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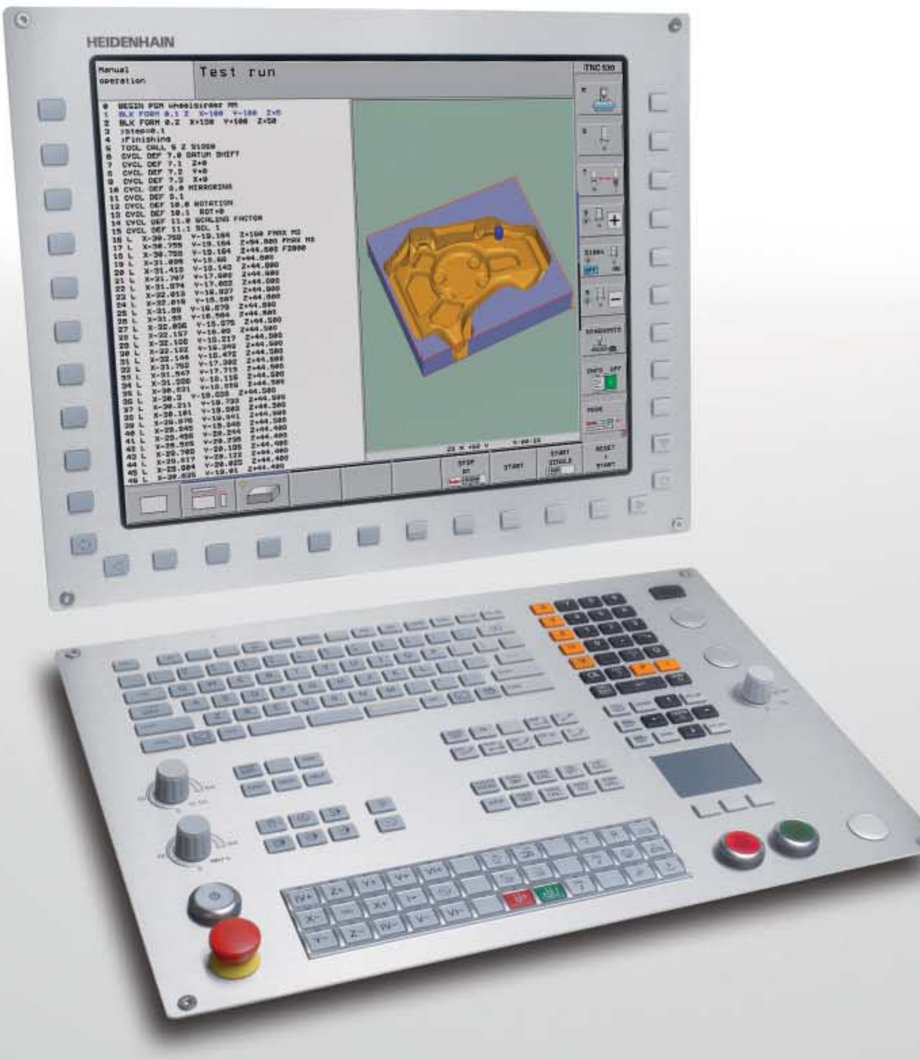


Software Function

Adaptive Control Functions

Very High Dynamic Response and Precision with the iTNC 530

Information for the Machine Tool Builder

October 2011

Adaptive Control Functions

For Very High Dynamic Performance and Precision with the iTNC 530

For years now, the iTNC 530 with digital drive control from HEIDENHAIN has proven itself on machines that place very high requirements on dynamic response and accuracy.

The control already offers numerous innovative servo-control functions for the high accuracy of fast path contours.

These include:
- Very short cycle times for position, velocity and current controllers
- Very short delay within the control
- High control loop gain
- Short reaction time to changing cutting forces
- Jerk limiting and smoothing
- Feedforward control
- Direct and conventional drives
- Position, speed, and current controllers together in one assembly
- HSC high-speed cutting
- Double-speed control loops (option)
- AFC adaptive feed control (option)

To increase productivity, machine tool users are asking for ever higher feed rates and acceleration values, while at the same time they need to maintain the highest possible surface quality and accuracy, placing very special requirements on path control.

The increase in control loop gain required for high traversing speeds can result in the structure of the machine to greater excitation of mechanical oscillations whose resonance values are fed back through the position and speed controls and adversely affect the control behavior.

