

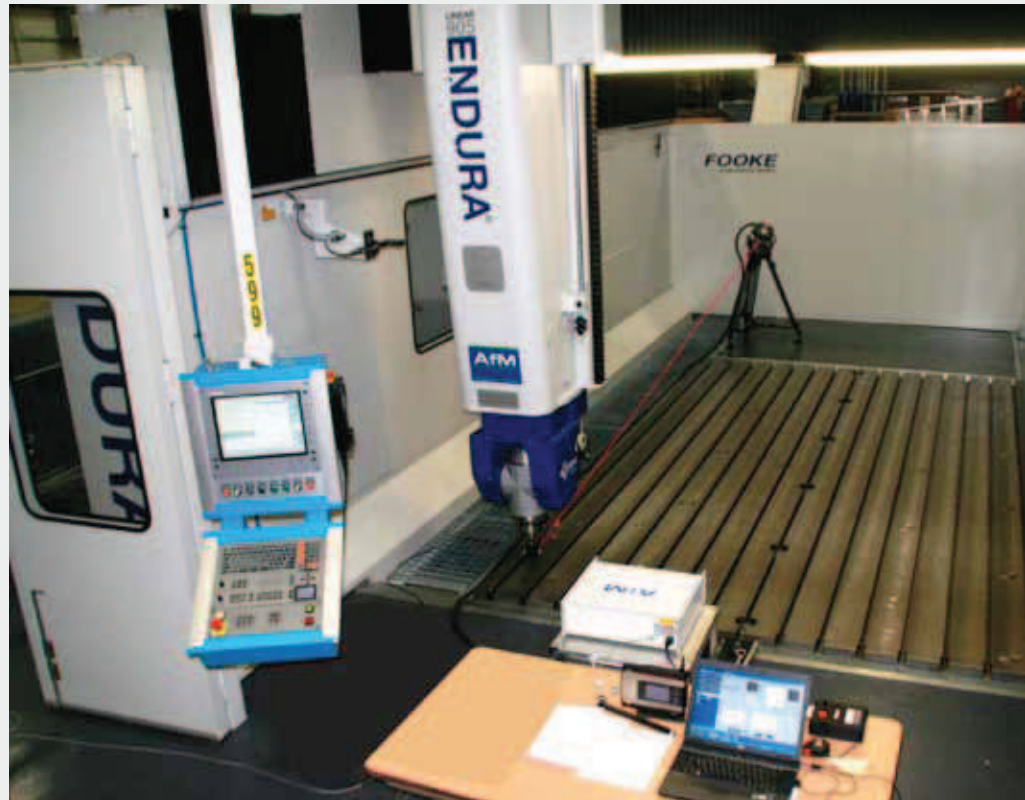
KinematicsComp Proves Itself in Practice

Greater Accuracy through Volumetric Compensation

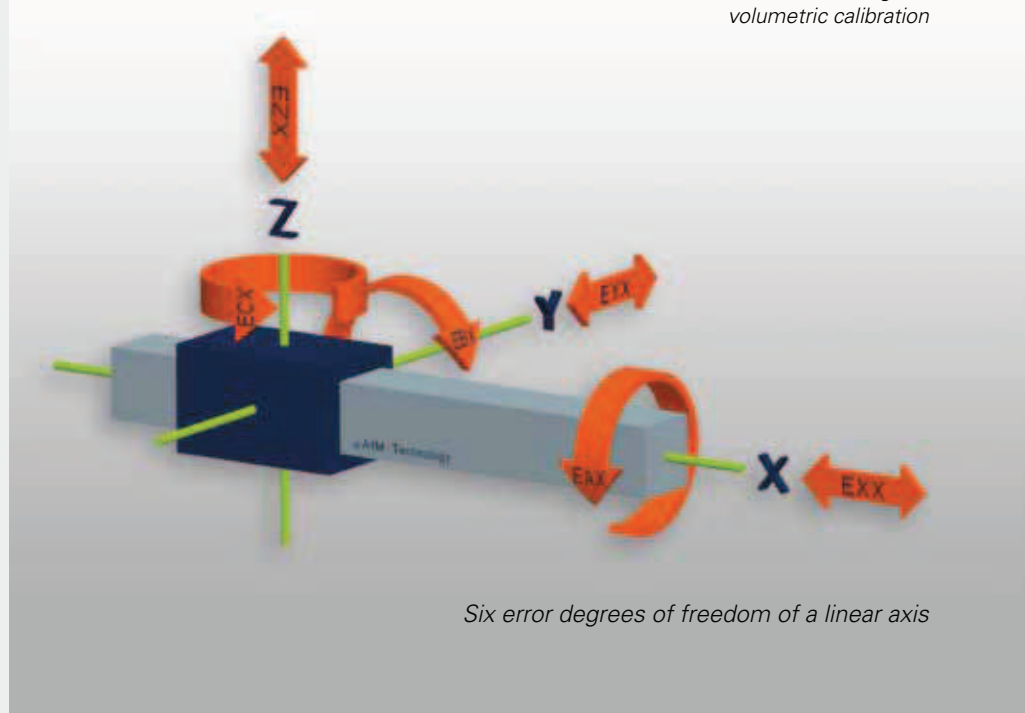
The toolbuilder Prospect Mold in Cuyahoga Falls, Ohio, USA, wanted a new gantry milling machine that would also set the standard in terms of accuracy. So the iTNC 530, with the KinematicsComp option, was chosen to control it. The machine tool was to be measured for calibration with a brand new technology – the etalon LaserTracer, used by AfM Technology from Aalen, Germany, for volumetric compensation. The result is convincing, as this case example shows.

