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Computationally efficient predictions of crystal plasticity based forming limit diagrams using a spectral database

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Abstract

The present investigation focuses on the development of a fast and robust numerical tool for the prediction of the forming limit diagrams (FLDs) for thin polycrystalline metal sheets using a Taylor-type (full constraints) crystal plasticity model. The incipience of localized necking is numerically determined by the well-known Marciniak–Kuczynski model. The crystal plasticity constitutive equations, on which these computations are based, are known to be highly nonlinear, thus involving computationally very expensive solutions. This presents a major impediment to the wider adoption of crystal plasticity theories in the computation of FLDs. In this work, this limitation is addressed by using a recently developed spectral database approach based on discrete Fourier transforms (DFTs). Significant improvements were made to the prior approach and a new database was created to address this challenge successfully. These extensions are detailed in the present paper. It is shown that the use of the database allows a significant reduction in the computational cost involved in crystal plasticity based FLD predictions (a reduction of about 96% in terms of CPU time).

Keywords: Crystal plasticity, Viscoplastic material, Numerical algorithms, Localized necking, Spectral method

1. Introduction

Reliable prediction of the onset of localized necking in thin metal sheets represents a challenging task in the design and manufacturing of sheet metal structural components. During biaxial stretching of sheet metals, the deformation evolves homogeneously at the beginning of the loading. This homogeneous deformation stage is generally followed by diffuse necking, which is characterized by a progressive strain concentration under a smoothly decreasing load. Then, the load abruptly drops with the development of localized necking, which corresponds to the ultimate deformation state that a stretched metal sheet can undergo before failure. For the prediction of localized necking, the well-known forming limit diagram (FLD) concept is most commonly used. This concept was initially

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