Here, the resonant behavior of the machine depends on several factors, such as the position of the axes in the working space, the weight of the fixed load on the machine table or the type of mechanical axis coupling.

To fully exploit the possibilities of the machine's dynamic properties, beginning with NC software 606 42x-02 these position-dependent and load-dependent influences can now be compensated with the aid of the following adaptive servo-control functions:

- CTC compensation of axis couplings (option 141)
- PAC position-dependent adaptation of controller parameters (option 142)
- LAC load-dependent adaptation of controller parameters (option 143)

iTNC 530

Load Adaptive Control (LAC)

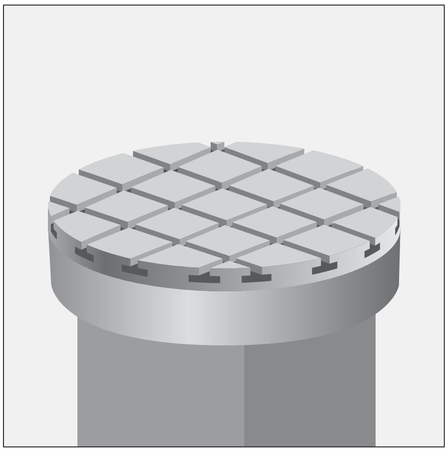
Load-Dependent Adaptation of Controller Parameters (Option 143)

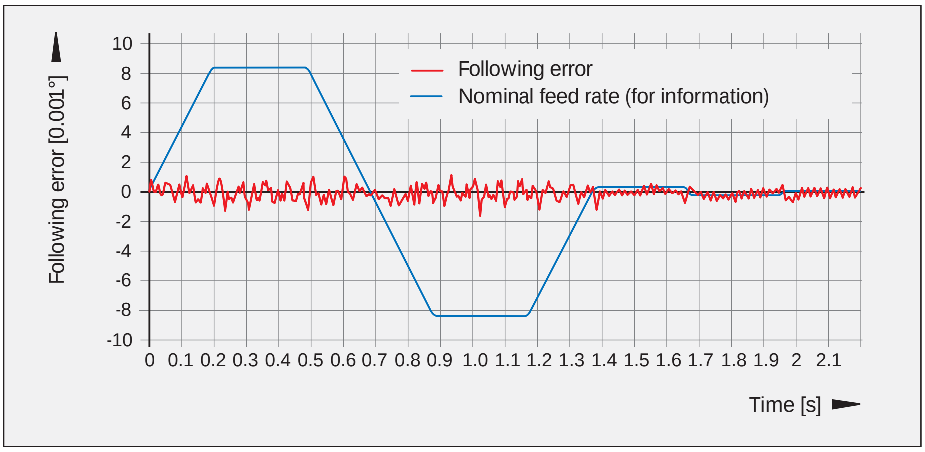
The dynamic behavior of machines with moving tables can vary depending on the mass or mass moment of inertia of the fixed workpiece.

The LAC option (Load Adaptive Control) enables the control to automatically ascertain the workpiece's current mass, mass moment of inertia and the friction forces.

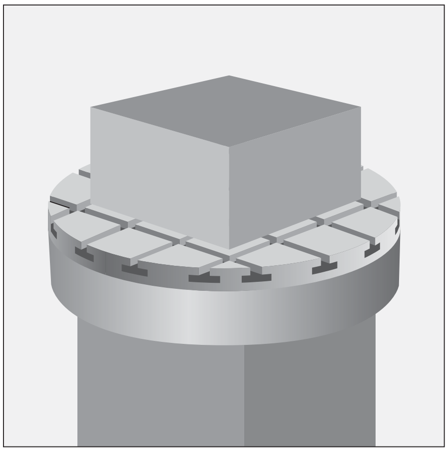
In order to optimize changed control behavior at differing loads, adaptive feedforward controls can exploit data on acceleration, holding torque, static friction and friction at high shaft speeds.

