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Modelling, Simulation and Experimental validation of Burr size in Drilling of Aluminium 6061 alloy

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Abstract

Precision manufacturing gained much importance in manufacturing industries in the recent past. Drilling process takes place in all manufacturing processes and influences the acceptability of the products, as the drilling is at the most final processing stage in the production line. The burr, which is a plastically deformed material, generated during drilling is an unnecessary output and often lowers the surface quality, reduces the product life. The model works through an energy balance equation which finds the point at which the downward cutting force of the drill is equivalent to the force required to plastically deform the remaining material underneath the drill into a burr. Elimination of burrs during drilling is a trivial task however, with proper selection of process parameters, it can be minimized. The present work aims at developing a mathematical model for burr formation in drilling operation. Thereby validating these models, experiments are conducted by varying different process parameters. The values obtained from experimentation are compared with simulated results developed in Deform^{TM} -3D.

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Keywords: Burr formation, Thrust force, Taguchi Method, FEA, Deform^{TM} -3D software

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1. Introduction

Nowadays, 3D modelling of the metal cutting processes is a more popular technique [1]. The main advantage of this technique is reduction in cost and time to predict parameters such as stresses, strain rates, thrust and temperature

Nomenclature

F_{thrust}	Drill thrust force
B_h	Burr height
F_Z	Cutting force of the drill
υ	Rake angle

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δ	Helix angle
β	Half of the point angle
μ	drill friction angle
φ	Shear plane angle
y_1	initiation height

were very difficult to found experimentally[2,3]. Especially, 3D finite element analysis show a significant advantage compared to other approaches to predict burr geometry [4] during metal cutting process. Present work carried out to accentuate the importance of 3D modelling of the drilling processes and to demonstrate its advantages. [5, 6] presented an overview of a two dimensional FEM code used by DEFORM to study orthogonal cutting. They detail many of the topics discussed in this paper but applied in two dimensions. His analysis is also applied toward orthogonal cutting as opposed to three dimensional drilling. Klocke et al. detail much of the basic FEM theory and machining theory embedded in DEFORM's code. One key advantage of then Lagrangian mesh in simulating drilling processes is the ability to know the entire time history of the key variables at every point during the simulation. That means, if a simulation crashes for any reason, a new simulation can start where the crashed simulation stopped. This is particularly useful because nearly every simulation has some sort of problem during the run. This is possible because the Lagrangian mesh is reformulated at nearly every time step, in order to manage the deformation of the material. One of the biggest strengths of DEFORM is its ability to mesh complex geometries. Significant deformation occurs in machining simulations and this has been historically problematic for the Lagrangian mesh. However, if the geometry is remeshed after each time step, the Lagrangian mesh is a reasonable choice to show burr formation. DEFORM is a leader in creating adaptive meshes and remeshing complex geometry and this makes it a desirable code for drilling analysis. One of the biggest strengths of DEFORM is its ability to mesh complex geometries. Significant deformation occurs in machining simulations and this has been historically problematic for the Lagrangian mesh. However, if the geometry is remeshed after each time step, the Lagrangian mesh is a reasonable choice to show burr formation. DEFORM [7] is a leader in creating adaptive meshes and remeshing complex geometry and this makes it a desirable code for drilling analysis.

2. Modeling and Simulation

2.1 Analytical Modeling

Burr formation model (Fig.1) originally depends on the stress and strain rate of the material flow at the end of the cut has to be analyzed in the finite element method. The finite element analysis (FEA) is effective to understand the material behavior in the process [8, 9, 10]. However, it has not yet been applied to the design of the drill geometry and takes a long time for the simulations. Other analytical models, therefore, is required to optimize the geometry in the drilling operation. An analytical model is developed by integrating by John-Cook coupled and Sofrona's model to predict the thrust force and burr height in drilling process.

From dimensions of geometry of twist drill 'q' value obtained, after that using metal cutting principles and theory of plasticity derived the following equations and found normal rake angle, drill friction amgle.

$$\tan\vartheta = \frac{(1 - q^2 sin^2\beta)\tan\delta}{\sqrt{(1 - q^2)}\sin\beta} - \frac{(q\cos\beta)}{\sqrt{(1 - q^2)}}$$

Where, $\mu = \frac{\pi}{6} + \frac{\vartheta}{2}$ and $q = \frac{web\ thickness\ of\ drill}{diameter\ of\ the\ drill}$

From John-Cook material flow, Ernst and Merchant equation, shear flow angle calculated as

$$\varphi = \frac{\pi}{4} + \frac{\vartheta - \mu}{2} = chip\ shear\ plane\ angle\ ;\ \tau_\omega = shear\ strength\ of\ the\ material, \frac{N}{mm^2}$$

f =feed, mm/rev, y_1 = Initiation height of the burr

$$\in = ratio\ of\ drill\ feed\ to\ the\ initiation\ height\ = \frac{f}{2y_1}$$