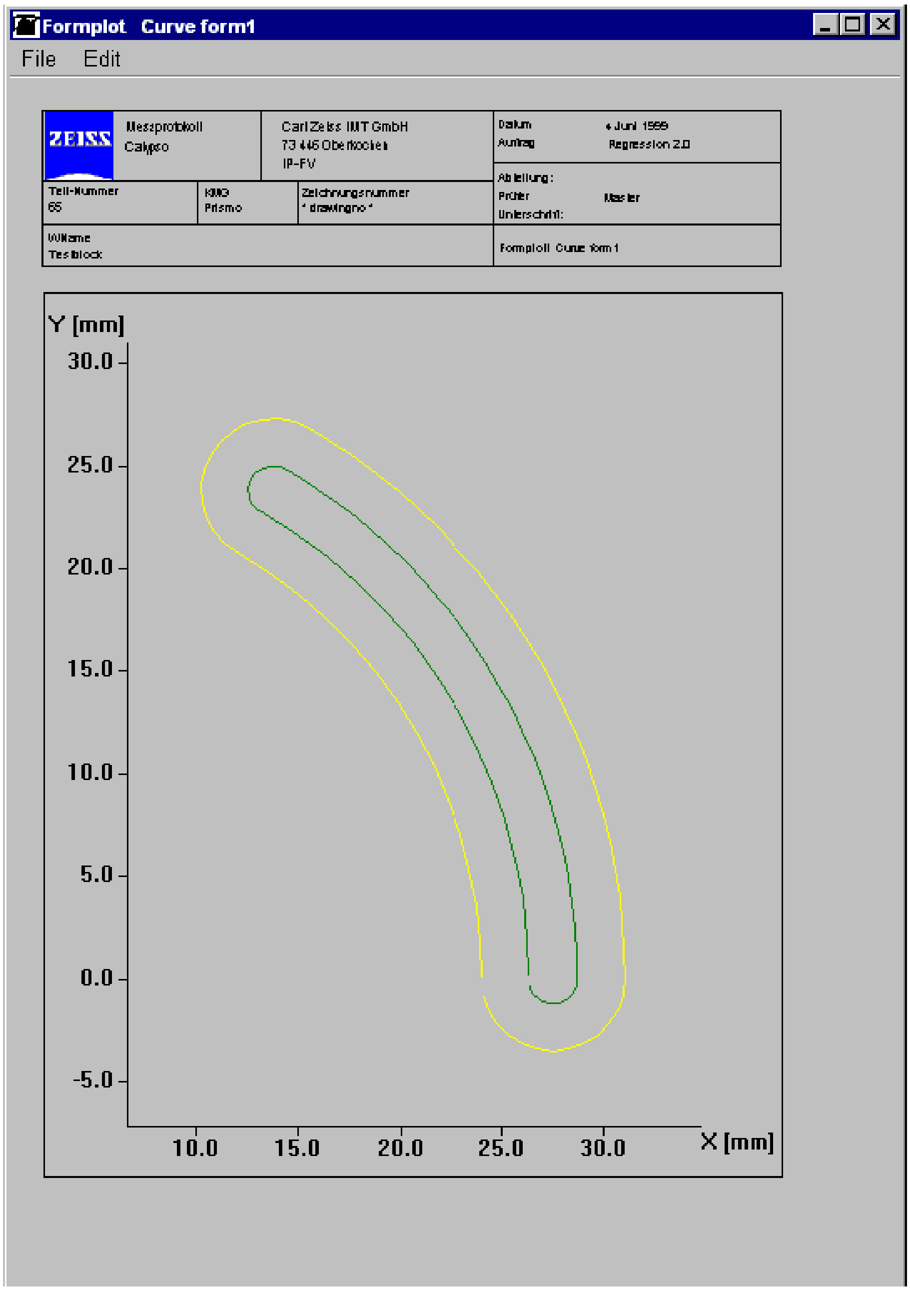
Example: Slope Type 3 form plot

The illustration shows the **Curve form 2D** form plot (landscape) by way of example.