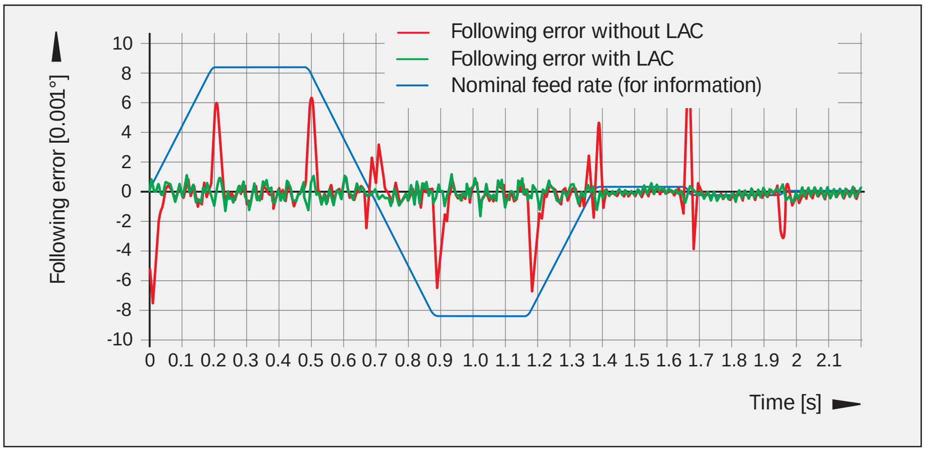
During workpiece machining, the control can also continuously adjust the parameters of the adaptive feedforward control to the current mass of the workpiece.





Optimal feedforward control for rotary tables without additional load and with following error within the tolerance band (± 0.001°)





Additional load changed:
- Without LAC: When the feedforward control is unchanged, the following error is outside of the tolerance band (± 0.008°)
- With LAC: When LAC in active in the feedforward control, the following error is within the tolerance band (± 0.001°)

Cross Talk Compensation (CTC)

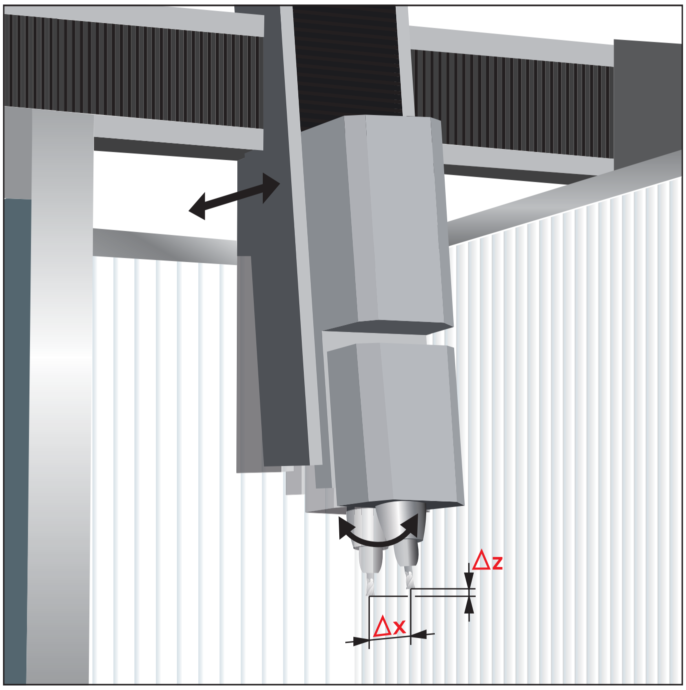
Compensation of Position Error through Axis Coupling (Option 141)

Dynamic acceleration processes introduce forces to the structure of a machine tool. They can briefly deform parts of the machine and thereby lead to deviations at the tool center point (TCP).

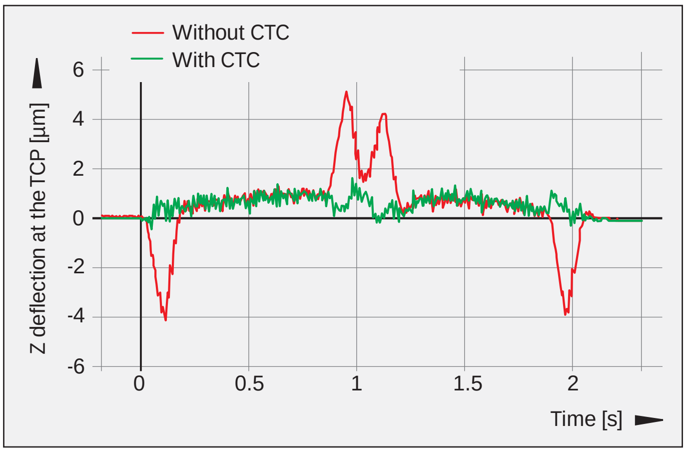
Besides deformation in axis direction, the dynamic acceleration of an axis due to mechanical axis coupling can also result in deformation of axes that are lateral to the direction of acceleration.

