

PROCEEDINGS

Unraveling the Effects of Johnson-Cook Constitutive Parameters on the Material Response in Orthogonal Cutting of Aluminum Alloys

Feng Pan^{1,*} and Alexander Hartmaier¹

¹The Interdisciplinary Centre for Advanced Materials Simulation, Ruhr University Bochum, Universitätsstraße 150, Bochum, 44801, Germany

*Corresponding Author: Feng Pan. Email: Feng.Pan@rub.de

ABSTRACT

Deformation-based manufacturing processes, such as metal machining, subject materials to severe plastic deformation under coupled thermo-mechanical loading and high strain rates. Accurate constitutive descriptions are therefore essential for predictive simulation and process optimization. The Johnson-Cook (JC) constitutive model is an empirical material model that incorporates strain hardening, strain-rate sensitivity, and thermal softening, which is widely applied in machining simulations. This study systematically investigates the influence of JC material parameters on orthogonal cutting outcomes, with a particular focus on chip formation and machined surface roughness. A JC constitutive parameter set for aluminum alloys was constructed based on literature, and a full factorial test set for the five JC parameters at three levels was designed. An automated Python-Abaqus workflow was developed for two-dimensional orthogonal cutting simulations and post-processing. Statistical analysis indicates that the cutting force is predominantly influenced by the strain hardening coefficient. Chip formation and surface roughness are primarily influenced by the yield strength, strain hardening exponent, and their interaction. The strain rate sensitivity coefficient plays a critical auxiliary role, as increases in its value amplify the dominant effects of yield strength and strain hardening exponent. The thermal softening exponent exhibits a negligible effect. A thorough analysis of the pattern of adiabatic shear bands and surface roughness further clarifies the physical origins of these statistical observations. The results reveal that a periodic shear instability develops during chip formation, with periodicity mainly controlled by yield strength, strain hardening coefficient, and strain hardening exponent. Variations in these parameters alter the flow stress and strain hardening behavior of the material, thereby modulating the stability, intensity, and spectral purity of the periodic adiabatic shear bands. This mechanism leads to periodic fluctuations in the cutting force and transmits a mechanical signal through the tool-workpiece system, directly influencing the geometric profile of the machined surface and ultimately affecting surface roughness. These findings provide a physics-based perspective on the deformation mechanics in subtractive manufacturing, offer actionable guidance for selecting and calibrating JC parameters for predictive cutting simulations, and support process and material design strategies aimed at improving surface quality.

KEYWORDS

Johnson-Cook constitutive model; orthogonal cutting simulation; chip formation; surface roughness

Acknowledgement: FP gratefully acknowledges the support of the Research School of Ruhr University Bochum (RUB) through the International Realization Budget project for funding his international outgoing activities and related travel.

Funding Statement: The authors received no specific funding for this study.

Conflicts of Interest: The authors declare no conflicts of interest to report regarding the present study.



Copyright © 2026 The Author(s). Published by Tech Science Press.

This work is licensed under a Creative Commons Attribution 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.