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Identifying bifurcation behavior during machining process for an irregular milling tool geometry

Ahmad Razlan Yusoff

Faculty of Manufacturing Engineering, University Malaysia Pahang, 26600 Pekan, Pahang, Malaysia

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ABSTRACT

High-productivity machining processes cause tool and material defects and even damages in machine spindles. The onset of self-excited vibration, known as chatter, limits this high material removal rate. This chatter vibration refers to machining instability during cutting processes, which results in bifurcation behavior or nonlinear effect wherein the tool and the workpiece are not engaged with each other. In particular, bifurcation for low-radial immersion conditions can be easily promoted and identified. In this study, an experiment on an irregular milling tool as a variable helix and variable pitch geometry was conducted under a flexible workpiece condition. The bifurcation behavior from regenerative chatter was identified and quantified from displacement sensor and inductive sensor measurements. A series of cutting tests was used to measure the vibration signals, which were then analyzed based on the frequency spectrum, the one-per-revolution effect, and the Poincaré section. According to results, Hopf bifurcation and period-one bifurcation instabilities apparently occurred to validate chatter stability prediction through a semi-discretization method. However, period-doubling bifurcation was only determined during the unstable cutting of a uniform tool that was not in variable helix/pitch or an irregular milling tool. An irregular tool geometry caused the modulation of the regenerative effect to suppress chatter, and period-doubling instability could not be exhibited during cutting as a regular tool behavior. This period-one chatter instability of an irregular milling tool should be identified and avoided by practitioners to achieve high productivity in machining using the aforementioned irregular milling tools.