

ACHIEVING THE HIGHEST ACCURACY

Case Study of the Volumetric Compensation of a Fooke Endura 905 Linear 5-axis machine tool by KinematicsComp from Heidenhain, powered by the German service company AfM Technology

It was spring time 2010 when AfM Technology, FOOKE and HEIDENHAIN made a project to verify the improvement of volumetric accuracy on a gantry machine tool type FOOKE ENDURA 905 linear, equipped with the software option KinematicsComp on a HEIDENHAIN iTNC 530 CNC.

The result of this test was very promising. Therefore, the US company Prospect Mold, supplier to the aerospace and car industry for high precision molds and small tolerance machined parts, decided to buy the whole package, a high quality machine tool, a progressive, reliable CNC system and the Volumetric Compensation from the service company with the vastest experience in this new technology.

After the assembly and setup of the machine tool at the company Prospect Mold in Cuyahoga Falls, Ohio by the FOOKE service staff, AfM Technology personnel performed the volumetric calibration and compensation of the ENDURA 905 Linear, by using one of the most modern Laser measurement systems (LaserTRACER) for machine tool and CMM calibration.



figure 1: FOOKE ENDURA 905 Linear during the volumetric calibration

What does “Volumetric Compensation” mean?

Conventional compensation approaches used in modern CNC controllers are able to compensate positioning and straightness deviations. Even though, significant components of the axes deviations are not considered. In essence, only one line in the working volume is compensated by standard laser interferometers. Neglecting the rotational errors (pitch, yaw, roll) of the axes deviations in other places in the volume will occur. Especially in large gantry milling machines, like the ENDURA with an axis travel of X 5.000mm / Y 3.000mm / Z 1.500mm, rotational errors can cause significant deviations, due to lever effect (extended Z ram). Each of the three moving axes in a cartesian machine tool has six deviations that contribute to the TCP (Tool Centre Point) positioning error.

They are:

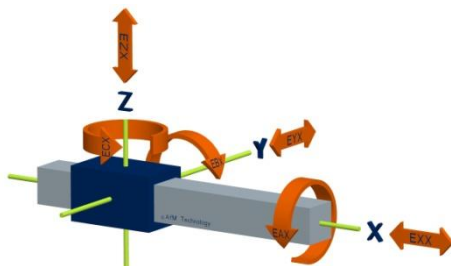


figure 2: 6 degrees of freedom of a linear axis

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

Also the squareness errors between the three cartesian axes must be added to this list. In total, the kinematic model used in the CNC needs to be enhanced by a list of 21 error components to control the TCP position with highest precision. With the HEIDENHAIN software option KinematicsComp, available since 2008 for iTNC530, all 21 error components of a 3 axis machine can be considered. When all these error components are known, the complete behaviour of the machine can be described within the HEIDENHAIN controller iTNC530 as a base for significant accuracy improvements in the entire working volume of the machine.

Measurement assembly and procedure

The environmental conditions at Prospect Mold were almost perfect. The temperature variance during the whole measurement procedure was within 2 degrees Celsius (average 20°C / 68°F), due to an air-conditioned shop floor. Nevertheless the LaserTRACER system accounts the temperature influence at all single axes / linear encoders by a wireless online temperature measurement system. The calibration of the completely uncompensated machine tool took only 6 hours and generated the “mechanical volumetric accuracy” out from almost 4000 laser length measurements, taken in the whole volume. The LaserTRACER has been mounted in 8 positions of the machine volume, among them the four edges, to get different line of sights to the single axes and their deviations.

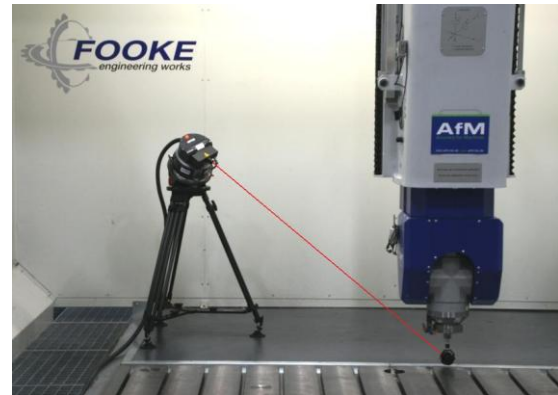


figure 3: Self tracking LaserTRACER used by AfM during error mapping

Incidentally mentioned, it is not necessary to align or fine adjust the LaserTRACER position. In contrast to standard laser tracker systems and straightness lasers, the LaserTRACER measures only length, not any angle. Therefore the uncertainty of the system is only 0,2µm + 0,3µm/m. The evaluation is based on a mathematical model of the machine tool and a multilateration system, similar to the “GPS”-System. By the integrated Monte-Carlo-Simulation, the uncertainty for each of the 21 parameters was calculated and gave values, smaller than 0.8µm resp. 0.8µrad. The range of the LaserTracer is a 15m radius and can be extended infinitely, by mathematical superposition in the TRAC-CAL software for the use in larger machine tools.

