

## Case Study

### VOLUMETRIC COMPENSATION OF A DROOP+REIN MACHINING CENTRE WITH FIDIA CONTROLLER

*„58 m<sup>3</sup> machine calibrated and compensated in just one day”*

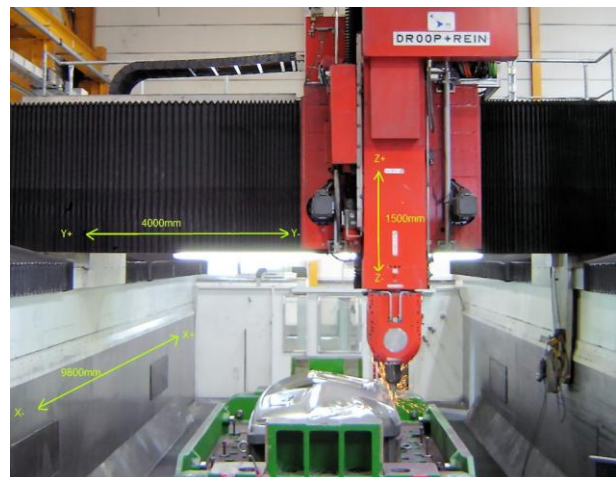
#### VOLUMETRIC COMPENSATION FOR RECOVERY AND IMPROVEMENT OF THE ACCURACY OF LARGE MACHINE TOOLS

Machine tools, especially large ones, change during their operation life due to bowing, sagging, wearing, etc. or because of foundation changes. These deviations can be reduced by compensating the mechanics of the machine. However the necessary long down time and the accuracy of the mechanical alignments are not sufficient for today's requirements. Thanks to modern controller technologies and the Etalon measurement system, most of the geometric deviations can be reduced in a short time. Consequently, production accuracy can be significantly increased, especially for large work pieces.

#### CONCAD IS COUNTING ON COMPETENT PARTNERS AND FIRST CLASS MEASUREMENT SYSTEMS

The company Concad GmbH in the south of Germany is specialised in the manufacture of large high-accurate moulds and tools for the automobile industry. The machining centre Droop+Rein type FOGS 4098 M30K is one of the machines being used. This machine has axes length of 9800mm \* 4000mm \* 1500mm and is controlled by a FIDIA C20 controller.

In order to get orders with smallest tolerances, Mr Schwab, the CEO of Concad has chosen the company AfM Technology (Accuracy for Machines) to perform the volumetric compensation. AfM is an experienced service provider in this field and uses, among others, the high-performance calibration system from Etalon.



THE MACHINING CENTRE FROM DROOP+REIN IS USED AT CONCAD FOR THE MANUFACTURING OF HIGH ACCURATE LARGE MOULDS

#### WHAT DOES “VOLUMETRIC COMPENSATION” MEANS?

Conventional compensation systems are able to compensate positioning deviations (correction for the spindle pitch error) and sometimes straightness compensation. Even though, significant components of the axes deviations are not considered. In essence, only one line in the working volume is compensated. Neglecting the rotational errors of the axes leaves deviations in other places in the volume. Each of the three moving axes in a Cartesian machine tool has six deviations that depend on the TCP (Tool Centre Point) positioning error and tool orientation error. They are:

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

Also the squareness errors between the three Cartesian axes can be added to this list: in total 21 errors of the kinematic model for deviations at the TCP. Especially in large portal milling machines like the FOGS, rotational errors (Pitch, Yaw, Roll) cause large errors due to lever effect (extended Z ram). Only when all these deviations are known, it is possible to describe the complete behaviour of the machine and improve it using software options from modern controllers.

## OBTAINING THE KINEMATIC BEHAVIOUR OF THE MACHINE

The kinematic behaviour of the machine in the working volume is described by the deviations introduced above. They have to be mapped according to metrological methods in order to provide the controller with the necessary information for compensation. Particularly in large machines, the complete acquisition of the geometrical deviations using conventional methods takes several days or even an entire week to be carried out, generating significant costs. Besides, some of the deviations cannot be determined accurately using conventional methods, the post-processing to create an individual volumetric error map is especially difficult. Etalon AG from Braunschweig offers a calibration system which is not only able to get all deviations very accurately, but also very fast. The error map can be generated automatically by the software for different controllers.