It is derived from the linear curve form. In addition, the regression line is shown.

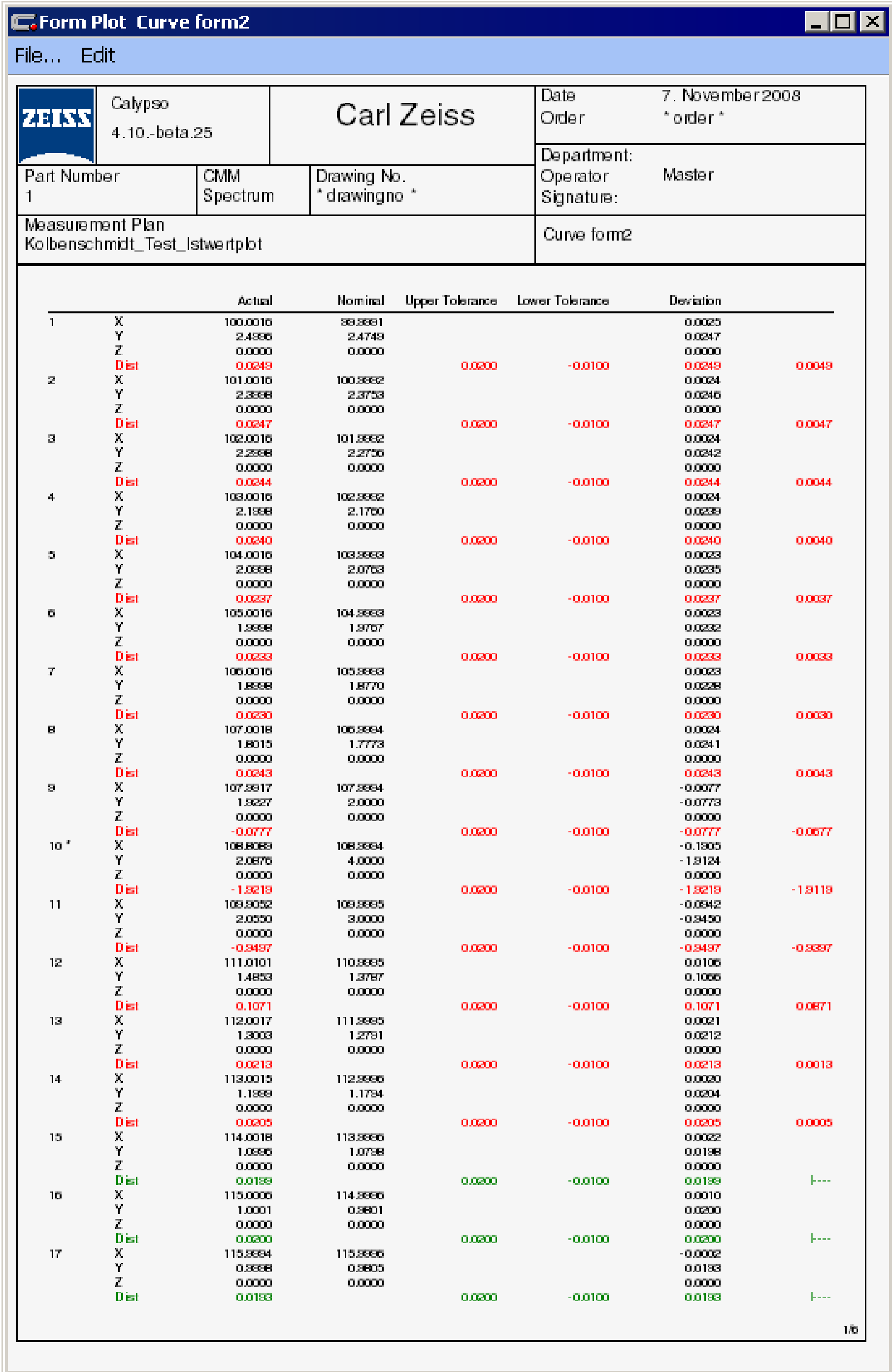
Example: Curve Form form plot

The illustration shows the **Curve form 2D** form plot by way of example.



