Dynamics Analysis of a Parallel Mill-turn Tool Spindle Head Driven by Dual-Linear Motors Using Extended Transfer Matrix Method

WU Wenjing LIU Qiang*

School of Mechanical Engineering and Automation, Beihang University, Beijing 100191

Received September 8, 2008; revised January 18, 2009; accepted February 23, 2009; published electronically March 6, 2009

Abstract: The hybrid dynamics of multi-rigid-body and multi-flexible-body system becomes the mainstream of multi-body dynamics. Currently there lacks a compact approach to model the hybrid dynamics, especially in modern machine tool application, due to the difficulty of solving the hybrid equations or the limitation of current software when dealing with the hybrid dynamics. The extended transfer matrix method (E-TMM), which extends elements in three-dimensional space with higher matrixes, is proposed to simplify the modeling process of the hybrid dynamics. The E-TMM modeling approaches of 3 basic elements including 3D vibrant rigid body, joint and flexible body are studied in details. A parallel mill-turn tool spindle head unit driven by dual-linear motors is chosen as a plant to demonstrate the E-TMM modeling process. By using E-TMM, the spindle head unit is simplified as a topological network consisting of the three types of element, i.e., 3D vibrant rigid body, joint and flexible body, including 11 rigid bodies, 14 joints and 1 3D-Timoshenko beam. Then the dynamic model of the system can be easily obtained by deducing the element-network by means of state vector transformation. The dynamic characteristics of the spindle head, such as natural frequencies, dynamic flexibility, etc. can be predicted by solving the obtained model. Experiment verification indicates that the E-TMM is valid with enough accuracy in the dynamic analysis of the parallel mill-turn tool spindle head. The E-TMM is capable of modeling the dynamics of machine tool structure with no requirements of deducing and solving the sophisticated differential equations. Moreover the E-TMM provides a simple and elegant tool for hybrid dynamic analysis in future dynamic design of machine tools.

Key words: NC machine tools, dynamics, modeling, transfer matrix method (TMM)

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