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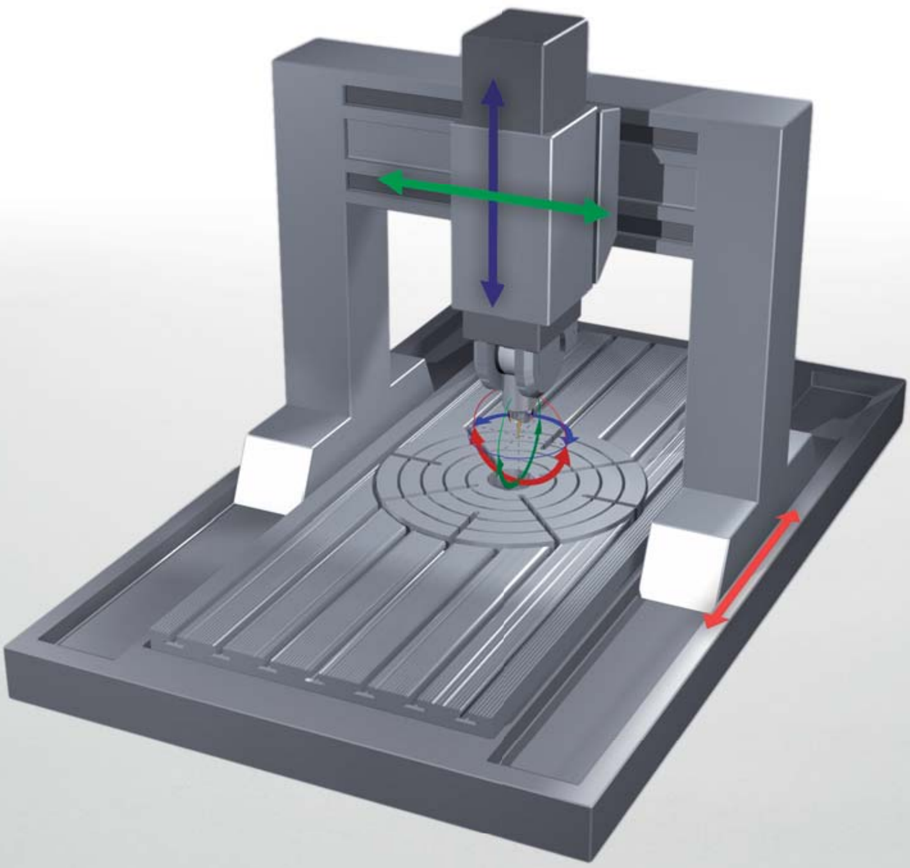


Software Function

KinematicsComp

Increasing the
Machining Accuracy

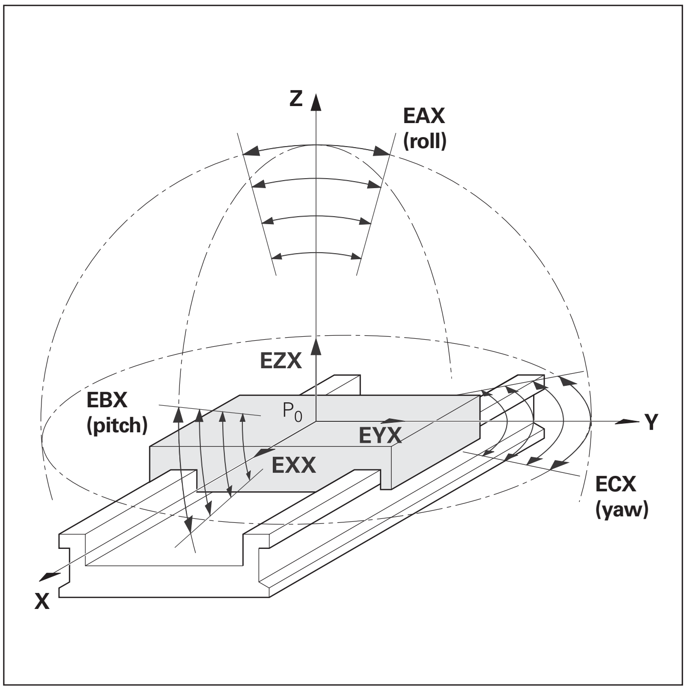
Information for the Machine Tool Builder

