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The Effect of 3D Grain Morphologies on the Formability of Aluminum Alloys

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The concept of Forming Limit Diagram (FLD) is one of the most useful tools employed to investigate the formability of sheet metals undergoing plastic deformation. In the present work, an elasto-viscoplastic crystal plasticity formulation is incorporated into a Fast Fourier Transform-based formulation to provide a computationally efficient numerical framework. The crystal plasticity formulation is combined with a modified Marciniak & Kuczynski (M-K) method to assess the formability of various aluminum alloys. The new multiscale numerical framework accounts for three-dimensional (3D) grain morphologies, grain interactions and provides full-field solutions of micromechanical fields. The proposed model is validated by comparing the predicted FLDs for the aluminum alloys (AA) 5754 and 3003 with the experimental forming strains. This is followed by a systematic study of the effects of grain morphologies on the FLDs. Furthermore, the new model is employed to study the formability of the aluminum alloy HA6016-X, which has functionally graded grain morphologies through the thickness of the sheet. The study reveals that among the various microstructural features, the grain morphology and gradients in grain morphology strongly affects the predicted forming strains.