High demands from customers and ever-tighter production tolerances led Prospect Mold to search for the perfect combination of machine tool, control and calibration system. The US company found everything that it needed in Germany: the machine tool, a Fooke Endura 905LINEAR, is a gantry-type 5-axis machining center. It was purchased for the production of large workpieces, molds and tools for the aerospace and car industry. Fooke is based in Borken, a city in North North Rhine–Westphalia, whereas HEIDENHAIN and AfM Technology are located in southern Germany. These three companies are known for their high levels of quality and accuracy even in the US, far beyond the German borders.

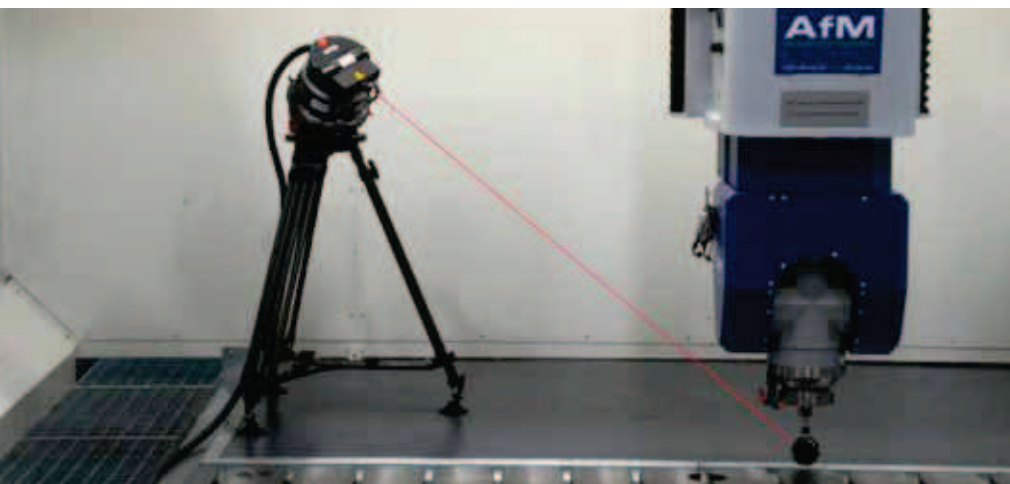
The project began with the three companies testing the potential of the volumetric accuracy. The results of this test were very promising.



The Fooke Endura 905LINEAR during the volumetric calibration



Six error degrees of freedom of a linear axis



The self-tracking LaserTracer while ascertaining the volumetric deviation

The basis: high repeatability, stable ambient conditions, and a control with a complete description of the kinematics

The accuracy of a machine tool can be increased if the kinematics description also maps the deviations from the ideal motion paths. HEIDENHAIN offers this procedure, known as volumetric compensation, with the KinematicsComp option for the numeric control. However, volumetric compensation can only reduce the reproducible (systematic) errors. Therefore, high repeatability and stable ambient conditions are important prerequisites for effective volumetric compensation.

First the deviations within the machine's working space must be found.

