Physical modelling of grinding forces: path to up-scaling

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Physical Modeling for Virtual Manufacturing Systems and Processes
Overview

Agenda

- Discretizations
- Material modeling
- Experimental setup
- Virtual wheel model
- 3D modeling
- Conclusion

Scratch experiments

Scratch simulations

Upscaling to grinding

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Grinding Process and Single Grit Scratch

Discretizations

Lagrangian (LAG)

Arbitrary Lagrange Eulerian (ALE)

Smooth Particle Hydrodynamics (SPH)

Particle Finite Element Method (PFEM)

(Juan Rodriguez* and Xialong Ye)

*J. Rodríguez, 2013, Procedia CIRP 8, pg.105 – 110
Discretizations

Cutting Forces vs. Discretization

![Bar chart showing cutting forces and normal forces for different discretizations: LAG, ALE, SPH, PFEM, and EXP.]

- **Cutting Forces (Fc)**
- **Normal Forces (Fn)**

*J. Rodríguez, 2013, Procedia CIRP 8, pg.105 – 110*
Material Modeling - Ductile

Model

Johnson-Cooke material model

\[ \sigma = f_1(A, B, \varepsilon, n) \times f_2(\dot{\varepsilon}, C) \times f_3(T, m) \]

Damage model

\[ \dot{\varepsilon}^f = h_1(D_1, D_2, \sigma_m) \times h_2(D_4, \dot{\varepsilon}) \times h_3(D_5, T, m) \]

Damage evolution

\[ D = \frac{L\varepsilon^{-pl}}{u_f^{-pl}} = \frac{u^{-pl}}{u_f^{-pl}} \]

Effective stress

\[ \sigma = (1 - D)\bar{\sigma} \]

Experiment

Simulation

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Material Modeling - Brittle

Model

Johnson-Holmquist material model

\[
\sigma_i^* = (A(P^* + T^*)^N (1 + (Cln\dot{\varepsilon}^*))
\]

\[
\sigma_f^* = B(P^*)^M (1 + Cln\dot{\varepsilon}^*)
\]

Damage model

\[
\varepsilon_p^f = D_1(P^* + T^*)^{D_2}
\]

Damage evolution

\[
D = \sum \Delta \varepsilon_p / \varepsilon_p^f
\]

Effective stress

\[
\sigma^* = \sigma_i^* - D(\sigma_i^* - \sigma_f^*)
\]

Experiment

SHPB test

Simulation

Incident bar

Transmitter Bar

Specimen

Effective stress evolution

Xihong Zhang, 2015, University of Western Australia, pg 31-50
Experiment

Indenter

Indenter holder

Specimen holder

Force sensor

X table

Linear device

Z table

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Experimental Outputs

Forces Signal

Surface Topography

specific energy \( (u) = \frac{F_t}{GA} \)

Virtual Wheel Modeling

Grinding Wheel Fabrication Procedure

- Mixing bond-grit and moulding (particle packing simulation)
- Firing bond-grit mould (firing simulation)
- Dressing of grinding wheel (dressing simulation)

Grit-Bond Compression  Firing  Dressing  Virtual grinding wheel

Implementation

- Choice of best discretization approach
- Material modeling and parametrization
- Validation with experiments
Specific Energy Calculations

- Energy required to remove unit volume of material
- Ratio of the tangential forces to the grove area
- Study specific energy required for single-grit, multiple-grit, and complete grinding process

Conclusion

- Discretizations: any other modeling techniques?
- Material models and contact model
- Experimental measurements
  - Surface topography measurements
  - CT Scans of abrasive grits, rendering?
- Inter-exchange of experimental or modeling data?