Grey Theory and Radial Basis Function Neural Network Applied to Thermal Error Compensation in a CNC Lathe

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ABSTRACT

The thermal effect on machine tools has become a well-recognized problem in response to the increasing requirement of product quality. The performance of a thermal error compensation system strongly depends on the accuracy of the thermal error model. To establish the compensation model of the thermal error of a CNC two-turret lathe, the methods of the grey theory (GT), feed-forward neural network (FNN), radial basis function neural network (RBFNN), and generalized regression neural network (GRNN) were used. Results found by the grey theory showed that the characteristic temperature rise at the spindle nose is the most important factor influencing the thermal deformation. Comparisons among all mentioned neural network models showed that the RBFNN model has the best ability to map the thermal drift to temperature ascent of the machine structure.

Keywords: ***Grey theory, feed-forward neural network, radial basis function neural network, generalized regression neural network, CNC lathe, thermal error compensation.***

1. Introduction

The thermal machine behavior is recognized as one of the major reasons for work piece inaccuracies. The error compensation for thermal deformation can be direct and indirect. Direct compensation is made immediately to the errors detected on-line. However, it is rather difficult to detect the errors in this way so the method is currently used only in laboratory. Indirect compensation detects the machinery's repetitive and foreseeable errors off-line, and then builds error tables or mathematical models for errors as an error database that will be used to determine compensation in processing. Due to its low cost and practical feature, the indirect compensation becomes ever widely applied. In indirect compensation, the development of forecasting model for heat errors is most important. Therefore the reliability of the model is always the focus and goal of relevant studies.

Excessive research has been carried out in the past in the area of thermal error modeling. The linear single variable model (Okushima, 1975), the exponential function model (Janeczko, 1988), and the regression analysis model (Yang, 1996) were used to compensate the thermal error in the early times. In 1990s, lots of researchers proposed a variety of thermal compensation models based on different schemes. Dynamic thermal errors were predicted on line by an artificial neural network model by Chen (Chen, 1995a; Chen, 1996; Chen, 1995b). A compact volumetric error model which can be used as a basis for a practical compensation scheme was proposed by Srivastava et al. (Srivastava, 1995). An auto-regressive model based on spindle rotation speed was developed by Li et al. (Zhang, 1997) to describe the thermal errors of a NC machine tool. A three-layer artificial neural network with a supervised back-propagation training algorithm was used to map calibrated thermal errors to temperature measurements in real cutting conditions by Chen (Chen, 1997). Wang

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