Mechatronics Concept

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VARNSDORF TOS

Výzkumné centrum pro strojírenskou výrobní techniku a technologii

ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

MACHINE DEFORMATION MEASUREMENT FOR ONLINE CORRECTION DURING MACHINING

The overall accuracy of a machine tool is given up to a certain extent by the quality and accuracy of its individual components. The machines are therefore very accurately set during the manufacture and assembly process to achieve a high degree of accuracy throughout their entire workspace. Furthermore, the correction tables are introduced into the control system to allow for the correction of the movement of machinery such as the dislocation of a given movement axis. However, all of these corrections are based on the measurements of the machine geometry carried out during installation or during a servicing of the machine and they don't change in normal work with the machine. The current methods of compensation of the machine's precision do not allow for the monitoring of the current status of the machine and the ability to compensate in real time for deviations in the geometry or deformation caused by the load of the machining force or thermal effects. On large machines, this can play a big part in the accuracy of the workpiece.

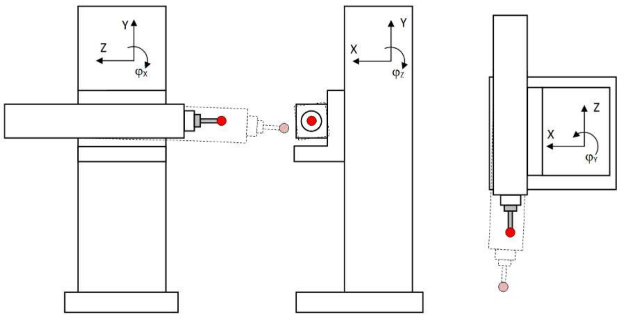
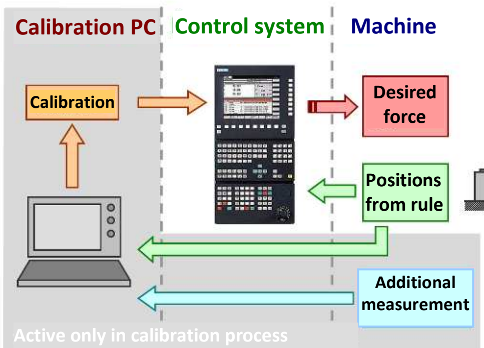


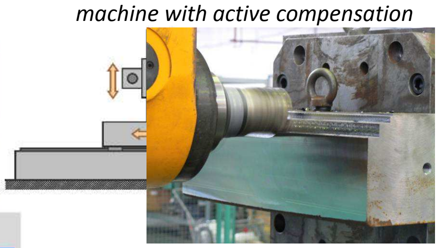
Illustration: possible deformation of a slide with action of the loading force on the tool on the WRD150 machine

It is for this reason that TOS VARNSDORF, together with the Research Center for Machinery Production Engineering and Technology at the Czech Technical University in Prague, has developed equipment and technology that can be used to measure the deformation and geometry of the machine, which is directly integrated into the design of the machine. Based on information from an additional measuring system, the required corrections to each axis of motion are calculated in real-time and introduced into the control system. As a result, the information about its current state is made available to the machine tool which is then able to actively compensate as necessary. Measurements of deformation and the geometry of the machine are intended to compensate for static events with frequencies up to 1 Hz.

Principle of connection of additional measurements with the control system



Machining on the WRD150 machine with active compensation



The technology of the built-in measuring of deformation and geometry of the machine has already been implemented on the WRD150 DUO machine. The operation of the system is implemented directly into the Siemens Sin 840D control system, which introduces the calculated compensations into the regulation.

User environment on Siemens 840D control system used to control compensation in an individual axis

The main elements of the additional measuring system consist of the following:

- **Laser cage to measure headstock deformation and spindle shift in the X and Z axes**
  Part of the X-axis slide is a composite unloaded frame made up of a carrier and a distributor of the laser beam (laser cage base). The headstock and the spindle make up a system of optical sensors (optical prism and PSD member) measuring the position of the incident laser beam. The optical sensors on the headstock measure the deformation of the end of the headstock against the slide and the optical sensors on the spindle measure the deformation (shift) of the spindle in the directions X, Z, φY, φZ against the slide. The measurement resolution reaches values below 1 µm.
- **Additional linear measurement of the spindle position in the Y axis**
  The measurement uses, together with the traditional linear ruler of the Y axis, the spindle displacement difference in the front and rear part of the headstock to calculate the spindle rotation in the direction φX.
- **Laser measurement of the shift and rotation of the end of the RAM against the spindle**
  The equipment consists of a separate unit (transmitter and receiver) mounted on the spindle plate and the reflector located at the end of the slide. The transmitter is a laser beam source and the receiver system consists of optical sensors (optical prism and PSD member), which evaluate the relative shift of the reflector at the end of the slide in the directions X, Y, φX and φY. The resolution of the power measurement of linear displacement is less than 1 micron.

