A Perfect Combination of Accuracy and Dynamics

Cycle 32 TOLERANCE for optimizing TNC path control

CNC machines are usually supplied with a "universal" configuration designed to suit a vast range of applications. If they have a TNC control, this universal configuration allows achieving good to excellent machining results. Cycle 32 TOLERANCE provides the possibility to further customize the machine to the task in hand. This is particularly useful, for example, when machining free-form surfaces with relatively long machining times. The cycle enables operators to achieve the ideal mix of accuracy and dynamic performance.

Each step in machining a workpiece would actually require a dedicated machine setup. For example, the setup for a finishing operation would be focused on a high contour accuracy and excellent contour smoothing. In a roughing operation, however, this setup would fail to take full advantage of the feed rate potential. The same applies the other way round. To achieve the best possible combination of accuracy and dynamics for all machining operations, operators need a way to fine-tune the predefined machine configuration—and thus also the TNC's path control. The TNC controls offer this possibility with **Cycle 32 TOLERANCE**, which is available as standard.

The wider the path, the faster the corner speed

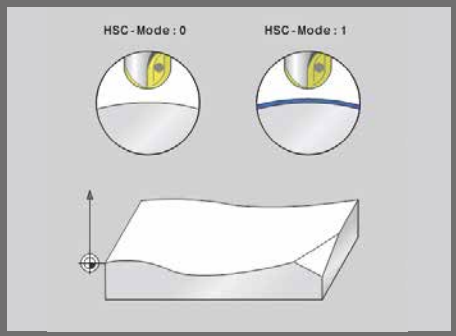
The path deviation T is usually set by the machine tool builder. It defines a default value for the maximum permissible contour deviation. **Cycle 32 TOLERANCE** enables operators to individually adapt the path deviation T to the specific machining operation by specifying the path width that is available to the control. In this way, operators can directly influence the maximum achievable machining feed rate—and thus the machining time. This is particularly useful for contour elements involving many direction changes, such as typical free-form surfaces.

An example from car racing illustrates the principle: The wider the track is, the faster the race car can go around a turn. The driver chooses the racing line that allows the highest speed through the turn. On a narrow track, in contrast, the driver has no choice of line and is forced to slow down.

Roughing operations, in particular, frequently support wider paths, and thus higher tolerances for the path deviation T. In this way the operator can also increase the maximum possible machining feed rate in narrow places. For finishing, the operator needs to reduce the tolerance value again or reset it to the value defined by the machine tool builder. This is done by programming **Cycle 32 TOLERANCE** once again with a low value or without a value.

"Lane Assist" included

Cycle 32 TOLERANCE additionally provides the parameter HSC MODE 0 or 1, which allows adjusting the path control settings. To stick with the car racing example: The HSC MODE parameter corresponds to a lane assist system in the race car. Level 0 permits only a slight deviation from the optimum line; the system intervenes at an early stage, even if this will lead to a loss of time. Level 1 allows a faster overall speed. It tolerates deviations from the optimum line as long as the defined tolerance T is not exceeded, i.e. as long as the wheels of the race car stay on the track.



Applied to the machine tool this means: If HSC MODE is set 0, the focus is on contour accuracy. During finishing, the defined path deviation T is not always used to the fullest by the TNC control in order to increase the contour accuracy. HSC MODE 1 places the focus on reducing the machining time. During roughing, this setting ensures that the path deviation T is used to best effect. It enables the machine to reach and maintain a higher machining feed rate in corners or narrow turns with sharp direction changes. This not only saves machining time. A constant machining feed rate also helps to extend the tool life.

Guide values facilitate programming

To determine the path tolerance T in **Cycle 32 TOLERANCE**, machine operators can use the following values as a general guide:

- For finishing, T should be at least 110 % to 300 % of the chord error used in the CAM system. The CAM chord error is usually defined in a range between 1 µm and 4 µm. Using these settings, the TNC will reproduce the contour to be machined as accurately and true to detail as possible. Depending on the focus of the finishing operation, the tolerance values will range between 5 µm for increased contour accuracy and 20 µm for increased contour smoothing. For high-precision machining operations, tolerances far below 5 µm are not uncommon.
- For roughing, operators should use higher values. The values depend on the desired oversize that is to be left on the contour. Typical values for roughing are a chord error between 4 µm and 30 µm in the CAM system and a path tolerance T between 0.05 mm and 0.3 mm.

Depending on whether a roughing or a finishing program is created in the CAM system, a position resolution to four decimal places is recommended, for example L X–12.0215 Y+12.8951 Z+12.1258. This helps to avoid a falsification of the contour due to rounding errors in combination with a low position resolution.

Cycle 32 TOLERANCE also takes rotary axes into account

For optimizing simultaneous 4-axis or 5-axis machining programs, Cycle 32 TOLERANCE additionally offers the possibility to set the tolerance for rotary axes TA to suit the type of machining operation. In simultaneous 5-axis machining operations, the maximum feed rate at the tool center point (TCP) is often not limited by the linear axes, but by the rotary axes. In these cases, the TNC control adapts the maximum machining feed rate to the slowest rotary axis.

The tolerance for rotary axes TA gives the TNC a value for smoothing the motion of the limiting rotary axes. In this way, the control can make the path contours more homogeneous. At the same time, the permitted smoothing results in more even paths, which can help to reduce the machining time. The influence of the limiting rotary axes on the maximum feed rate at the TCP is reduced.

A key benefit of the TNC control is that the contour—and thus the path at the TCP—will not deviate from the nominal path despite the additional tolerance for rotary axes TA. The TNC takes the TCP deviation resulting from the smoothing of the rotary axes into account and compensates it in compliance with the defined path tolerance T.

When defining the rotary axis orientation, the resolution for rotary axes in NC programs should be specified to four decimal places, for example L X–12.0215 Y +12.8951 A+12.1258 B+32.8945. When using vector programs, the output of the orientation vector should be specified to seven decimal places, for example: LN X–12.0215 Y+12.8951 TX–0.0455636 TY+0.2118529 TZ+0.9762388. Too low an output resolution can negatively affect the machining results.

In complete control of dynamics and tolerances

Thanks to the special path control of the TNC, very dynamic machine motion can be achieved. At the same time the control ensures that the defined tolerance values are observed. Regardless of the machining mode, the machine will always comply with the defined path tolerance T.

On straight contour sections or large-diameter arcs, the TNC does not use the path tolerance T to the fullest. In these cases, this is not necessary anyway in order to reach the maximum machining feed rate. The control simply moves along the center of the contour path defined by the NC program. In addition, the path tolerance T does not affect positioning movements with exact stop, e.g. when approaching drilling positions.