Public Abstract

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Title:Kalman Filter Design for Real-Time Estimation of Modal Parameters and Cutting Force Coefficients for Determining the Dynamic Stability of High-Speed Low-Radial-Immersion Milling Processes

Chatter is a particularly severe and damaging form of tool vibration that can occur in metal-machining processes, such as milling. Chatter accelerates tool wear and degrades the surface finish of the part being machined. Approaches used in industry (which makes extensive use of high-speed low-radial-immersion milling, especially for aerospace applications) to avoid chatter are often overly conservative and reduce the rate at which material is removed from the workpiece, limiting productivity. To increase productivity while avoiding chatter requires detailed knowledge of the characteristics of the particular tool and workpiece in use. These characteristics can be measured with special equipment before machining the desired part, but they can also vary significantly while machining, especially as the tool wears over time. A control system is desired that can estimate the relevant system characteristics in real time while machining, in order to predict and avoid the onset of chatter more accurately and improve productivity. Little research has focused on such a control system, however.

The most notable exception is a previous study by Joe Kennedy, in which a commonly used algorithm called an Extended Kalman Filter (EKF) is used to estimate parameters that describe how the tool vibrates, based on measurements of the tool's vibration taken with a capacitive sensor near the tool. The current study continues Kennedy's work by using two capacitive sensors and revising his filter implementation to provide more of a guarantee that the filter's estimates will converge to accurate values. The current study also modifies his approach by alternatively estimating parameters that describe how much force is applied to each cutting tooth for a given size of chip cut out of the metal workpiece. These parameters were not estimated in his approach and are also critical for predicting the onset of chatter.

The new EKF implementations were tested on simulated tool vibration measurements and are found to perform accurately and repeatably. The new approaches were also tested on experimental measurements, and simulations conducted with the resulting parameter estimates showed good correlation with experimental tool vibration trajectories but did not consistently predict the onset of chatter with accuracy. Model modifications--such as including more detailed calculations of the inertial forces acting on the tool, and providing a way to accounting for imperfections in the way the tool was mounted--are also proposed in this study. Preliminary simulations with these modifications do not correlate well with experiments but produce intriguing results, encouraging further investigation.

Though many improvements to the system must be made before it could be implemented in real-time machining applications in industry, the findings of this study could aid in the development of a real-time control system for chatter prevention. Such a system could significantly improve productivity and expand automation of machining processes in manufacturing.