October 2009

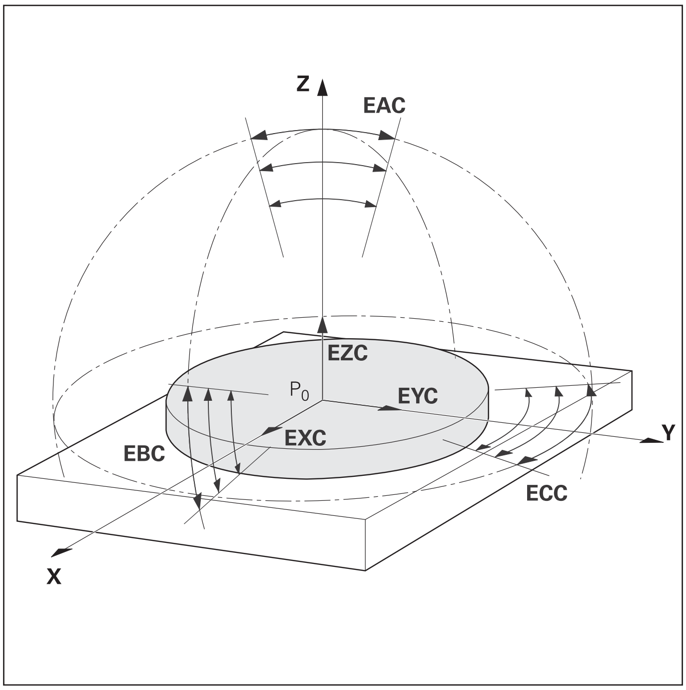
KinematicsComp
Increasing the Machining Accuracy

Demands regarding the complexity and dimensional accuracy of all types of machined parts are becoming increasingly stringent. Maintaining the narrow tolerances required can be problematic, especially on large machines and during five-axis machining. The KinematicsComp software option from HEIDENHAIN puts you in the position of compensating geometry errors of the machine tool.

Geometry errors of a machine tool
The machine tool itself even causes some of the errors. The axes of a CNC machine must obey various geometric demands, including requirements regarding straightness and angularity. ISO 230 comprehensively documents the aspects of various errors on machine tools. This makes it clear that many errors result from the axes in motion. These include not only familiar errors, such as positioning and angular errors, but also pitch, yaw and roll as well as the wobble of a rotary axis. If the errors are considered in more detail, one finds seven relevant errors per linear axis, and even eleven errors per rotary axis. This means that on a five-axis milling machine, 43 different errors are caused solely by the motions of the axes. And each further axis adds to the number of error sources. Since the model stored in the CNC is that of an ideal machine, demands must be placed on certain geometric properties of the axes. The control calculates the necessary axis movements based on the coordinates programmed in this machine model. Until now, deviations from this ideal model could only be compensated in certain, relatively simple, cases.



Component errors of a linear axis as per ISO 230-1



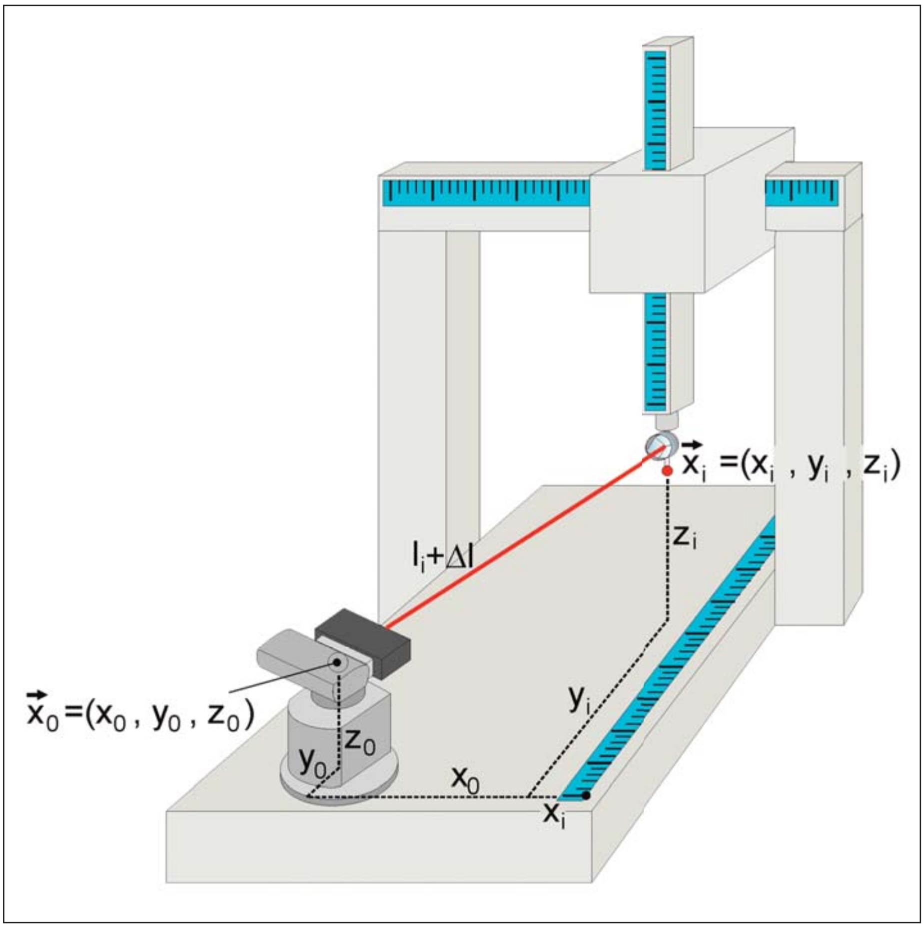
Component errors of a rotary axis as per ISO 230-1

