Geometric Stability Index for Milling and Modeling of Chip Pulling Effect

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Abstract

Prediction and mitigation of chatter vibrations in machining operations and optimizing overall machining mechanics are crucial for achieving greater productivity and manufacturing efficiency. This thesis first explores effect of directional relationships on chatter stability in milling process. Based on the directional relationships, a geometry-based chatter stability index (CSI) is proposed to improve chatter stability of the process. It is well-known that chatter stability depends on cutting conditions and tool geometry; whereas it is less known that it also depends strongly on the directional relations between the machining process and the flexible directions of the machine. In this research, these directional factors affecting chatter stability are extracted from process kinematics and dynamically compliant directions of the structure. Three cases are considered and analyzed; namely, 1) if the machine tool/workpiece structure is flexible only in single direction, 2) if it is flexible in two orthogonal directions and finally 3) when those flexible directions are not orthogonal. Tool feed direction is considered to be the optimization parameter to maximize process stability. Next, this study is extended for ball-end milling process. Geometry based CSI is proposed to predict the relative chatter stability. A single case when the structure is very flexible in one single direction is considered and analyzed. The tool inclination angle is considered as an optimization parameter for maximizing the process stability. Finally, the research focuses on the numerical modeling of the orthogonal cutting with chip pulling concept. It is intuitive that when the cut chip is pulled with a certain amount of force, friction forces on the rake face of the tool could be cancelled to improve the material shear mechanism. The material point method (MPM) is used to model the orthogonal cutting. Two cases are considered, namely: 1) when the pulling force is applied parallel to the rake face of the tool and 2) when it is not parallel. The simulation results show the efficiency of the cutting process can be improved significantly by simple chip pulling concept. Maximum pulling force is determined through simulations to understand the limitations of the chip pulling effect.

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