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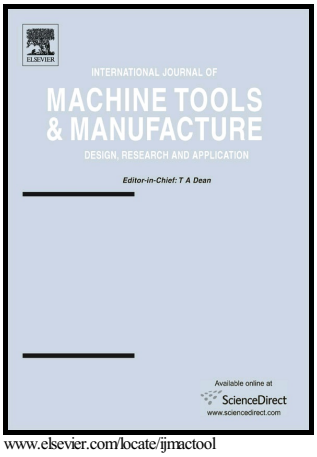

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Robustness Modeling Method for Thermal Error of CNC Machine Tools Based on Ridge Regression Algorithm

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Abstract

For thermal error compensation technology of CNC machine tools, the collinearity between temperature sensitive points is the main factor for determining the predicted robustness of thermal error model. The temperature sensitive points are input variables of the thermal error model. This paper studies the thermal error of Leaderway V-450 type CNC machine tools during different seasons. It is found that although the commonly used temperature sensitive point selection methods can significantly reduce the collinearity between temperature sensitive points, the correlation between some of the selected temperature-sensitive points and thermal error is weak. This causes the temperature-sensitive points to be variable and the predicted accuracy and robustness of thermal error to be reduced. Therefore, in this paper, the temperature sensitive points are selected directly by their correlation with thermal error to eliminate variability. However, the experimental results also show that the collinearity between temperature sensitive points is very large. Hence, the ridge regression algorithm is used to establish a thermal error model to inhibit the bad influence of collinearity on the thermal error predicted robustness. Thus, the "robustness ridge regression machine tool thermal error modeling method" is proposed, the "RRR method" for short. In addition, in the "RRR method", the correlation coefficient is used to measure the correlation between temperature sensitive points and thermal error instead of the commonly used gray correlation; because this paper finds that the gray correlation algorithm is essentially inapplicable for measuring a negative correlation. Based on the thermal error experiment data for the whole year, the "RRR method" is compared with two currently used methods, and the results show that the "RRR method" can significantly enhance the long-term predicted accuracy and robustness of thermal error. Finally, the application effect of practical compensation shows that the "RRR method" is usable and effective.

Keywords: CNC machine tools; Thermal error; Collinearity; Predicted accuracy and robustness; Ridge regression

1. Introduction

Thermal error represents 40~70% of the total error of machine tools [1, 2]. It is cost-effective to reduce thermal error by establishing a mathematical model between thermal error and temperature. This can predict thermal error by measuring the temperature of machine tools and compensate for it in advance [3]. In this method, the predicted accuracy and robustness of the thermal error model play an important role in the compensation effect. The predicted robustness reflects the holding capacity of the predicted accuracy under various external conditions. It is an important indicator of the thermal error compensation effect of machine tools [4]. Generally, the stronger the correlation between input variables of the model and thermal error, the more accurate the prediction [5]. However, there may be collinearity between input variables, which can enhance the sensitivity of the thermal error model to disturbances [6]. Even though the model has good fitting accuracy, it cannot maintain a good prediction accuracy under a changing rotation speed,