Public Abstract
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In this work, two separate mathematical models, a traditional and new model, are presented for an end-milling process. The traditional model assumes circular tool motion, while the new model accounts for trochoidal tool motion resulting from the feed of the workpiece past the rotating tool. Simulated bifurcation diagrams are generated using each model and compared to experimental results. An extended Kalman filter (EKF) algorithm is created for estimating the states and modal parameters of the milling process given the tool deflections in the x and y-directions and rotational angle. Once parameter estimates are calculated, stability analysis is performed to generate the stability bound of the system as a function of the spindle speed and depth of cut. A control system is designed for a simulated milling process that uses updated EKF parameter estimates to track the stability bounds of the system through time. Through knowledge of these stability bounds, the spindle speed and/or feed rate are varied to avoid instability (i.e. avoid the onset of chatter vibrations). This control system is unique in its ability to adapt to changing system dynamics. A chatter detection method is also given based on the root-mean-square (RMS) value of the once-per-tool deflection data. This method cannot avoid chatter vibrations form forming; however, it can detect and quantify the severity of chatter vibrations.

By comparing simulated and experimental results, the new milling model is found to more accurately predict the dynamics and stability of an actual milling operation. End milling contains a subcritical bifurcation resulting in hysteresis of the bifurcation point. Consequently, both chatter and chatter-free tool vibrations can exist for a single set of milling conditions. Stability jumps within the hysteresis region are shown to be possible. The experimental tool deflection data collected shows signs of runout in the tool/spindle of the milling machine. Therefore, modifications to the new milling model are made to simulate runout in the analytical results (these results better match the tool dynamics from experimental tests). The EKF modal parameter estimates of experimental and simulated deflection data are found to be accurate within 6.5% of their nominal values at a constant spindle speed and depth of cut. However, due to linear time-invariant assumptions in the milling model, the parameter estimates change as the spindle speed and depth of cut are varied. Therefore, parameter estimates must be updated in order to provide an accurate stability bound for the current state of the milling operation. Using updated stability information, the control system is able to keep the simulated milling processes chatter-free over large depth of cut ranges. Finally, tracking RMS values of the once-per-revolution tool deflection is shown effective in detecting the onset of chatter and gaging the chatter vibration magnitude.