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Dynamic Compensation for Environmental Temperature Variation in the Coolant Refrigeration Cycle as a Means of Increasing Machine-Tool Precision

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Abstract : Thermal effects are the largest source of dimensional error in precision machining, and a major proportion is caused by ambient temperature variation. The use of coolant is a primary means of mitigating these effects, but there has been limited work on coolant temperature control. This research critically explored whether CNC-machine coolant refrigeration systems adapted to actively compensate for ambient temperature variation could increase machining accuracy. Accuracy data were collected from operators' checklists for a CNC 5-axis mill and statistically reduced to bias and precision metrics for observations of one day over a sample period of 27 days. Temperature data were collected using three USB dataloggers in ambient air, the chiller inflow, and the chiller outflow. The accuracy and temperature data were analysed using Pearson correlation, then the thermodynamics of the system were described using system identification with MATLAB. It was found that 75% of thermal error is reflected in the hot coolant temperature but that this is negligibly dependent on ambient temperature. The effect of the coolant refrigeration process on hot coolant outflow temperature was also found to be negligible. Therefore, the evidence indicated that it would not be beneficial to adapt coolant chillers to compensate for ambient temperature variation. However, it is concluded that hot coolant outflow temperature is a robust and accessible source of thermal error data which could be used for prevention strategy evaluation or as the basis of other thermal error strategies.

Keywords : CNC manufacturing, machine-tool, precision machining, thermal error
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