ABSTRACT

A method for quick identification of spatial-variant thermal errors using on-machine measurement of a three-dimensional reference artifact is proposed. Comparing geometry information of the artifact measured on the machine tool with geometry information calibrated by a coordinate measuring machine, we can calibrate thermal errors of machine tools. Thermal drifts of the cutting tool edge at a workspace origin, thermal expansions of three leadscrews and thermal distortions of C-shaped machine frames are calibrated simultaneously in one setup of the artifact. It takes only about 4 minutes to calibrate spatial-variant thermal errors. The accuracy of the proposed method is confirmed through the diagonal test of ANSI/ASME B5.54.

1. INTRODUCTION

Accuracy of machined components is one of the most critical considerations for any manufacturers. Internal and external heat sources cause thermoelastic deformations of machine tools and in the end result in geometric inaccuracies of the workpiece. In the 1960s, the significance of thermal errors in manufacturing and its possible solutions were already pointed out by some researchers[1-2]. The methods for testing thermally induced geometric errors were summarized by Tlusty and Mutch[3]. By studying a large amount of data, Peklinik[2] remarked that thermal errors could comprise 40-70 percent of the workpiece error in precision machining.

Thermal errors have usually been measured using equipments such as laser interferometers and non-contact capacitance sensors[4-6]. Laser interferometers can accurately calibrate thermal errors of individual machine components at different machine positions. However, calibrating thermal errors individually is not only time-consuming but may also neglect thermal interaction among error sources, because the machine axes are operated simultaneously in real machining conditions. Non-contact capacitance sensors can measure thermal drifts and tilt motions of the spindle at the same time, but position-dependent information can't be provided. Since thermal errors have spatial-variant characteristics resulted from thermal expansions of machine axes, non-contact capacitance sensors must be used together with other equipments if a volumetric error model is required.

The major problem with traditional thermal error measurement strategies using the above equipments is that thermal errors are measured under the air-cutting conditions as specified in the ANSI and ISO standards[7-8]. The production machine is forced to be idle during the air-cutting experiments that may take a long period of time. Moreover, the experiments have to be repeated periodically for renewing the data for error compensation during the life of the machine. This is one of the reasons why real-time thermal error compensation techniques are not generally accepted by industrial applications, although those techniques