Predicting subgrain size and dislocation density in machining-induced surface microstructure of Nickel using supervised model-based learning

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Abstract

Microstructure evolution under interactive effects of severe shear strains, strain-rates and the accompanied temperature rise often follows complex trajectories. Encapsulating the process–structure linkages under these conditions is vital for prediction and control of product outcomes from processes that involve severe plastic deformation. This paper examines the microstructure transformations during severe shear deformation induced by plane strain machining (PSM) on high-purity (99.99%) Nickel. Deformation conditions in both chips and the surface are created using PSM and characterized via *in-situ* techniques which are then juxtaposed with orientation imaging microscopy (OIM) via electron back scattered diffraction (EBSD). The dislocation densities are quantified using the broadening of X-ray diffraction peaks of crystallographic planes. We capture the variation of microstructure response (subgrain size and dislocation density), by applying the supervised model-based learning techniques combined with physics-based models to enhance the predictions performance. The features involved in the study are cutting speed, rake angle, temperature, strain, strain-rate, in addition to lnZ and a rate parameter R identified from the saturated characteristics of work hardening in stage IV relevant to subgrain sizes. We use principal component analysis (PCA) as our dimensionality reduction algorithm resulting in significant model improvement. The developed model is used in conjunction with finite element simulation of PSM to predict the subsurface subgrain size. Furthermore, principle of similitude (PS) is incorporated in the subgrain size model for predicting the dislocation densities in both the deformed chip and the machined subsurface. The proposed framework (PCA model- FEM simulation-PS relation) is shown to offer opportunities for creating multifunctional surface microstructure in an array of machining manufacturing processes.

Keywords
Microstructure, prediction, deformation, machining, materials engineering

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