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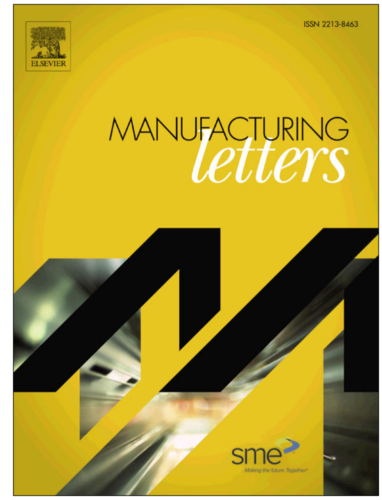

Letters

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Material Driven Machining Process Modeling

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Abstract: A material driven machining process modeling framework is proposed to incorporate thermal-mechanical-microstructural coupling in which the material microstructure dynamics and process mechanics are computed simultaneously. The material microstructure evolution in the machining process is obtained from dynamic recrystallization model which takes the strain, strain rate and temperature history as input. A microstructure sensitive flow stress model is used to correlate the material microstructure with material mechanical properties. The detailed implementation of the proposed framework is illustrated by the machining of titanium alloy. As the output of the model, the machining forces, residual stress profile and machined surface microstructure states are validated against the experiments.

Keywords: Microstructure, Machining, Titanium alloy, Modeling

1 Introduction

The machining process is a complicated material removal process, which requires careful design and optimization to ensure the process efficiency and desired machining end-product service functionality. The traditional machining process design heavily relies on the design of experiment. The Taguchi method has enjoyed wide popularity due to its easy implementation [1]. However, as a statistical tool, the inflexibility of the method requires extensive repeated experiments given any slight change on any process parameters, machine tool configuration or workpiece material system. For a complicated machining process design, the genetic algorithm method is proposed [2]. The shortcoming of this method comes from the execution time and stability of the results obtained from genetic algorithm optimization. Similar method such as artificial neural networks or principle component analysis have also been developed for the process modeling [3]. All those methods are essentially based on the existing experimental observations, which suffer from inflexibility and instability.

Recent development of the machining process modeling has enabled the direct correlation of the machining process parameters, machine tool configuration and workpiece material with the final end-product surface integrity properties, such as dimensional accuracy, residual stress and surface roughness [4]. However, additional machined surface properties such as surface material microstructure states alteration, microhardness are not fully explored. The material microstructure alteration in the machining process could be obtained through the coupled thermal-mechanical-microstructural modeling framework. The new proposed framework could provide more comprehensive explanation for the machined induced surface integrity change in the machining process. Since the machining process mechanics is influenced by the material microstructure states, the material microstructural alteration could result in significant material mechanical properties changes. On the other hand, the material microstructural evolution path is dependent on the thermal-mechanical loading history in the machining operation. For the accurate machining process modeling, the material microstructure consideration is required.

Previous research work has shown considerable material microstructure changes in the machining process. Rotella et al. [5]report obvious grains size and microhardness changes on the machined surface of aluminum alloy in the face turning. A recursive finite element based model is proposed for the grain size evolution prediction. Campbell et al. [6] find that the chip segmentation is strongly influenced by the grain morphology change in the shear band in high speed turning of aluminum. For a multiphase titanium alloys, Pan et al. [7-9] reported the phase transformation and grain size evolution effect both on the