Test piece for visualization of thermally induced deviations on five-axis machine tools

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Abstract

In order to manufacture precision work pieces efficiently, the machine tool needs, among others an improved geometrical accuracy. This is significantly influenced by thermal-mechanical deviations [1]. To detect such deviations the machine tool is usually subjected to complex measurements and monitoring as described in standards such as ISO 230-3 [2].

This approach is not eligible for frequent industrial use. The sensors and the special machine setup cause high costs. Therefore, a high demand for an easier method to regularly check thermal-mechanical deviations of machine tools exists. There are already test pieces for five-axis milling machines that indicate geometrical errors. These test pieces can be used as a reference for the quality of a machine tool, for example after a collision or for acceptance tests. International standards like the DIN/ISO 10791-7 [3] describe the characteristics of different test pieces to evaluate the performance of machining centers. However, to date test pieces to detect thermal-mechanical deviations have not yet been applied widely.

In this paper a thermal test piece is introduced that has been developed to visualize thermal deviations on a five-axis machine tool. This test piece with a corresponding 6 hour test cycle has been designed to reveal the temperature-induced changes of the machine tool and the associated deviations. The test cycle includes a 3 hour warm-up and a 3 hour cool-down phase. Deviations in X-, Y- and Z-directions are visualized at 7 different time points in hourly intervals. The test piece is manufactured from a 200 mm diameter aluminum cylinder that has 35 machined surfaces that are used to detect the deviations. For each of the 7 time points surfaces for the X-, Y- and Z-deviation are machined.

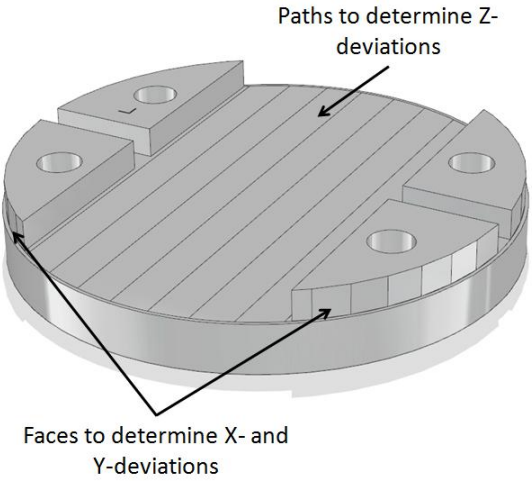

Figure 1: Proposed thermal test piece.
The test piece has a 200 mm diameter, a height of 25 mm and it is manufactured from aluminium. 28 surfaces are used to visualize the X- and Y-deviation in which always two are parallel to each other. 7 paths are used to visualize the Z-deviation.

For analyzing the test piece is measured with a coordinate measuring machine or with a micrometer and a dial gauge on a measuring table. In addition to the measurement, the thermally induced Z displacement can be checked by visual inspection.

The test piece has been validated using two different 5-axis machine tools with a different kinematic setup. Several test pieces were manufactured. The measurements show that the proposed test piece accurately and reproducibly visualizes thermal-mechanical induced deviations of the five-axis machine tools tested.

[1] J. Mayr et al. Thermal issues in machine tools. *CIRP Annals-Manufacturing Technology*, 2012.
[2] ISO 230-3: 2007, Test code for machine tools- Part 3: Determination of thermal effects, 2007.
[3] DIN/ISO 10791-7: 2001, Test conditions for machining centres – Part 7: Accuracy of a finished test piece, 2001.