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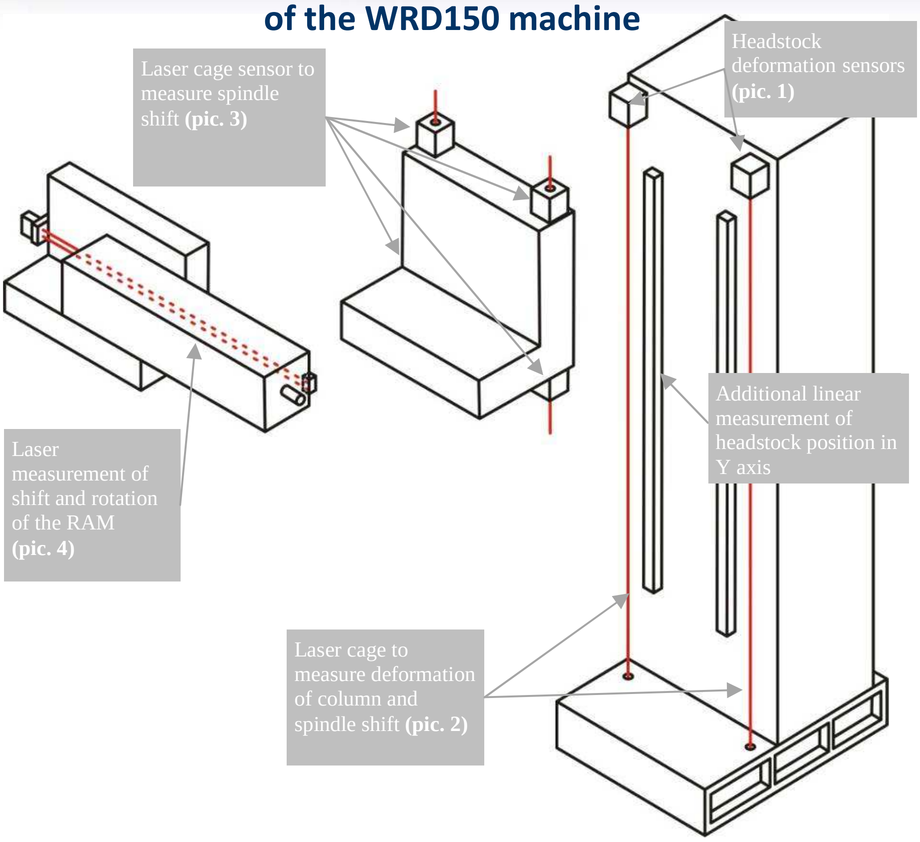
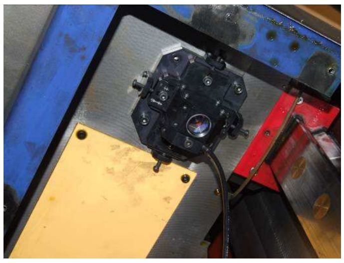
Schematic representation of the built-in additional measurements of deformation of the load bearing structure of the WRD150 machine



Pic. 1 – Headstock deformation sensors

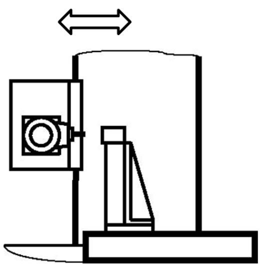
Pic. 2 – Unloaded composite frame with laser cage

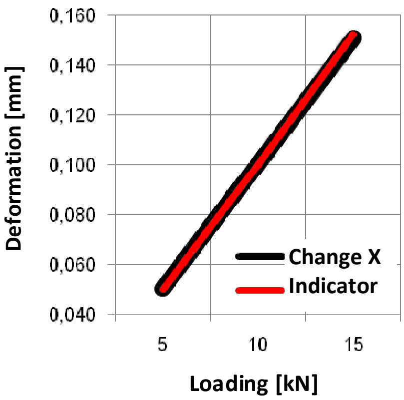


Pic. 3 – Laser cage sensor to measure headstock shift

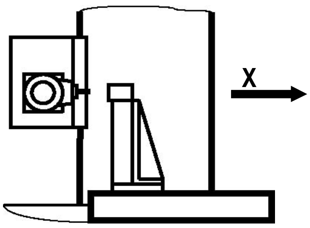
Pic. 4 – Laser measurement of shift and rotation of the RAM end

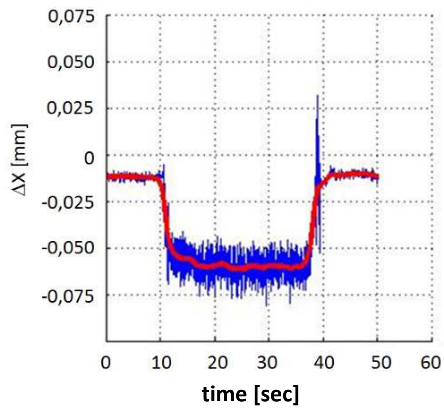
Effect of the additional measurement is further demonstrated by the results of machine loading tests at the point of the tool in the direction of the X axis.
The machine deformations plotted in the graph depend on the loading during the measurement process with a dial indicator and measurements set into the machine.





Record of measurement of the end of the RAM deformation during machining and calculated corrections for the control system in the direction of the X axis.
The graph shows the measurement of deformations in the direction of the X axis (in blue) and, based on these measurements, the corrections sent to the control system (in red).





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TOS VARNSDORF a. s., Tel: +420 412 351 203, Fax: +420 412 351 269, E-mail: info@tosvarnsdorf.com
www.tosvarnsdorf.eu, www.tosvarnsdorf.com