Robust prediction of machine tool thermal error using ANFIS-based modelling, fusing temperature and displacement measurement

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Abstract

An attractive technique for the prediction of thermal errors in precision machining systems is by data driven modelling methods, whose application has been prevalent in the research domain and is effective under repeatable conditions. The main barrier to uptake by machine tool users is the significant amounts of lost production time required to acquire training and testing data to produce accurate models that are robust to variation in machine environment and process. It is unlikely that all conditions that will be experienced by the machine can be replicated during this testing phase, which increases the risk of poor compensation when the conditions exceed the model boundaries.

An additional problem when retrofitting a thermal error compensation solution is the compromise between the number and type of sensors and eventual accuracy. It is seldom possible to measure the thermal distortion of a machine tool directly, yet inference from temperature measurement is often limited by the hysteresis caused by problems in detecting the core material temperature of the structure.

This paper addresses these challenges by fusing temperature data with some restricted displacement data to provide the system feedback. It is trained using intermittent, and therefore temporally sparse, test regimes thereby significantly reducing the impact on production schedules. The modelling system uses Adaptive Neuro-Fuzzy Inference System (ANFIS) prediction models combined with Fuzzy c-means clustering to enable the novel combination of sparse but fused data to be used effectively. The results, using a variety of input data types and frequencies, show significant improvement in accuracy of the model compared to typical data and black box methods.