The result of the volumetric deviation for the uncompensated machine was 100µm, which is quite a good value for a machine tool volume of 22,5m³. Moreover, all 21 single deviations for the X / Y / Z axis and the repeatability of the machine have been calculated by the TRAC-CAL software. With these parameters, AfM Technology generated the compensation tables for the HEIDENHAIN iTNC 530 controller.

After the KinematicsComp activation, the verification measurement of the compensated ENDURA 905 Linear machine tool was made in another 6 hours, in order to proof the effectiveness of the applied compensation of the KinematicsComp option in the real machine operation.

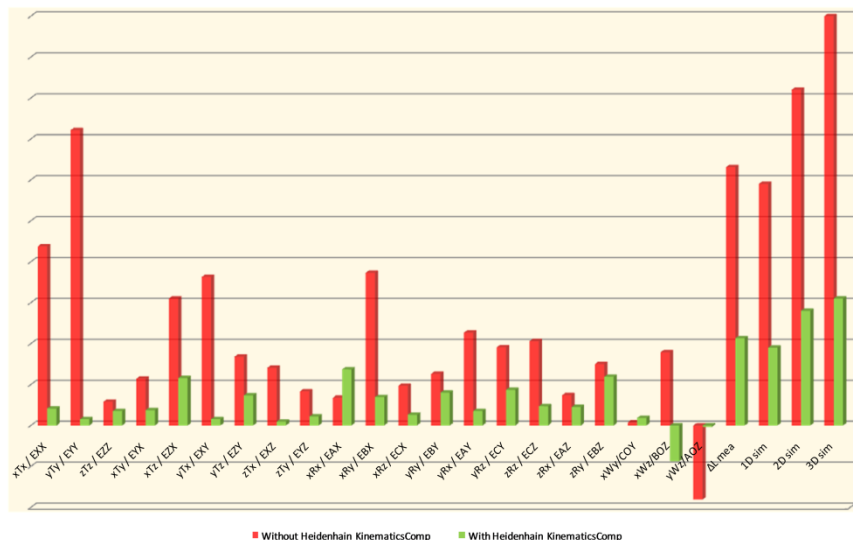


figure 4: Improvement of volumetric accuracy by KinematicsComp

Results

The evaluation of the 21 residual errors indicated a significant improvement of volumetric accuracy by 69% with active KinematicsComp on the HEIDENHAIN iTNC 530. The results are shown in figure 4 and figure 5: the FOOKE ENDURA 905 linear milling machine with volumetric compensation exceeds the tolerance requirements of the aerospace and car industry .

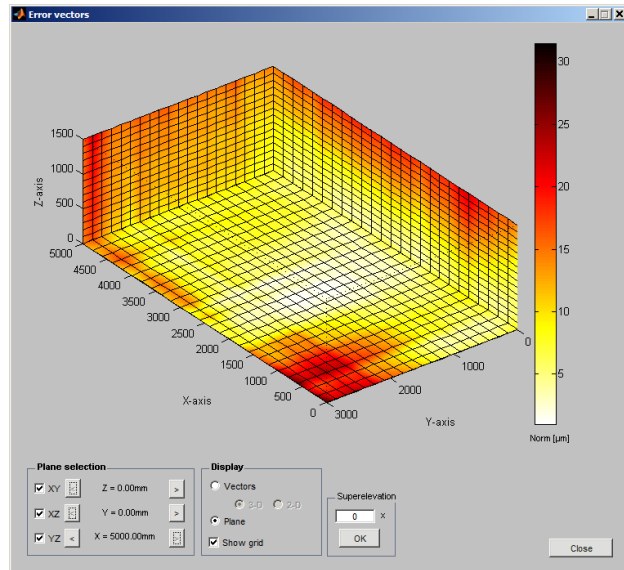


figure 5: Compensated machine volume

Conclusion

Even on a large FOOKE ENDURA machining centre, AfM Technology, using the LaserTRACER calibration system, was able to measure all systematic deviations accurately and generate compensation data in a very short time. To perform the task of mapping the data points and creating a high fidelity set of compensation tables manually, would be very difficult and much more resource intensive.

The considerable reduction of the deviations with the KinematicsComp option in the HEIDENHAIN iTNC 530 controller could be confirmed by the verification measurement. Because of the good repeatability of the FOOKE ENDURA machine tool and the stable environment, Company Prospect Mold is now able to achieve considerable higher accuracy for large work pieces.