Example: Point list in the form plot

The following illustration shows a point list in the **Curve Form** plot by way of example.



		Actual	Nominal	Upper Tolerance	Lower Tolerance	Deviation	
1	X	100.0016	99.9991			0.0025	
	Y	2.4996	2.4749			0.0247	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0249		0.0200	-0.0100	0.0249	0.0049
2	X	101.0016	100.9992			0.0024	
	Y	2.3998	2.3753			0.0246	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0247		0.0200	-0.0100	0.0247	0.0047
3	X	102.0016	101.9992			0.0024	
	Y	2.2998	2.2756			0.0242	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0244		0.0200	-0.0100	0.0244	0.0044
4	X	103.0016	102.9992			0.0024	
	Y	2.1998	2.1760			0.0239	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0240		0.0200	-0.0100	0.0240	0.0040
5	X	104.0016	103.9993			0.0023	
	Y	2.0998	2.0763			0.0235	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0237		0.0200	-0.0100	0.0237	0.0037
6	X	105.0016	104.9993			0.0023	
	Y	1.9998	1.9767			0.0232	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0233		0.0200	-0.0100	0.0233	0.0033
7	X	106.0016	105.9993			0.0023	
	Y	1.8998	1.8770			0.0228	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0230		0.0200	-0.0100	0.0230	0.0030
8	X	107.0018	106.9994			0.0024	
	Y	1.8015	1.7773			0.0241	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0243		0.0200	-0.0100	0.0243	0.0043
9	X	107.9917	107.9994			-0.0077	
	Y	1.9227	2.0000			-0.0773	
	Z	0.0000	0.0000			0.0000	
	Dist	-0.0777		0.0200	-0.0100	-0.0777	-0.0677
10 *	X	108.8089	108.9994			-0.1905	
	Y	2.0876	4.0000			-1.9124	
	Z	0.0000	0.0000			0.0000	
	Dist	-1.9219		0.0200	-0.0100	-1.9219	-1.9119
11	X	109.9052	109.9995			-0.0942	
	Y	2.0550	3.0000			-0.3450	
	Z	0.0000	0.0000			0.0000	
	Dist	-0.3497		0.0200	-0.0100	-0.3497	-0.3397
12	X	111.0101	110.9995			0.0106	
	Y	1.4853	1.3787			0.1066	
	Z	0.0000	0.0000			0.0000	
	Dist	0.1071		0.0200	-0.0100	0.1071	0.0871
13	X	112.0017	111.9995			0.0021	
	Y	1.3003	1.2791			0.0212	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0213		0.0200	-0.0100	0.0213	0.0013
14	X	113.0015	112.9996			0.0020	
	Y	1.1999	1.1794			0.0204	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0205		0.0200	-0.0100	0.0205	0.0005
15	X	114.0018	113.9996			0.0022	
	Y	1.0996	1.0798			0.0198	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0199		0.0200	-0.0100	0.0199	|----
16	X	115.0006	114.9996			0.0010	
	Y	1.0001	0.9801			0.0200	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0200		0.0200	-0.0100	0.0200	|----
17	X	115.9994	115.9996			-0.0002	
	Y	0.9998	0.9805			0.0193	
	Z	0.0000	0.0000			0.0000	
	Dist	0.0193		0.0200	-0.0100	0.0193	|----