KinematicsComp compensates machine errors
The new KinematicsComp function of the iTNC 530 enables the machine manufacturer to save a comprehensive error description of the machine in the control. In the kinematics model, the manufacturer describes the machine's degrees of freedom and the positions of the rotary axes. Until now it had only been possible to define the nominal geometry of the machine. Now the actual behavior of all axes can be integrated in this original kinematics model. All axis-specific errors listed in the ISO standard can be configured. In addition, further descriptions are also possible, such as the thermal expansion at defined locations.

Determining the geometric deviations
Errors must first be determined before they can be compensated. Along with the classical geometric measurement method using a ruler, compass and dial gauge, newer methods and equipment will increasingly be used in the future, such as laser tracers and laser trackers. These are 3-D coordinate measuring devices that use lasers to determine any positions in space through interferometric measurement. They are capable of very precisely measuring the spatial errors at the tool tip throughout the machine tool's entire work envelope.

Advantages of KinematicsComp
Large machines especially benefit from KinematicsComp's significant improvements of a machine's accuracy. As the result of moving large masses over long traverse paths, mostly unavoidable larger geometric deviations from the ideal model arise. The use of mechanical means to cope with these sources of errors requires considerable effort, and is even then only partially successful. Once the machine is installed at its final location, the amount of optimizing work necessary for such mechanical methods is sometimes not acceptable. This new feature of the iTNC 530 promises great economic value in such cases, since measurement with a laser tracer, for example, should normally be completed within just one to two days.

KinematicsComp therefore offers excellent possibilities for increasing the accuracy of machine tools even more. This new method for projecting the real conditions of the machine onto the kinematics model makes it possible to significantly reduce the effective errors of the axis movements. The more closely the error can be repeated, the better the result of machining the workpiece will be.



