A novel multiscale material plasticity model for prediction of material behaviour in high-performance cutting

J.X. Bai[1,2], Z. Tong[1*], X. Jiang[1]

[1] EPSRC Future Metrology Hub & Centre for Precision Technologies, University of Huddersfield, Huddersfield HD1 3DH, UK

[2] Tribology Research Institute, State Key Laboratory of Traction Power, Southwest Jiaotong University, Chengdu 610031, China

*Corresponding author: z.tong@hud.ac.uk

Abstract

The achievable surface quality significantly depends on the material behaviour during high-performance cutting. In this paper, a multiscale material plasticity simulation framework is developed to predict the material hardening process in high performance cutting. The multiscale model was developed based on the coupling of discrete dislocation dynamics (DDD) with finite element analysis (FEA) calculation platform. A dislocation density-based constitutive equation was developed to consider formation and alteration mechanisms of dynamic recrystallization. A physics-based 3D-DDD numerical algorithm was used to determine the critical parameters of the constitutive equation pertaining to controlling dislocations multiplication and annihilation activities. This is achieved by tracking the movement of edge and screw dislocations such as generation, propagation, siding and interaction, etc. The flow stress attributed to crystal plasticity, dislocation density and grain refinement were implemented as a user-subroutine of a finite element package to predict the microstructure evolution in different cutting conditions. For validation, the developed multiscale model was used to stimulate the material behaviour under different cutting environment and a classic FEA cutting model was employed as a reference. Compared with the results from FEA simulation on cutting forces and strain-stress distribution prediction, it is found that the proposed multiscale cutting model can also well predict the microstructure characteristics of materials in cutting zone. Dynamic recrystallization (DR) was found in the machining process under different cutting conditions. This provides new insights into the material behaviour in high-performance cutting and would allow the further development of a DR-based model for functional design and process optimisation.

Keywords: high-performance cutting; microstructure; discrete dislocation dynamics; constitutive equation

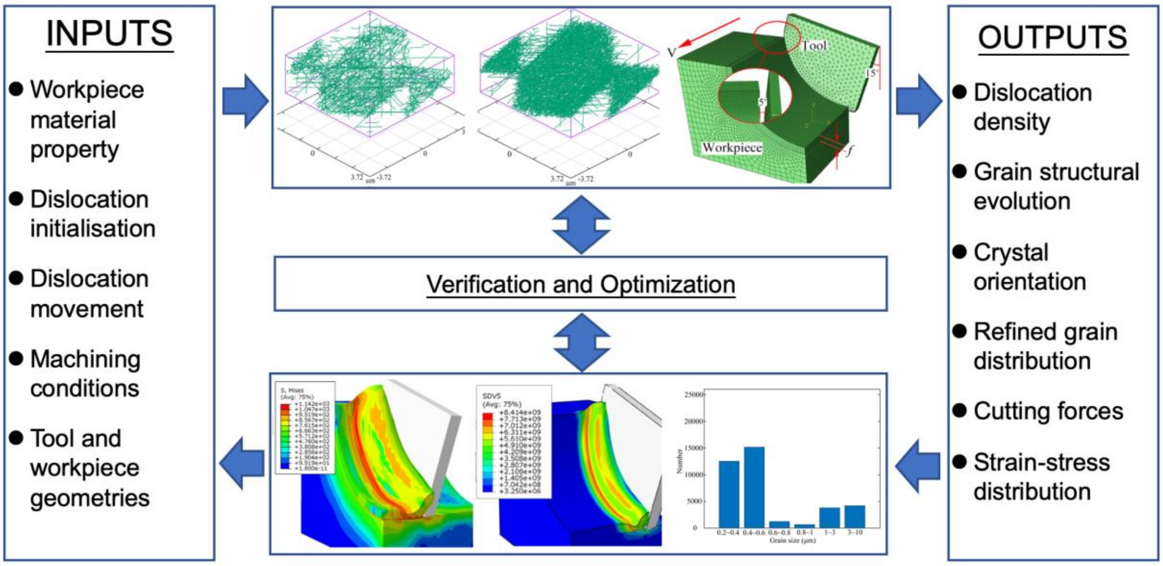

Fig. 1 The multiscale material plasticity simulation framework