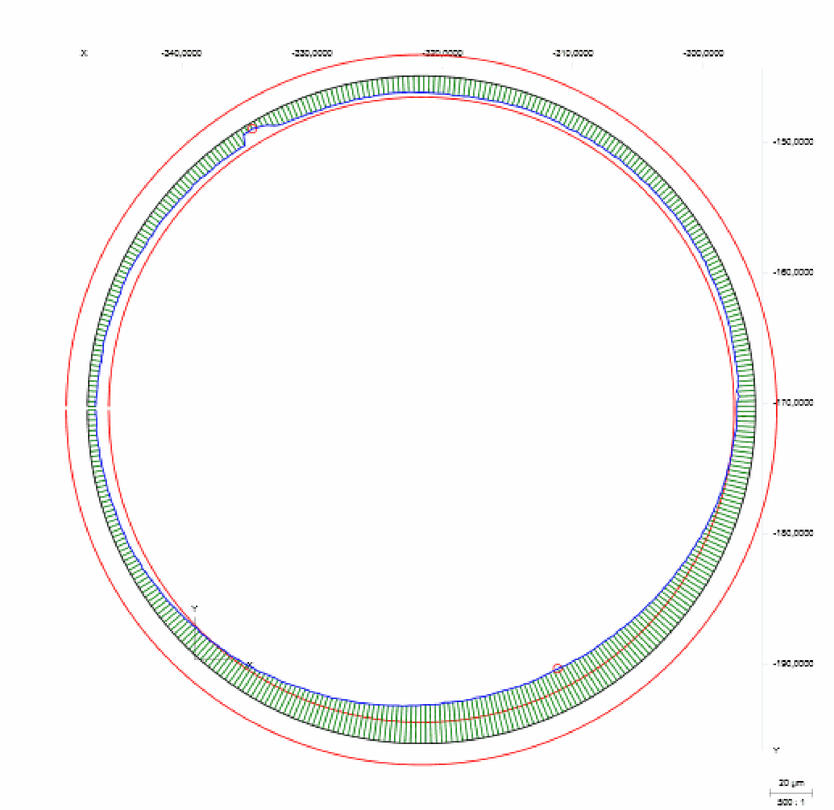
Example: Curve distance plots

The following examples show various curve distance plots.

For details, please refer to Examples of form and location plots in the Online Help.

Curve plot

A curve plot shows the deviation between the nominal distance and the actual distance in graphic form. It is not a representation of the actually measured values and does not show the form of the workpiece.

