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## Machine Tool Thermal Displacement Error Detection Enabling Design Changes and Active Compensation

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### Abstract

With any ultra precision machine tool, it is known that geometric errors cause inaccuracies to the workpiece. Thermal effects are responsible for up to 75 % of these errors, with up to 60% of machine running costs attributable to thermal issues mitigation [1]. Reducing these errors will benefit the volumetric precision of the machined part and enable a reduction of the environmental temperature control requirements to lower associated costs. In this paper we discuss experiments where we extrapolate data from the use of a low cost, repeatable and highly sensitive quadratic strain sensing system (QSSS). [2,3] This is measuring structural displacements and is applied outside the working area on our Twin Turret Grinder (TTG) to understand how volumetric machine errors are caused by thermal effects and how they relate to tool centre point (TCP) errors. The TTG is a stiff and highly symmetric machine with a unique twin turret design that enables measurement in a sensitive direction between turret centres. During initial testing on a TTG 3000 machine recently delivered to a precision bearing ring manufacturer under typical production conditions (production facility not being temperature controlled), many hundreds of components were ground, all well within specification. During grinding, machine data (air temperature, machine temperature, control fluids temperature, etc.) were logged, along with the base distortion sensors. FEA was used to predict the machine bed motions that would result from the logged temperatures. The FEA predicted bed growth over the grinding trial was 0.007 01 mm. The measured growth was 0.007 5 mm Further experiments will match measured QSSS data to six degrees of freedom (DOF) of TCP error using a Renishaw XM60 laser to give confidence of accurate compensation. With future machines we aim to use this knowledge of the TCP behaviour to predict and actively compensate errors.

Thermal expansion, active compensation, Metrology

[1] Mayr J, et al 2012 *Thermal issues in machine tools p 1*

[2] Fletcher S, Chuku D, Furness T, Focareta A, Longstaff A. Rectilinear strain sensing framework for real time compensation of structural distortions in precision machinery. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture*. 2022;237(13):2130-2136. doi:[10.1177/09544054221136414](https://doi.org/10.1177/09544054221136414)

[3] Furness T, Fletcher S, Longstaff A 2022 Design and validation of a thermo-mechanical self-calibrating displacement sensor for embedded applications. In Proceedings of the Special Interest Group Meeting : Thermal Issues. euspen.

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