This is especially so if the point of force application on an axis does not coincide with its center of gravity, which can cause pitching during the braking and acceleration phases.

The resulting position error at the TCP in the direction of the accelerated axis and lateral axes is proportional to the amount of acceleration.



Servo control optimized for Z=0, following error within the tolerance band (± 1 µm)

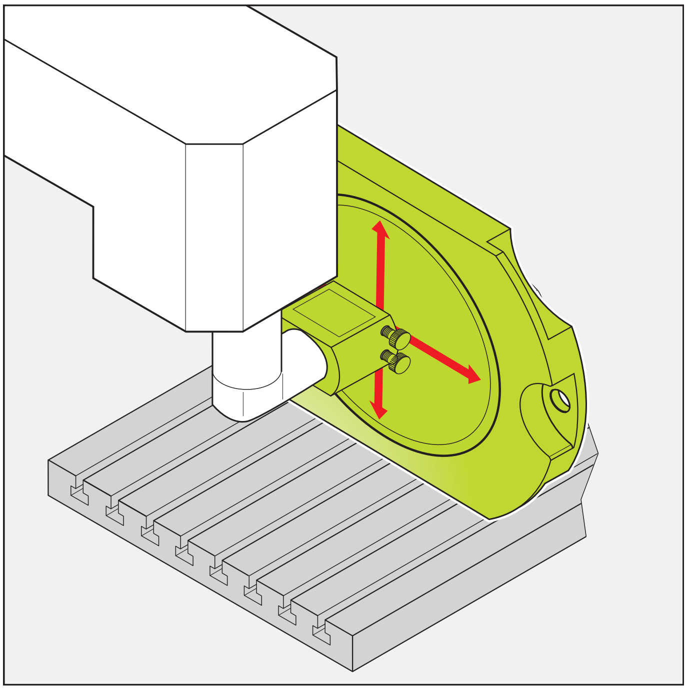


Deflection at the TCP in the Z axis from movement in the X direction.

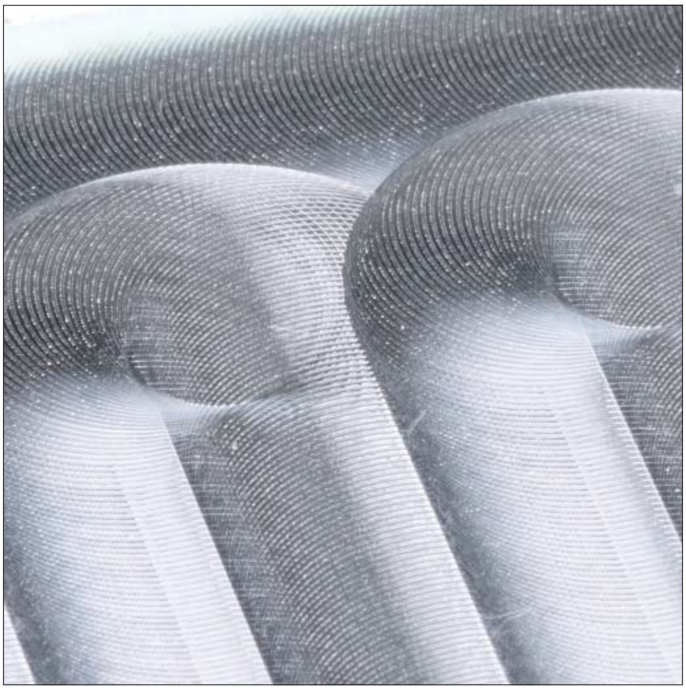
If the dynamic position error as a function of the axis acceleration is known from measurements at the TCP, this acceleration-dependent error can be compensated with the CTC servo-control option (Cross Talk Compensation) in order to prevent negative effects on the surface quality and accuracy of the workpiece.

A grid encoder (KGM) in the plane fixed with two mutually mechanically coupled axes can be used to measure the acceleration-dependent position error of these axes.

Often, the resulting error at the TCP depends not only on the control but also on the position of the axes in the working space. This can also be compensated by the servo control option CTC.