## THE SOLUTION FOR THE HIGH-ACCURATE CALIBRATION OF LARGE MACHINE TOOLS

The calibration system from Etalon consists of a universal measurement device, the LaserTRACER, and a software TRAC-CAL that calculates the deviations and generates error maps for different controllers automatically. The LaserTRACER is a self-tracking interferometer similar to a laser tracker. But the main difference between the two is: The inherent limited accuracy due to the encoders in the mechanism of the laser tracker that affects its measurements directly. In the LaserTRACER these uncertainties are avoided due to a patented procedure in which it relies exclusively on length measurements. It is particularly important in the measurement of long distances, where the effects of changes in refraction index of the air (bending the laser beam) and the uncertainty of the encoders become dominant. For the Droop+Rein machine with a spatial diagonal over 10 m these influences can result in a measurement uncertainty over 100 µm! Even using classic interferometers, the measurement of straightness will be influenced by bending of the laser beam in the air. Therefore the measurement of long lengths with conventional methods brings high uncertainties. The calibration system from Etalon overcomes these problems using only length measurements in a way similar to the multilateration principle used by the Global Positioning System (GPS). User influence is practically excluded because no fine adjustment is necessary and through the calculation of the complete data set at once, the deviation parameters are coherent to each other. Discrepancies will be evaluated by the software to qualify conformity to the kinematic model and spatial machine repeatability.

## MEASUREMENT ASSEMBLY AND PROCEDURE

The LaserTRACER covers the entire volume of the FOGS machine because of its 15 m working range (larger machine volumes can be measured by splitting the volume or using the TRAC-CAL software with an interface for a laser tracker). The reflector is fixed where the tool would be in the spindle. The LaserTRACER is mounted in 6 positions over the four corners of the volume. In each position a measurement set is carried out automatically. There is no fine adjustment of the components necessary. Sensors for air temperatures, pressure and humidity are used to correct the laser deviations due to environmental influences.



THE INTERFEROMETER OF THE LASERTRACER FOLLOWS THE REFLECTOR ATTACHED TO THE SPINDLE AUTOMATICALLY THROUGH THE WHOLE VOLUME. DURING THIS PROCESS, HIGHLY ACCURATE MEASUREMENTS ARE CARRIED OUT, FROM WHICH THE DEVIATIONS WILL BE CALCULATED.

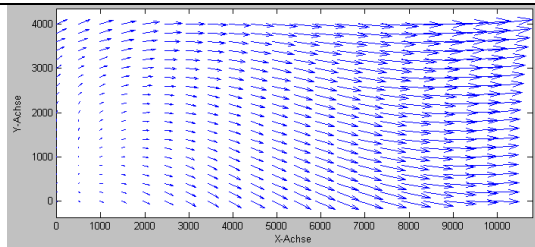
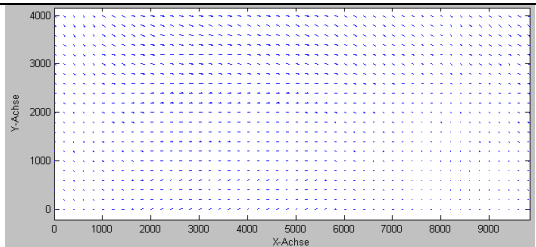
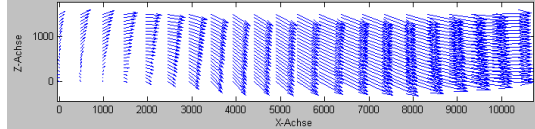
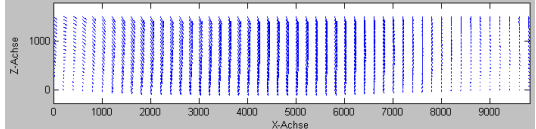
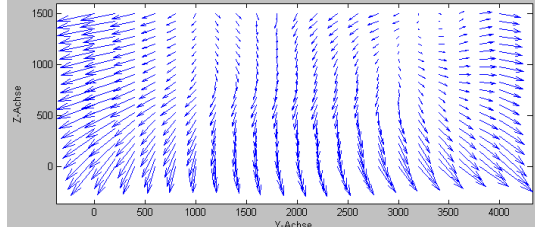
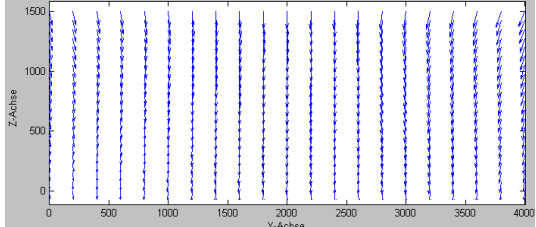
The planning of the measurement is made in the TRAC-CAL software, which only needs to be made for each machine once. It comprises the possible measurement paths that are feasible by the machine. For the chosen paths, there is a space between each point of 200 to 75 mm, making it 4094 measurement points in the volume. The planning was made in advance by AfM before driving to customer, in order to shorten the time on customer side. The Monte-Carlo simulation

