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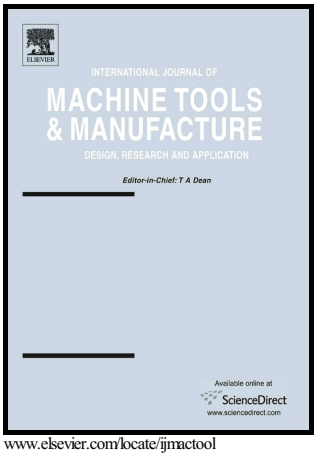

www.elsevier.com/locate/ijmactool

PII: S0890-6955(16)30203-6
DOI: http://dx.doi.org/10.1016/j.ijmachtools.2016.10.001
Reference: MTM3199

To appear in: *International Journal of Machine Tools and Manufacture*

Received date: 29 August 2016
Revised date: 28 September 2016
Accepted date: 4 October 2016

Cite this article as: Shuang Ding, Xiaodiao Huang, Chunjian Yu and Wei Wang, Actual inverse kinematics for position-independent and position-dependen geometric error compensation of five-axis machine tools, *International Journa of Machine Tools and Manufacture* http://dx.doi.org/10.1016/j.ijmachtools.2016.10.001

Actual inverse kinematics for position-independent and position-dependent geometric error compensation of five-axis machine tools

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Abstract

This paper proposes an efficient actual inverse kinematics method to compensate the geometric errors of five-axis machine tools. The analytical expressions of corrected numerical control (NC) code are derived according to the invertibility, associative law of multiplication, and block calculation of homogenous transformation matrix (HTM). No additional analysis and models are needed for the compensated expressions, appropriate conversion with the geometric error model based on HTM is sufficient. It is simple, convenient and universal for geometric error compensation. The corrected NC code can be obtained through algebraic operation, without time-consuming iteration, differential, or pseudo-inverse algorithm. Then compensation accuracy and efficiency of the method are simulated. And the results indicate higher efficiency compared to existing method. At last, the method is verified by cutting experiment on a five-axis machine tool. Both simulation and experiment results can validate the feasibility of the method. The proposed method significantly improves the computation efficiency and is considered more suitable for real-time compensation.

Keywords: Actual inverse kinematics; Five-axis machine tool; Geometric error; Real-time compensation.

1. Introduction

Five-axis machine tool plays a crucial role in modern manufacturing, for its unique advantages of processing complex parts. However, the additional two rotation axes introduce more geometric error sources and increase the difficulty of machining accuracy improvement. Since the geometric errors are one of the major factors resulting in poor accuracy, it is always a key issue to reduce or eliminate the geometric errors [1]. Error compensation technologies have been proven as an economical and effective way to enhance the machining accuracy, because of the systematicness and repeatability of geometric errors [2]. Besides, cutting force and thermal induced dynamic geometric deformations should also be compensated with real-time measuring and time-varying modeling [3,4]. Therefore, efficiency and quality of the compensation method are the keys to guarantee the compensation performance.

Many published papers have studied the compensation mechanisms and have made remarkable achievements. The commonly used methods are iterative method [2,5-12] and differential method [13-19]. Iterative method was widely studied because of its precision and adaptable characteristics. Representatively, Cui et al. [2] reconstructed the NC