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Development of a Mechanistic Force Model for CNC Drilling Process Simulation

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Abstract
This paper presents a methodology to obtain force information during CNC machining simulation for drilling process especially when the workpiece is inclined to the drill axis or has internal cavities. First, a mechanistic force model is introduced to relate drilling forces to drill geometry and drilling process parameters. Next, an algorithm is introduced to calculate contact boundary between drill point and workpiece especially when the workpiece has irregular shape for each step. Finally, maximum drilling forces for each drilling step are obtained by applying the mechanistic force model to the calculated contact boundary. The model is demonstrated on and validated with designed cases. The results show that the mechanistic force model can predict the drilling forces accurately with varying drill geometry and process parameters and the model can deal with drilling into irregular workpiece.

Keywords: mechanistic model, CNC machining simulation, thrust force, torque

1 Introduction

Large NC code for machining complex and expensive parts is customarily simulated in a virtual machining environment before loading into the CNC machine for actual machining operation. This crucial step helps identify potential errors like tool collision, over or less cut of workpiece produced by the NC code. Recently, optimization modules have been developed and integrated to these virtual machining environment platforms to modify NC code aiming to increase machining efficiency by optimizing the feed rate. They do so by keeping the material removal rate (MRR) constant by adjusting feed rate at each line of the NC code. For example, OptiPath module in Vericut (CGTech, Inc) and PS-Optifeed module in PowerMILL (Delcam) increase feed rate when the MRR is lower and decrease feed rate when the MRR is higher than a set MRR to achieve a constant set MRR.

However, optimization of feed rate to realize a constant MRR has some limitations. For example, when a tool is machining into an inclined workpiece, the radial force acting on the tool will deflect or

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break the tool even at a lower MRR. A solution to this issue requires instantaneous force information to be considered for NC code optimization. An accurate force model with respect to many parameters including tool geometry parameters and machining process parameters is necessary for such optimization module. Though, empirical force models are simple and convenient to be integrated in CAM software, not many tool geometry parameters can be included. Moreover, a lot of calibration experiments are required, which are costly and time consuming. Numerical models or finite element models may circumvent the need for experiments, but necessitate detailed tool and workpiece material properties which are hard to obtain for the diversity of materials employed in the field. Therefore, mechanistic model is used for such integration, which need only a few calibration experiments and can include enough input parameters. Karunakaran et al. introduced an octree-based NC simulation system to optimize feed rate by using an instantaneous mechanistic force model for milling process (Karunakaran, Shringi, Ramamurthi, & Hariharan, 2010). Third Wave Systems production module (Third Wave Systems), MACHPRO (MAL Inc.) and new force module under Vericut (CGTech Ltd.) are also based on mechanistic force model to optimize feed rate for milling and turning processes. However, no such module is available for drilling process especially when drilling into irregular workpiece like with inclined surfaces and internal cavities.

This paper presents a methodology to model drilling forces information during NC code (APT/CLS) verification of drilling process for further optimization usage. The drilling force module is developed and integrated into Vericut. First, a mechanistic model is introduced to relate drilling forces to drill geometry and drilling process parameters. Then, an algorithm is developed to obtain contact boundary between drill tip and workpiece based on API functions provided by vericut at each CL (cutter location) step. Third, the instantaneous maximum drilling forces are obtained by applying the proposed mechanistic model to the engaged cutting edges of drill bit. Finally, a typical aerospace material Ti6Al4V is used to calibrate the mechanistic force model and verify the drilling module under Vericut.

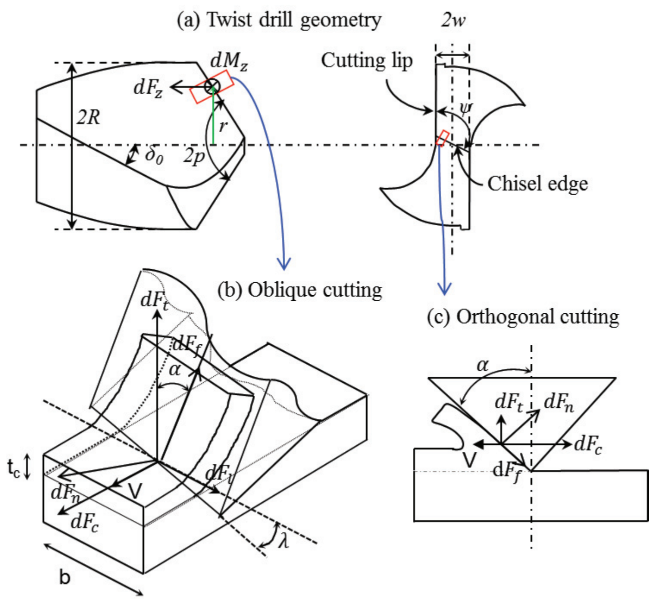

Figure 1 Twist drill geometry and elemental cutting sections

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