Volumetric Compensation is not a tool to produce cheaper machine tools, instead of it is a tool to make good CNC machines significantly more accurate.



About AfM Technology

AfM Technology GmbH is a solutions provider in the area of mobile measuring technology. The specialty of the company lays in the calibration measurement, monitoring and compensation of deviations of machine tools, coordinate measuring machines and other positioning equipment.

As a partner from most of the CNC Control producers, AfM offers its customers not only the software option, but also machine tool calibrations and verifications of volumetric compensations from only one source. This includes the introduction and the training, as well as the sale of ETALON LaserTRACER Systems and customized carbon fibre accessories, type ThermoStab. The engineers at AfM Technology have a lot of experience in the generation of optimum measurement strategies for different machine tools.

Hereby AfM rely on their vast metrological experience, state of the art technology and cooperation with reputable partners. AfM offer their customers, customer made solutions ranging from service, engineering support, software packages for the optimization of PLM and Quality processes, accessories for the 3D measuring technology, through to completely assembled systems.

The goal of AfM Technology is their international presence at all major markets of the machine-building industry and to offer their customers the highest professional competence and fastest possible reaction time.

AfM Technology GmbH

Gartenstraße 133
D-73430 Aalen, Germany
Phone +49 (0)7361 / 889608-0
info@afm-tec.de
www.afm-tec.de



About FOOKE

From its establishment in 1904 through to today, Fooke's policy has always been one of ongoing further development. Only by maintaining continuity, one can „live“ changes and succeed in realising them. Clear structures, a high level of flexibility and flat hierarchies as well as our project- and process-structured organisation focusing on customer needs are just some of the elements that define our working practices.

We are always searching for new solutions, innovative developments and technical achievements, in order to develop the best solution for our customers. To make the impossible possible is a cornerstone of our corporate philosophy. Therefore, we attach particular importance to nurturing a harmonious three-way relationship between our customers, our employees and our suppliers.

Over the course of the past decades, we have developed into an industrial competence centre and are an accepted partner for many companies at the leading edge of technology in the national and international market. Our core competencies include the development and transfer of engineering and production technology. Our inter-disciplinary working methods have widened the scope of our experience and provided us with cross-sector product skills.

FOOKE GmbH

Raiffeisenstraße 18-22
D-46325 Borchen, Germany
Phone +49 (0)2861 8009-01
info@fooke.de
www.fooke.de

HEIDENHAIN

About HEIDENHAIN

DR. JOHANNES HEIDENHAIN GmbH develops and manufactures linear and angle encoders, rotary encoders, digitals readouts (DROs) and TNC numerical controls. For more than 40 years, HEIDENHAIN has been supplying DROs for machine tools, and since 1976, HEIDENHAIN shop floor oriented TNC controls have proven very successful on CNC machine tools. Today, the iTNC 530, together with high accuracy linear and angle encoders, enable machine positioning movements that are very fast and yet true to contour. In the conflict of interests between machining time, surface quality and volumetric accuracy, the iTNC is capable of making an approach optimized for the milling machine and the manufacturing process. End users are also able to influence the result of milling with simple changes to the parameters. The path control of the iTNC enables optimization of machining times under given requirements for accuracy and surface quality.

Dr. Johannes HEIDENHAIN GmbH

Dr.-Johannes-Heidenhain-Straße 5
D-83301 Traunreut, Germany
Phone +49 (0)8669 31-0
info@heidenhain.de
www.heidenhain.de



About Prospect Mold

Company Prospect Mold is a modern, highly sophisticated shop with a sincere desire to satisfy our customer's requirements. We pride ourselves on our ability to combine the many talents of our employees with the ever-changing technological advancements in the mold making industry.

Since the founding in 1945, Prospect Mold has engaged in a relentless drive for improvement and perfection. In so doing, we have earned a reputation for delivering complex compression and injection molds of the highest quality. In a further effort to diversify and strengthen our core abilities, Prospect Mold has dramatically increased the use of 5-axis machining to enter into the aerospace tooling market. Since 2001, we have acquired many new mills, each a little faster and larger than the last. We now supply complex contour tooling and production part machining too many of the world's largest aerospace companies. From cure fixtures, to trim fixtures to carbon fiber parts, Prospect Mold is leading the way for today's airplanes.

Prospect Mold, equipped with state of the art machinery and coupled with a very talented group of employees, intends on remaining a world class leader on our industry. Our goals will forever continue to be meeting and exceeding our customer's expectations.

Prospect Mold Inc.

1100 Main Street
Cuyahoga Falls, OH 44221, USA
Phone +1 (330) 929-3311 Ext. 131
info@prospectmold.com
www.prospectmold.com