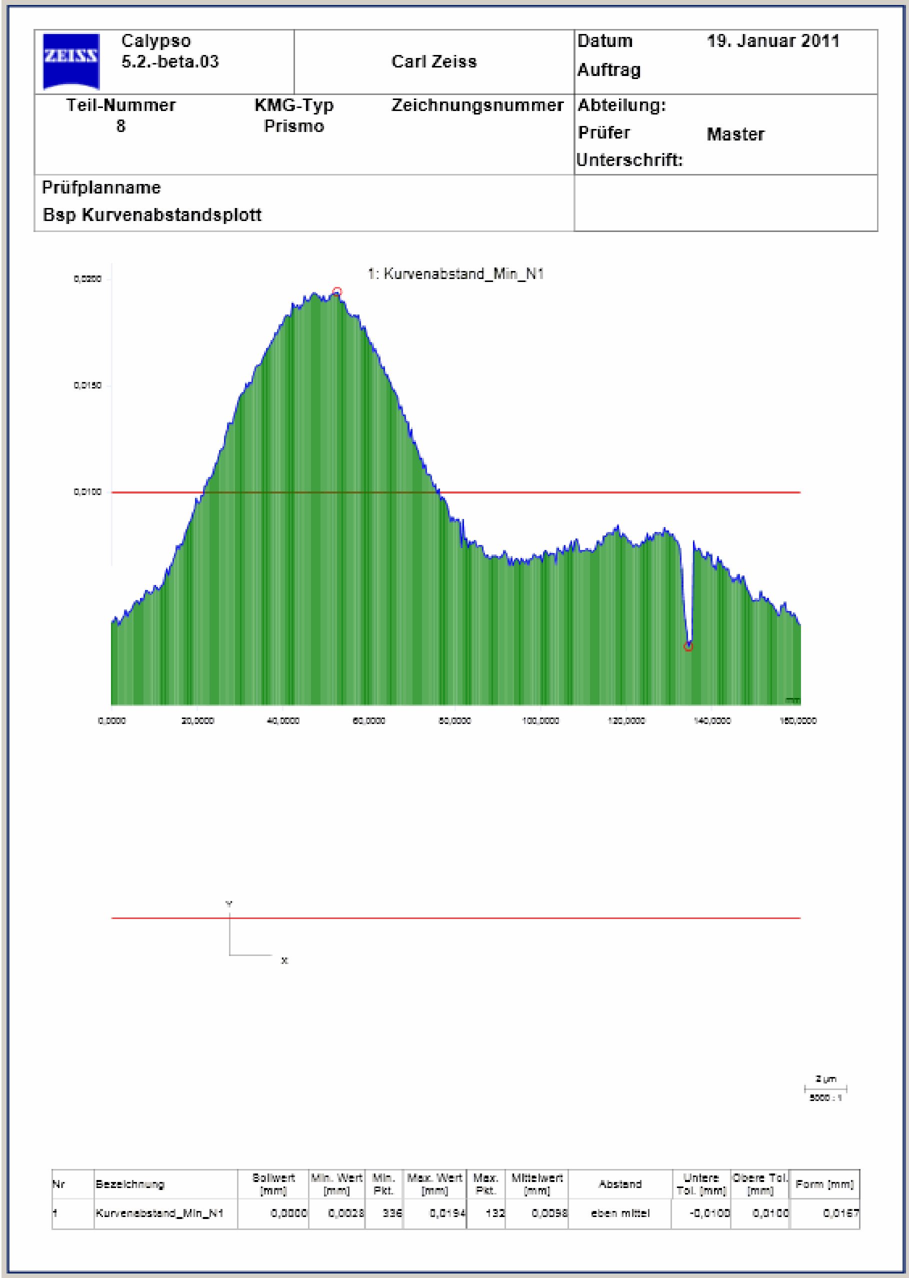


Calypso 5.2.-beta.03		Carl Zeiss	Datum 19. Januar 2011 Auftrag	
Teil-Nummer 8	KMG-Typ Prismo	Zeichnungsnummer	Abteilung: Prüfer Master Unterschrift:	
Prüfplanname Bsp Kurvenabstandsplott				

Nr	Bezeichnung	Sollwert [mm]	Min. Wert [mm]	Min. Pkt.	Max. Wert [mm]	Max. Pkt.	Mittelwert [mm]	Abstand	Untere Tol. [mm]	Obere Tol. [mm]	Form [mm]
1	Kurvenabstand_Min_N1	0,0000	0,0028	336	0,0194	132	0,0098	eben mittel	-0,0100	0,0100	0,0167

Line plot

The **line plot** shows the difference between the actual distance and the nominal distance for each measuring point based on the first measuring point.

