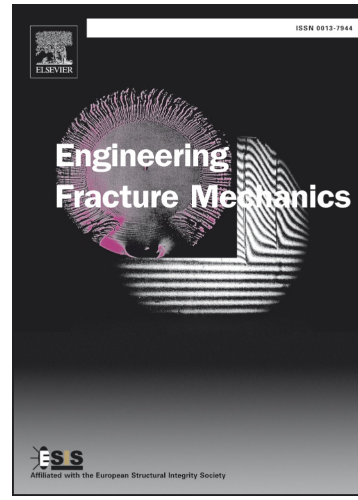
Accepted Manuscript



Numerical Simulation of Orthogonal Cutting using the Material Point Method

John A. Nairn

PII: S0013-7944(15)00381-1
DOI: http://dx.doi.org/10.1016/j.engfracmech.2015.07.014
Reference: EFM 4759

To appear in: *Engineering Fracture Mechanics*

Received Date: 31 October 2014
Revised Date: 19 June 2015
Accepted Date: 8 July 2015

Please cite this article as: Nairn, J.A., Numerical Simulation of Orthogonal Cutting using the Material Point Method, *Engineering Fracture Mechanics* (2015), doi: http://dx.doi.org/10.1016/j.engfracmech.2015.07.014

Numerical Simulation of Orthogonal Cutting using the Material Point Method

John A. Nairn

Wood Science and Engineering, Oregon State University, Corvallis, OR 97330, USA
Tel: +1-541-737-4265 Fax: +1-541-737-3385
Email: John.Nairn@oregonstate.edu

Abstract

A material point method simulation of orthogonal cutting that can simulate cutting into steady-state chip curling is described. The modeling used ductile fracture mechanics using cohesive zone in the cutting path. Robust simulations required a new mechanism to damp kinetic energy artifacts associated with dynamic crack propagation. The simulations displayed two regimes — crack-tip touching, where the tool reaches the crack tip, and plastic bending, where the tool is separated from the crack tip by a gap. The simulations were compared to analytical models that were revised to account for rubbing forces and hardening laws.

Keywords: A. Cutting, B. Material Point Method, C. Computational Mechanics, D. Cohesive Zones

1. Introduction

Several recent papers advocate modeling of orthogonal cutting as a ductile fracture mechanics problem for a crack propagating in the direction of the tool tip [1, 2, 3, 4, 5, 6, 7]. Some analytical modeling [1, 6] and experiments [4, 5, 8] show the fracture mechanics view can help interpret experiments and explain some problems of classic cutting models based solely on plasticity and friction [1, 2]. A suggestion of this new approach is that cutting experiments can be used to measure the toughness of ductile materials. The concept is that extrapolation of cutting forces to zero depth of cut should have non-zero intercept equal to the material's fracture toughness. The challenge is to devise the best experimental methods for getting reliable extrapolations in the presence or large amounts of work due to plasticity and friction. Recommendation of such experimental protocols should be guided by modeling. The current analytical modeling has been limited to basic material properties, simple yielding models (such as elastic-plastic), and simple frictional contact. This paper's goal is to develop a numerical model for orthogonal cutting with the potential to handle more realistic material properties (such as large-strain constitutive laws), arbitrary plasticity and contact laws, and more realistic specimen geometries and boundary conditions.

The numerical modeling of orthogonal cutting through to steady-state chip curling and wrapping involves large strains (especially shear strains due to plastic slip), large displacements and rotations, dynamic contact both between the tool and the cut material and between layers of a curling chip, and evolution of an explicit crack. The finite element method