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Combined microstructure-based flow stress and grain size evolution models for multi-physics modelling of metal machining

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Abstract: Intense thermomechanical loading in metal machining induces a microstructure change at different zones in the workpiece (machined surface, chip and tool tip). This paper deals with a multi-physics modelling of the cutting process, where the thermo-viscoplastic behaviour of the workmaterial is described by a physical model, denoted Mechanical Threshold Stress (MTS) model, and by the classical Johnson–Cook (JC) flow stress law for comparison purpose. The workmaterial microstructure change during cutting (grain size evolution) is described by a physical-based Dislocation Density (DD) model, which is combined with the MTS model in the framework of an ALE-FE approach. The model is developed for a 2D orthogonal cutting simulation. Combined MTS–DD material models were implemented in Abaqus/Explicit FE code. The first step of the multi-physics model is analysed by comparison of predicted cutting forces and chip thickness with experimental ones and those predicted by the JC model. In the second step, the grain refinement during cutting is predicted, revealing zones where the microstructure is highly affected, particularly through the depth of the machined surface, where the thickness of the affected subsurface is estimated.

Keywords: Machining; thermo-elasto-viscoplasticity; Microstructure; Grain size; Finite element

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