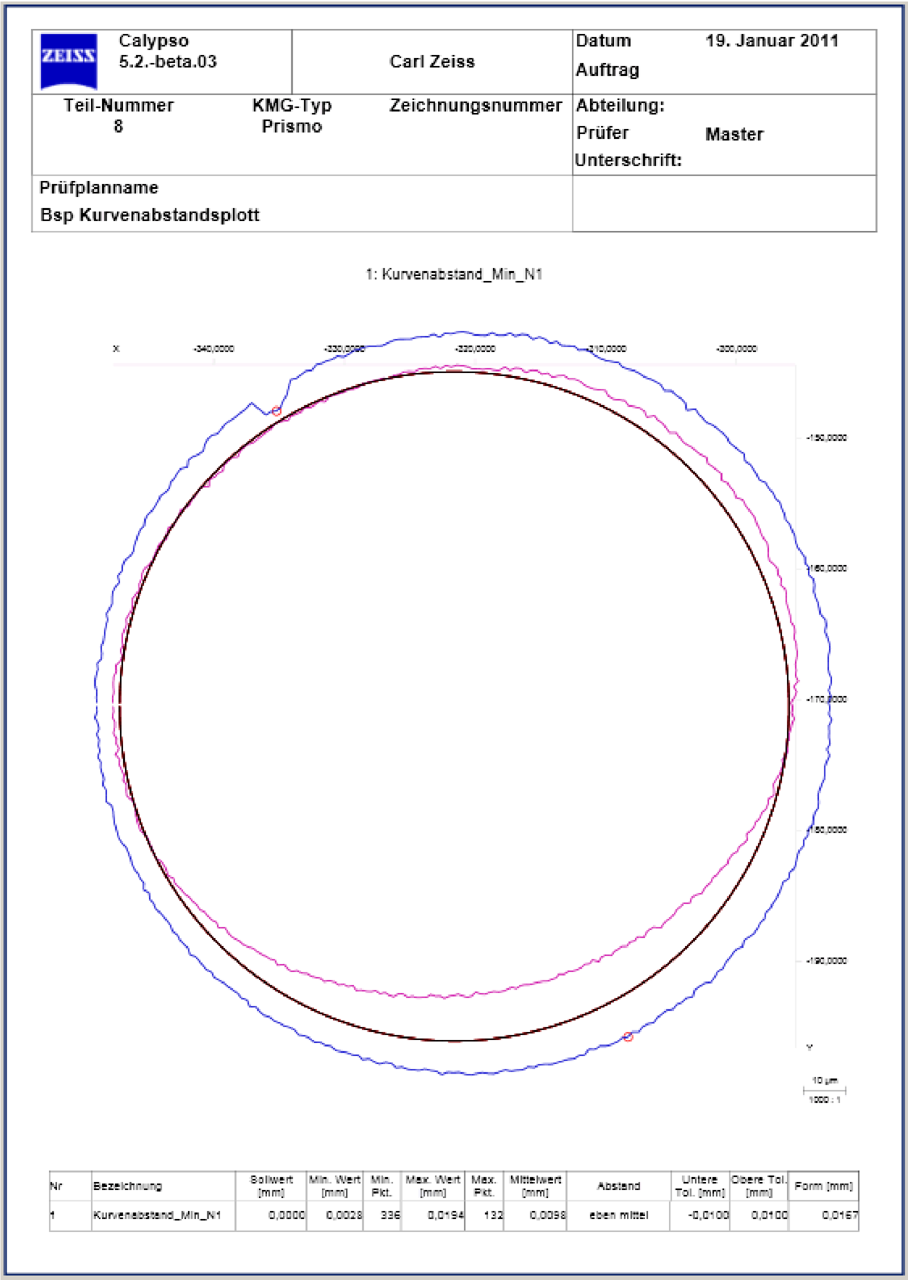


ZEISS Calypso 5.2.-beta.03	Carl Zeiss	Datum	19. Januar 2011
		Auftrag	
Teil-Nummer 8	KMG-Typ Prismo	Zeichnungsnummer	Abteilung:
			Prüfer Master
			Unterschrift:
Prüfplanname Bsp Kurvenabstandsplott			

Nr	Bezeichnung	Sollwert [mm]	Min. Wert [mm]	Min. Pkt.	Max. Wert [mm]	Max. Pkt.	Mittelwert [mm]	Abstand	Untere Tol. [mm]	Obere Tol. [mm]	Form [mm]
1	Kurvenabstand_Min_N1	0,0000	0,0028	336	0,0194	132	0,0098	eben mittel	-0,0100	0,0100	0,0167

2-curve plot

In the **2-curve plot**, the two curves are placed one on top of the other. The location of the curves is immediately visible.



Calypso 5.2.-beta.03	Carl Zeiss	Datum 19. Januar 2011 Auftrag
Teil-Nummer 8 / KMG-Typ Prismo	Zeichnungsnummer	Abteilung: Prüfer Master Unterschrift:
Prüfplanname Bsp Kurvenabstandsplott		

Nr	Bezeichnung	Sollwert [mm]	Min. Wert [mm]	Min. Pkt.	Max. Wert [mm]	Max. Pkt.	Mittelwert [mm]	Abstand	Untere Tol. [mm]	Obere Tol. [mm]	Form [mm]
1	Kurvenabstand_Min_N1	0,0000	0,0028	336	0,0194	132	0,0098	eben mittel	-0,0100	0,0100	0,0167

NOTE

Several curve distance plots can be output in a graphic.

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