Sliding Mode Control of Machining Chatter in the Presence of Tool Wear and Parametric Uncertainties

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Abstract: Chatter suppression is essential for achieving high precision and surface quality in machining processes. In this paper, a control strategy is presented for chatter suppression in cutting process in the presence of tool wear and parameter uncertainties. A single-degree-of-freedom model of a turning process in the orthogonal cutting configuration is used to set up the nonlinear delay differential equation of motion that includes the effects of tool flank wear. Uncertainties in cutting velocity, tool wear size and parameters of the dynamic model are included in the model of the cutting process. The force provided by a piezo-actuator is taken as the control input of the system. A sliding mode control scheme is used and an effective control law is derived that suppresses chatter. Results of stability analysis and sliding mode control for two distinct cases of sharp and worn tools are presented and compared, which show the effectiveness of the approach.

Keywords: Regenerative chatter, nonlinear model, stability analysis, sliding mode control.

1. INTRODUCTION

Chatter is an undesirable phenomenon in machining processes, which can result in reduction of material removal rate (MRR), poor surface finish and increase in tool wear. Machine tool chatter can be classified into regenerative and non-regenerative chatter. The former is due to the interaction of the cutting force and the workpiece surface undulations produced by preceding tool passes, while the latter is due to other phenomena such as mode coupling, and usually occurs when there is no interaction between the vibration of the system and the undulated surface of the workpiece, such as in threading. The regenerative type is found to be the most detrimental phenomenon in most machining processes. In the early works on the subject (Merrit, 1965; Tobias, 1965) modeling of the dynamic process, structural aspects and stability limit aspects of regenerative chatter were studied extensively. The most common approach to avoid undesirable chatter vibration is through the adjustment of operational parameters, i.e., cutting conditions (Tlusty et al., 1983; Tlusty, 1985). Stability lobes are usually obtained to find sets of cutting conditions leading to stability while maintaining a