KGM setup for measuring cross couplings in the X/Z plane



Effects of machine vibration on a workpiece:
Left: Without CTC, errors at the TCP result in grooving in the surface
Right: With CTC, a better surface quality is attained

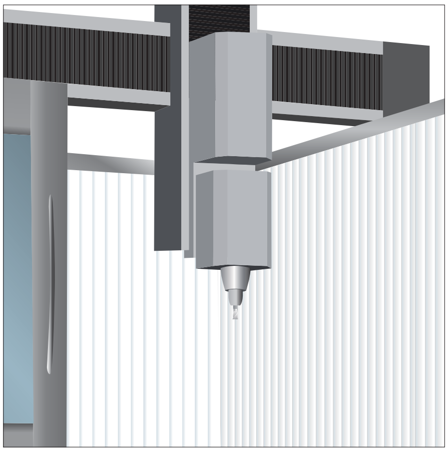
Position Adaptive Control (PAC)

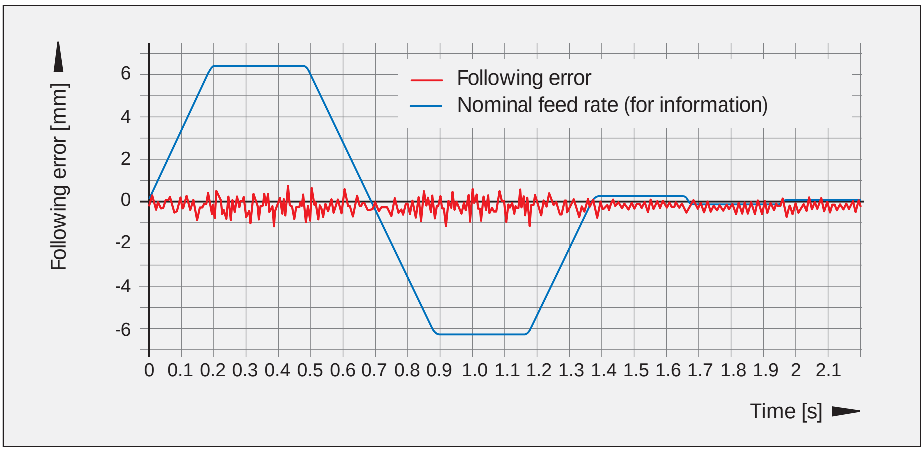
Position-Dependent Adaptation of Controller Parameters (Option 142)

Depending on the positions of the axes in a working space, the kinematic conditions of a machine give it a variable dynamic behavior that can adversely affect the stability of the servo-control.

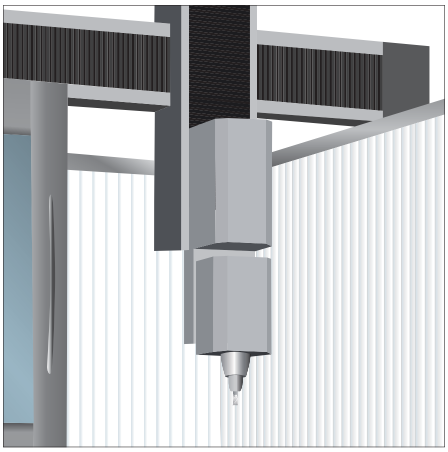
To exploit the machine's dynamic possibilities, you can use the PAC option (Position Adaptive Control) to change machine parameters depending on position.

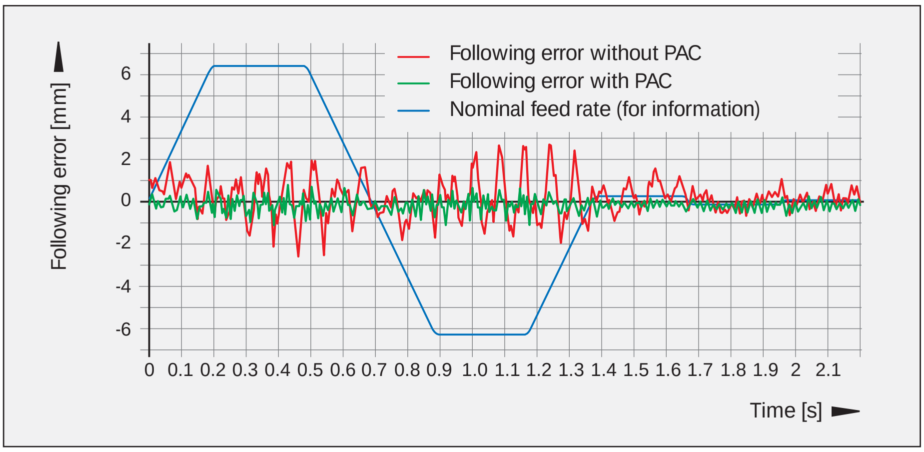
It makes it possible to assign respectively optimal loop gain to defined support points. Additional position-dependent filter parameters can be defined in order to further increase control loop stability.





