MEASUREMENT AND COMPENSATION FOR GEOMETRICAL AND POSITINING ERRORS IN ALL THE WORKING VOLUME OF A LARGE DIMENTION GANTRY MACHINE

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Abstract

Reduction of the positioning errors in the complete working volume of a machine tool of large dimension using the volumetric compensation and the accuracy check by the body diagonal positioning measurements.

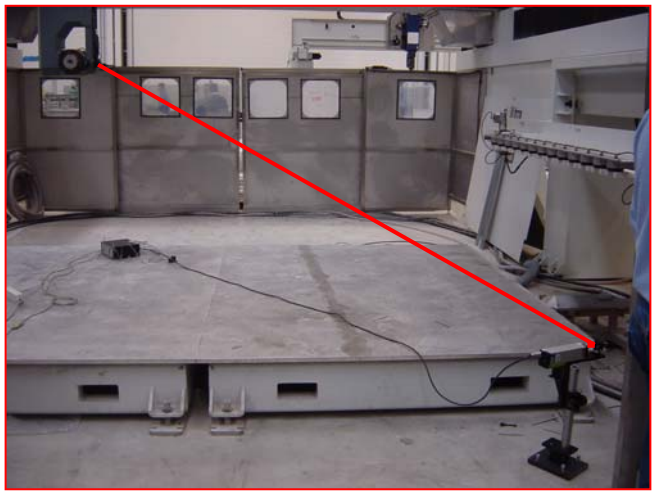
Scope

The scope of testing is the verification of the possibility of the compensation of a large dimension machine tool, in all the degree of freedom made possible by the used CNC, Fanuc 18i, in economically affordable time. The tested machine is CMC model REX with a working volume of 200 cubic meter wit diagonal elongation of 5,5m (18,5ft).
The test is characterized of three phases:
La prova è stata caratterizzata da 3 fasi:

1 error verification
2- correction table generation and compensation
3-residual error verification

Measure of the volumetric errors by the diagonal positioning measurements.

The measurements of diagonal positioning error, or volumetric error, have been performed following the recommendation of the standard UNI –ISO 230-6 (ASME B5.54) for a quick check on volumetric performances. The error along the diagonal is sensible to the errors in the three orthogonal directions. The laser is positioned in one of the volume corners and aligned along the diagonal to reach the opposite corner. The machine is programmed for a coordinate movement of all the axes along the diagonal and the positioning error along the diagonal have been collected.

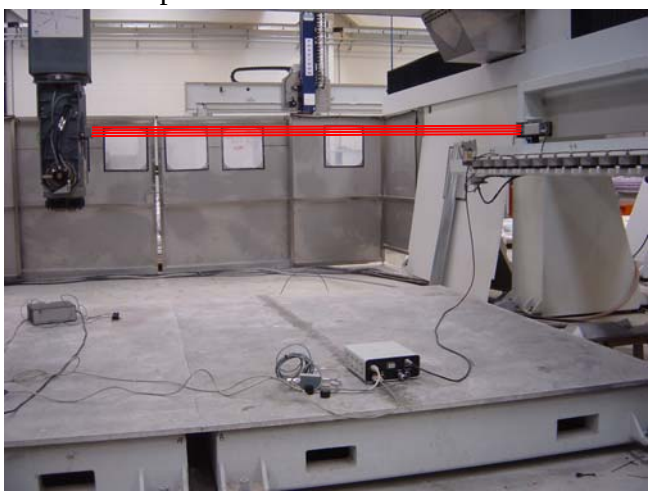


The diagonal measurement results are used for:
1) Determination of the machine accuracy conditions before the compensation,
2) The measurement of the squareness error of the axis movement, for compensation,
3) The verification of the volumetric accuracy after compensation.

Unfortunately the traditional diagonal give not enough information to identify the error sources except for the squareness errors. If the error exceeds the spec limit, it is necessary to provide to the measurement of the error sources: three linear positioning and six straightness in order to generate the compensation tables.

Measurement of the linear positioning error and straightness errors for the compensation table generation.