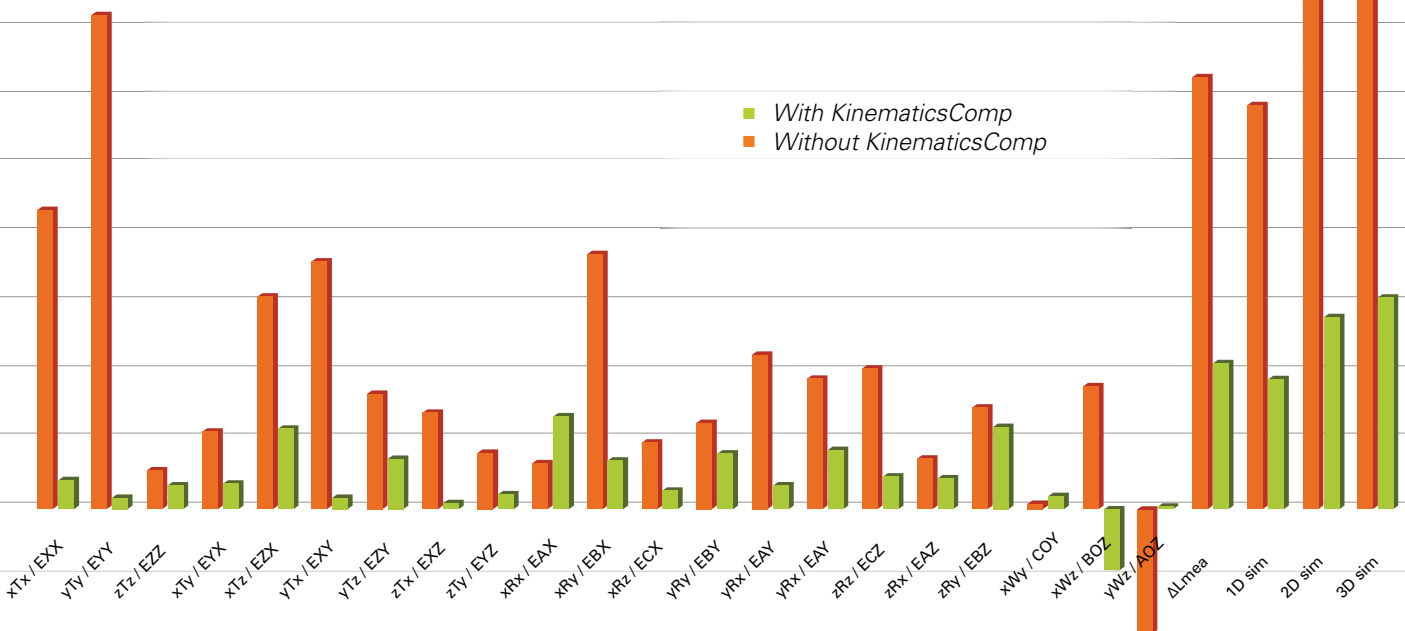
Conventional measurements, using laser interferometers, mostly only determine the positioning accuracy and straightness of the axes. Additional efforts are necessary to ascertain the roll, pitch and yaw as significant sources of error.

That is not the case with the etalon LaserTracer: the system automatically directs the laser at the tool center point, in order to determine the exact distance between the immobile fixpoint of the measuring system and the tool center point. Numerous axis positions are moved to in order to ascertain the

volumetric deviation. The LaserTracer does not need to be readjusted for each position of the machine axes, since the beam is automatically directed at the reflector. According to etalon, linear measurement with the LaserTracer has an accuracy of $0.2 \mu\text{m} + 0.3 \mu\text{m}/\text{m}$. The software takes all error degrees of freedom of the linear axes into account:

- Linear positioning accuracy
- Vertical straightness
- Horizontal straightness
- Roll
- Yaw
- Pitch →

Improvement of the volumetric accuracy with KinematicsComp



21 parameters were to be ascertained for the three linear machine axes (three squareness parameters as well as 18 parameters of the axes along test points in the traverse range). Once all deviations from the ideal geometry have been determined precisely, the KinematicsComp control option can effectively improve the accuracy of the machine tool. Machinists using the iTNC 530 with KinematicsComp profit from the higher accuracy at the tool center point even with different tool lengths and spindle head orientations.

