Chatter Prediction of Curved Thin-walled Parts Considering Variation of Dynamic Characteristics Based on Acoustic Signals Acquisition

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Abstract

High-speed milling of thin-walled components with complex curvilinear profiles often faces challenges related to machining instability, commonly known as chatter. This phenomenon results from dynamic interactions between the cutting tool and the workpiece, intensified by the low rigidity and the varying dynamic characteristics of the part along the tool path. This research introduces a dynamic model specifically designed to predict machining stability for curved thin-walled parts. Utilizing the semi-discretization method, the tool trajectory is segmented into small, straight elements to locally approximate the behavior of an inclined plane. Dynamic characteristics for each segment are derived from experimental modal analysis and incorporated into the simulation model to generate global stability lobe diagrams. Model validation is performed through cutting tests, measuring acoustic intensity to detect instabilities. The acoustic pressure emitted by a structure correlates with tool displacement, enabling the use of a microphone as a sensor to predict chatter instability. In stable cutting conditions, the dominant frequencies correspond to the spindle speed and its harmonics and the tooth passage frequency. Detecting a peak at an additional frequency serves as a clear indicator of chatter. The microphone's ease of use avoids the positioning challenges associated with other sensor types. To mitigate the effects of ambient noise, numerical band-pass filters and frequency analysis methods, such as FFT, are employed. Experimental data closely match the predicted stability limits, validating the model's accuracy and effectiveness. This work provides a robust approach to enhancing machining stability predictions, ultimately improving the efficiency and quality of high-speed milling operations for thin-walled components.

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