The measurement of the linear error have been performed with a laser with two parallel beams that allows to detect simultaneously two displacement errors measuring position and angle at the same time and calculating the straightness. The measurements have been done at the center of travel for each axis. The dual beam laser have been aligned in order to measure the positioning error along one axis (i.e. X) and the straightness of one of the two perpendicular axes (i.e. Xy). The machine tool is programmed for fix movements intervalled by a pause. The data are collected automatically by the software during the pause. The part program for laser alignment and the machine test are generated by the LDDM metrology software congruently with the measurement parameters.
Le misure di posizionamento e di rettilineità sono state eseguite al centro dell'escursione di ogni asse. The laser is rotated by 90° around the movement axis to be ready to collect the straightness data "on fly" without machine stops. The measurement are repeated for the 3 Cartesian axes. The time spent for the measurement was 4 hour only.



The collected data was analized by the analisys software LDDM2.69. The 3 linear compensation tables the 6 straightness and squareness comp. tables and the two configuration tables for the CNC GE-Fanuc 18i –128points have been generated by a dedicated calculation software. In the software have been loaded the 9 laser data files, the 3 squareness errors, indicated the information for the definition of compensation and the software generated the error table automatically as text file. The time for the verification of the collected data and the generation of the tables: 1 hour.

Verification Measurements

The machine have been measured along the 4 diagonal by interpolated movements of the 3axis as described before. The laser have been mounted on a support in the lover corner of each diagonal and by the beam bending mirror, aligned along the diagonal. The retroreflector have been mounted close to the tool position. The machine is programmed for moving the tool from one corner to the opposite corner. The laser beam have been aligned parallel to the diagonal movement, the typical alignment tolerance is better of 0,5mrad or 0,5mm on 1 meter .

Error budget

The accuracy of the measurement system is high, better than 1ppm, the typical error sources are: alignment error or cosine error, errors due to the temperature and pressure measurements. In the diagonal errors is necessary to consider the typical error for interferometric measurements :

The variables are the following:

Temperature measurement	0,1°C
Pressare measurement	0,5 mBar
Total travel	5 m
Dead travel	250 mm
Material Expantion Coeff.	12 μ / m / C°
Abbe offset	50mm
Laser wavelength error	1 μm /m

Error budget calculation:

Air temperature compensation	1ppm x 5m x 0,1 °C = 0,5 μm
Air pressare compensation	0,3 ppm X5m X0,5mBar = 0,75 μm
Material Expansion	12 μ / m / C° x 5m x 0,1 °C = 6 μm
Dead travel	1ppm x50 mm x 0,1°c = 5 μm
Abbe error	0,05m x 20 μ Radianti = 2 μm
Cosine error	$0,5^2$ mRad. /2 x 5m = 0,5μm
Wavelength error	1ppm x 5m = 5μm

The total error or the uncertainty of the measurement is the following:

$$E = \sqrt{0,5^2 + 0,75^2 + 6^2 + 5^2 + 2^2 + 0,5^2 + 5^2} = 8,5\ \mu m \quad \text{o } 1.5\ \mu m/m$$