Servo control optimized for Z=0, following error within the tolerance band (± 1 µm)





Servo control at Z = -500

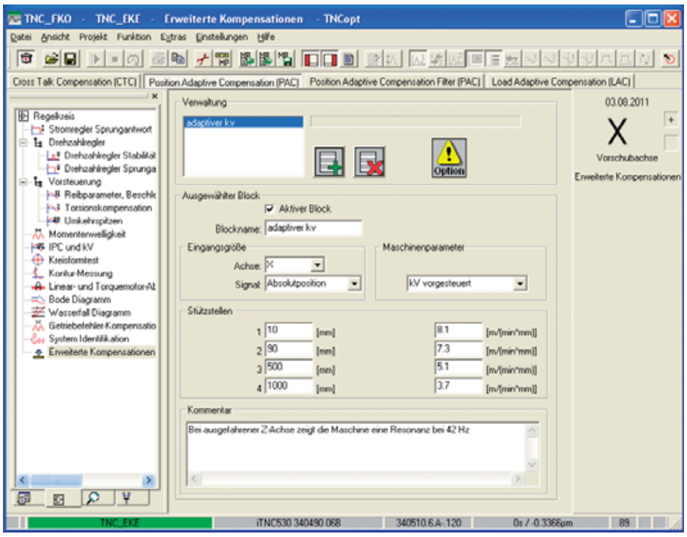
- Without PAC: with clearly visible oscillations and following error outside of the tolerance band (± 3 µm)
- With active PAC: following error stays within the tolerance band (± 1 µm)

Accessories

The PC software **TNCopt** is available as a powerful tool in commissioning digital control loops. It can be used to find parameters for the position and velocity controllers as well as for filters and compensation algorithms. Parts of the commissioning procedure can also be conducted automatically.

Functions
- Commissioning of the current controller
- Commissioning the velocity controller
- Optimization of friction compensation
- Optimization of reversal peak compensation
- Optimization of the kV factor
- Circular interpolation test, contour test
- Linear motor adjustment
- Bode diagrams

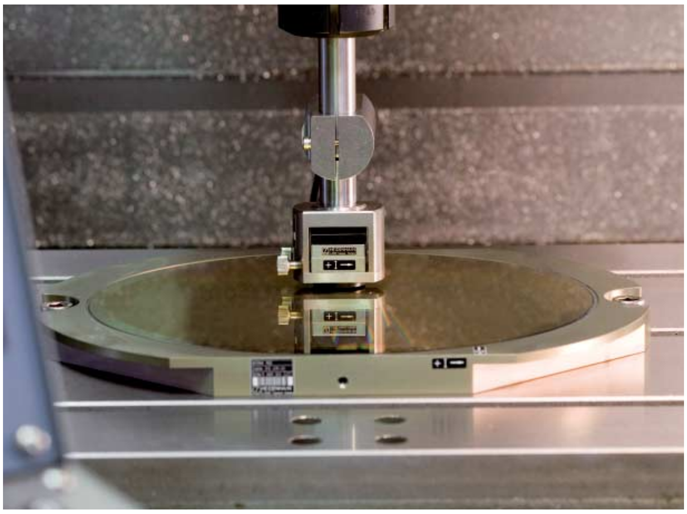
As of TNCopt version 6.0, separate user interfaces are available for the CTC, PAC and LAC adaptive control functions. All of them provide input masks for all functions for entering and editing parameters.



Commissioning software TNCopt

The KGM 181 and KGM 182 **grid encoders** from HEIDENHAIN make it possible to measure position error without contact and at high speeds. The KGM consists of a grid plate with a waffle-type graduation embedded in a mounting base, and a scanning head. During measurement, the scanning head moves over the grid plate without making mechanical contact. The KGM encoders capture any motions in a plane and separately transmit the values measured for the two axes.

Both encoders enable you to make highly accurate 2-D measurements and are therefore ideal, for example, for the metrological acquisition of error caused by axis coupling.


KGM grid encoder

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