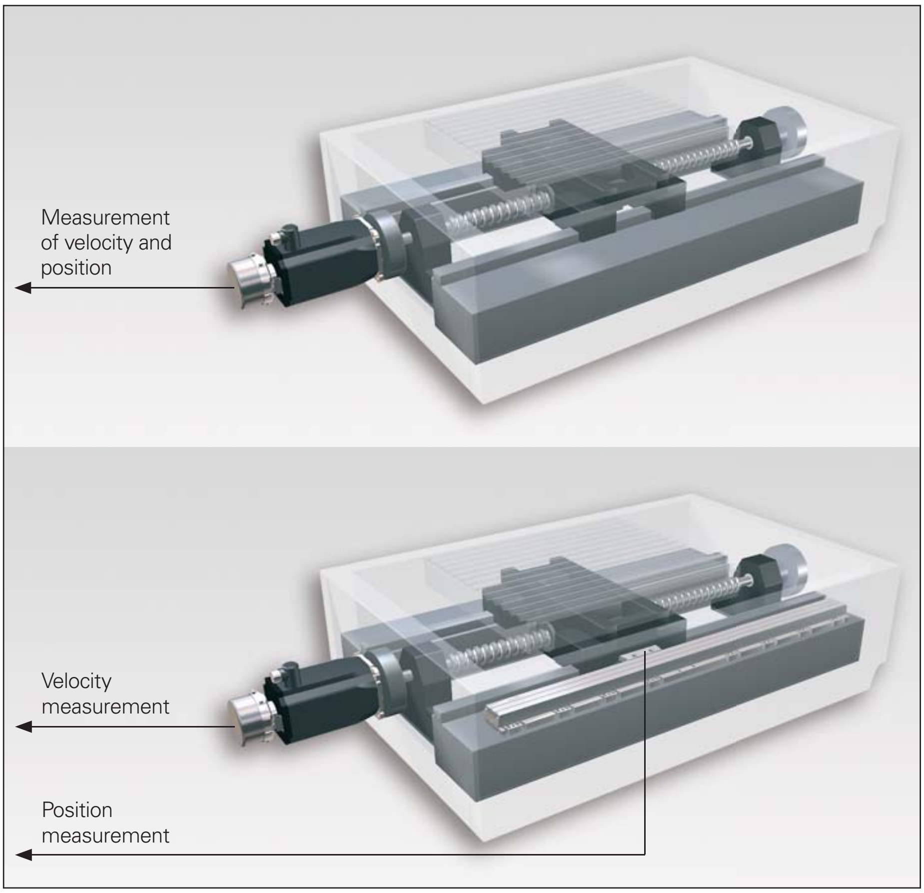
Determining the geometric deviations with a laser-based coordinate measuring device (source: PTB-Mitteilung 117)

Prerequisites for Successful Compensation

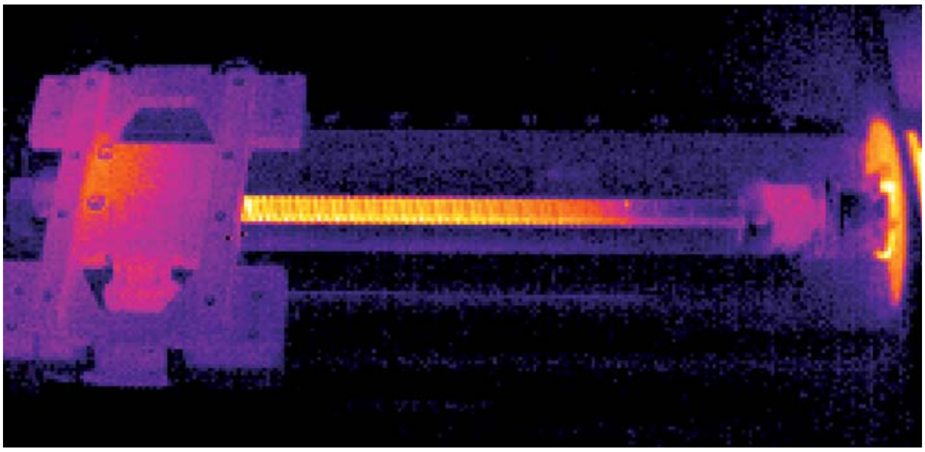
Measurement of geometric deviations is necessary at numerous locations on a machine tool before compensation can take place. However, the repeatability of the deviations during actual operation is definitive for the quality of the compensation. Under this aspect, it is very important that the thermal stability of the machine tool—both in regards to internal as well as external sources of heat—be considered.

Thermal drift is primarily caused by feed axes on the basis of recirculating ball screws. The temperature distribution along the ball screw can rapidly change as a result of the feed rates and the moving forces. On machine tools without dedicated position encoders, the resulting changes in length (typically: 100 µm/m within 20 min.) can cause significant flaws in the workpiece. In this semiclosed-loop mode, the device measuring the speed—usually a rotary encoder—is also used to measure the position.

If a separate position encoder—linear encoders for linear axes, angle encoders for rotary axes—is used for measurement of the slide position, the position control loop includes the complete feed mechanics. This is referred to as closed-loop operation. Play and inaccuracies in the transfer elements of the machine have no influence on position measurement. This means that the accuracy of the measurement depends almost solely on the precision and location of the linear encoder.



Position feedback control in semiclosed-loop mode (top) and in closed-loop mode (bottom)



Heating of a recirculating ball screw during multipass milling at a mean feed rate of 10 m/min.
This thermographic snapshot shows temperatures of 25 °C ▬ to 40 °C ▬.

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For more information
- *iTNC 530* brochure
- Software Function *KinematicsOpt* data sheet
- *Machining Accuracy of Machine Tools* technical information sheet

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