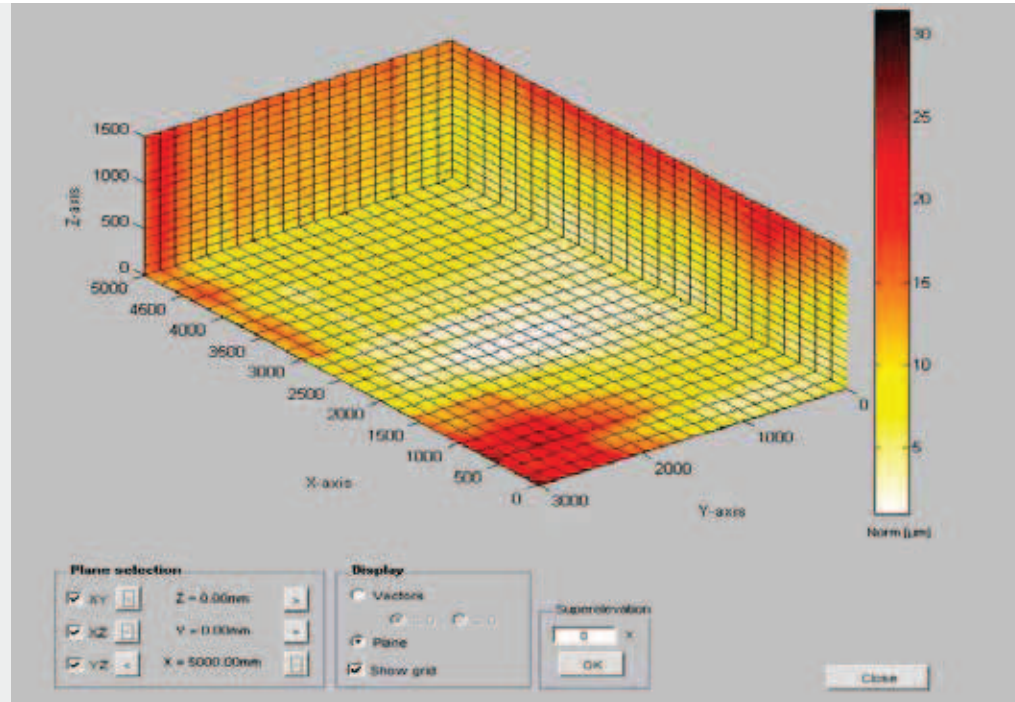
The procedure: Exact determination of volumetric deviations

For complete measurement, the LaserTracer was set up at eight different positions, and about 4000 points were measured in six hours. The influence of temperature was also considered when processing the measured values. The ambient conditions at Prospect Mold were almost perfect: the temperature variance of the air-conditioned shop floor over several days was within 2 °C. AfM Technology's system used wireless technology to transmit the temperatures of the HEIDENHAIN linear encoders attached to each axis.

The LaserTracer measures only the length of the laser beam for determining the machine's deviations. The evaluation is based on a mathematical model of the machine tool and a multilateration system, similar to the "GPS" system, which uses the signal propagation times from several satellites to determine the exact location on Earth of the receiver.

First the uncertainty for each of the 21 parameters was calculated by the Monte Carlo simulation integrated in the software. The calculated values of less than 0.8 μm and 0.8 μrad gave a good indication of what the ideal measuring strategy would be.

The overall result of the volumetric deviation for the uncompensated machine was less than 100 μm , which is quite a good value for a machine-tool volume of 22.5 m^3 .



Position deviations in the machine tool's work envelope after activation of KinematicsComp

The proof: KinematicsComp increases the accuracy

In order to prove the effectiveness of the applied compensation, the milling machine was measured again with the same procedure and duration, but this time with the KinematicsComp software from HEIDENHAIN. The accuracy was improved by 69% on average, which is a significant improvement for a machine already as precise as the Endura 905LINEAR. As a result of this compensation, the machine with KinematicsComp exceeds the accuracy requirements of the aerospace and automobile industries.

Conclusion: Makes precise machines even more exact

Even on a milling machine as large as the Fooke Endura 905LINEAR, it was possible to determine the systematic deviations in all degrees of freedom in a very short time using the LaserTracer calibration system, and to compensate for them with KinematicsComp. The combination of a machine with good repeatability, a suitable measurement procedure, and effective compensation with KinematicsComp of the iTNC 530 can be used to further increase the accuracy of superior machine tools. +

AfM Technology GmbH

AfM Technology GmbH is a solutions provider in the area of mobile measuring technology. The specialty of the company lies in the measurement and compensation of deviations of machine tools and coordinate measuring machines. AfM also supports its customers when introducing volumetric compensation, and when purchasing the etalon LaserTracer system and the accessories of the AfM ThermoStab product series necessary for measurement.

+ www.afm-tec.de

FOOKE GmbH

For over 25 years now, Fooke has been manufacturing 5-axis gantry milling machines, which have proven themselves in the aerospace, rail and automobile industries, as well as in the production of models, prototypes, molds and tools.

From its establishment in 1904, Fooke's policy has always been one of ongoing further development, in order to offer its customers long-lasting value based on excellent technology.

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