implemented in the software predicted an uncertainty of less than 5µm or µrad for all of the 21 deviation parameters of FOGS machine, even for lengths over 10m. The machine program in G-Code was transferred to the Fidia controller via flash pen. Finally the six programs were run and the LaserTRACER position was changed between each of them. The measurement time of one position took approximately 30 minutes and the change in the position was made in a matter of minutes. In order to achieve such a short time, the LaserTRACER was connected to the machine controller through a trigger port in the PLC. This way, the whole measurement of a position could be carried out in one single step.

## RESULTS

The calculation of the 21 parametric deviations is carried out in TRAC-CAL almost at the push of a button. The provided compensation data were installed in the Fidia C20 Controller. The compensation option VAC (Volumetric Axes Calibration) - developed in cooperation between AfM and FIDIA - was then switched on. “An advantage of the software option VAC is that it’s not only available for new machine tools, but also as an upgrade for older controllers versions” says Wolfram Meyer from AfM.

In order to proof the effectiveness of the applied compensation of the Fidia VAC in the real machine operation of the Droop+Rein, the machine was once again measured with activated VAC. A comparison of the remaining deviations with and without active compensation can be found in the table below. The error vectors are representing the deviations from an ideal machine.

Plane	without VAC	with VAC Based on the data of the calibration system from Etalon
XY (horizontal Plane)		
XZ (vertical plane along Y)		
YZ (vertical plane along X)		

IN THE VECTOR PLOT ON THE LEFT IS POSSIBLE TO SEE CONSIDERABLE SYSTEMATIC DEVIATIONS. ON THE RIGHT ARE THE ACTUAL REMAINING DEVIATIONS. THE VECTORS ARE NOT ONLY MUCH SMALLER, BUT ALSO MORE HOMOGENOUS.

## CONCLUSION

Even with an axis up to 10 m of the Droop+Rein machining centre, AfM using Etalon calibration system was able to measure all systematic deviations accurately and generate compensation data in a very short time. The considerable reduction of the deviations with the VAC in the Fidia C20 Controller could be confirmed by the verification measurement. Because of the good repeatability of the machine and the stable environment, the company Concad is now able to achieve considerable higher accuracy for large work pieces.

### **ABOUT CONCAD**

The business spectrum of Concad GmbH comprises tool, prototype, model and mould construction as well as small batch production. From the construction to tool making and part manufacturing to assembly, the customer has from one company the essential processes in automobile development. Over 70 highly motivated and engaged employees, machinery of the newest state of the art and a continuously growing know-how are the factor for its success.

▷ [www.concad-gmbh.de](http://www.concad-gmbh.de)

### **ABOUT AfM**

AfM Technology GmbH is a solution provider in the field of mobile metrology. The company's main focus is in the metrological mapping, compensation and monitoring of geometric deviations of machine tools and coordinate measuring machines as well as mobile 3D metrology. In order to do that, AfM counts on metrological experience, newest technology and the cooperation with well-known partners. The technicians at AfM have a lot of experience in the generation of optimal measurement strategies for different machines. AfM offers its customers customised solutions as mobile service partner in engineering and software developer. As exclusive partner from FIDIA in Germany and Italy, AfM offers its customers not only the software option VAC, but also machine calibration and verification of volumetric compensation from only one source.

### **ABOUT ETALON**

Etalon AG is specialized in calibration, monitoring and accuracy improvement of machine tools and coordinate measuring machines. The company is located in Braunschweig and was founded in 2004 as a spin-off from the Physikalisch Technischen Bundesanstalt (PTB). Etalon offers its customers innovative and user-friendly solutions, academic know-how, standardization requirements and metrological experience integrated in its software. Currently it counts on a world-wide sales network, renowned customers in machine manufacturers, automobile and research institutes that rely on Etalon technology.

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