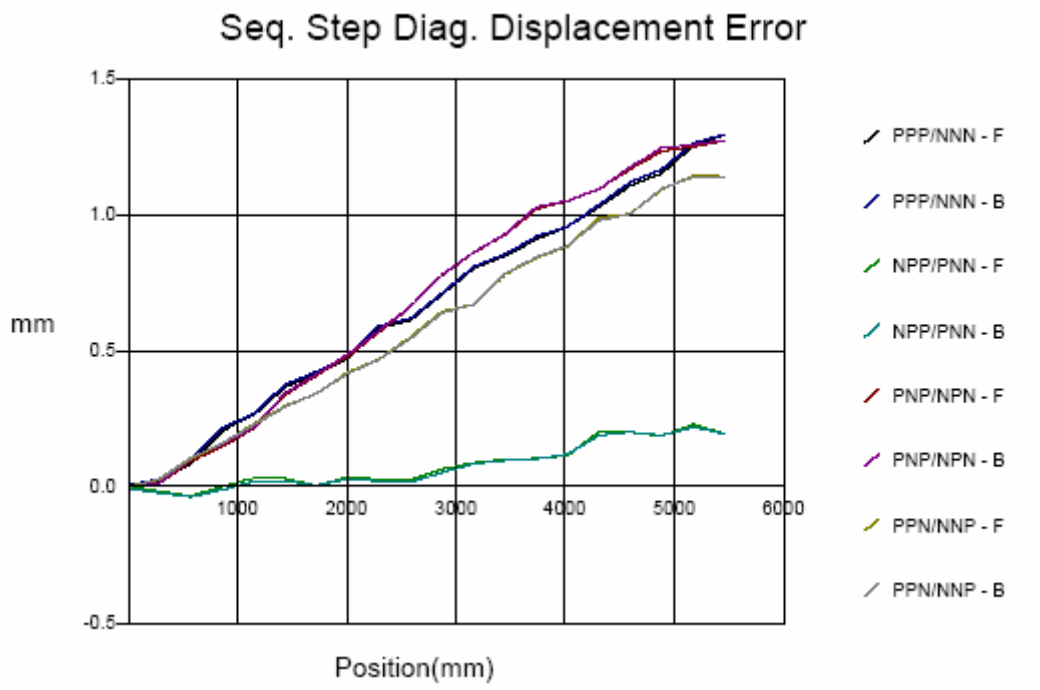
Used instruments:

Optodyne -MCV 500 Compact linear measurement system, single beam, single aperture (coaxial beam)

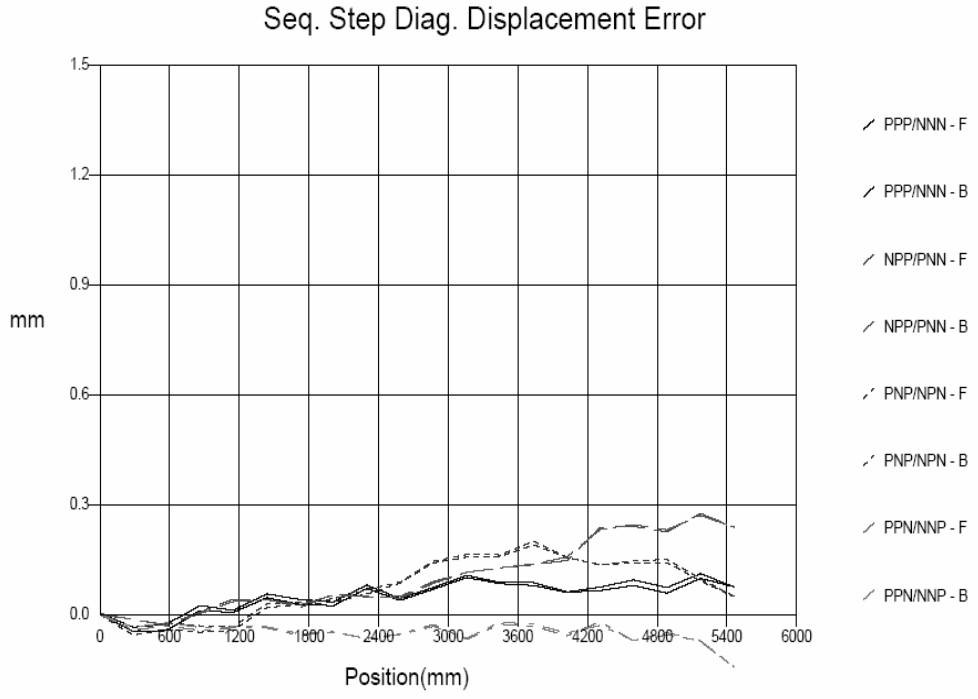
Optodyne -MCV 4000 Dual Beam Laser Calibration System

Results of testing

The maximum error by diagonal test before the compensation is 1,3mm (.0512”)



The accuracy after the compensation is 0,41 mm (.0016”)



Conclusions

The machine, after compensation and the volumetric accuracy certification, obtained the benefit of 300% in respect to the initial accuracy.
The result have been obtained in less than 8 hours.