ABSTRACT

"Generation and Evaluation of Meso-scale Machine Tool Designs for Micro-Machining Applications"

Henry Chen's

Doctor of Engineering in Manufacturing Oral Defense
will be held on
February 8, 2005
from 12:00 p.m. to 1:30 p.m.
1062 H. H. Dow

If you plan to attend Henry's Oral Defense, please let Kathy Bishar at kbishar@umich.edu know by Friday, February 4.

Chair: Jun Ni

Current trends toward product miniaturization requires fabrication techniques that can efficiently and economically produce meso-scale components with complex micro-features over a wide range of material types. Meso-scale machine tool systems (mMTs) have been proposed as an attractive alternative to MEMS and convectional full-size precision machine as it offers many advantages, including: reduced footprint, energy consumptions, and relative precision requirements. As a newly emerging technology, mMT does not have comparable experience and knowledge-based research as full-size machine tool that can be drawn on to optimize its design and performance. This research addresses this barrier through the development of an integrated design environment that enables the systematic generation and simulation-based performance assessment of mMT designs, including kinematics, thermal, and machining dynamics.

The development of an extended generalized structural representation with graph theory allows for the systematic generation and assessment of candidate mMT designs. By substituting suitable parameterized components into the directed graph representation, the information inside the parameterized components can be synthesized to predict the behavior of the assembled mMT, and is demonstrated with the developed multi-axis kinematics error module which generates the corresponding kinematics error of various mMTs and simulates the body-diagonal travel errors.

Thermal error, generally a dominant source of error for full-size machine tools, is expected to be reduced and become negligible for mMT with proper design measures. The expected thermal characteristics of mMT are analyzed with respect to scaling relationships, and sample experiments were conducted on mMT platforms to verify these analyses. Furthermore, a methodology based on numerical simulations is proposed to investigate the effects of various design and environmental parameters on mMT's thermal behavior.

Machining dynamic, which greatly affects productivity, is also expected to behave differently for mMT. A methodology is developed which enables the evaluation of the machining dynamics of various mMT designs. First, a micro-milling force model that accounts for the effect of minimum chip thickness is proposed and validated. Second, a receptance coupling technique is applied to allow for the synthesis of any candidate mMT's dynamic response from the parameterized components' dynamic response. The micro-milling force model, in conjunction with the synthesized dynamic response of mMT, is used for the analysis of machining stability and investigation of machine configuration effects.

The above research will address the barriers previously identified, and will contribute to the reduction in development cycle time and accumulation of expertise in future designs of mMT.