Prediction of Forming Limits Under Non-Proportional Strain Paths Using a Multi-Surface Plasticity Model

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KEYWORDS: *Localized Necking, Ductile Failure, Void Growth and Coalescence, Plastic Anisotropy, Sheet Metal Formability.*

Predicting the forming limits of sheet metals under complex loading paths encountered in forming operations is a challenging problem because ductile failure strongly depends on the loading path. Conventional forming limit diagrams (FLDs), obtained using proportional biaxial loading experiments, cannot be used to predict failure under strongly non-linear loading histories. Failure in sheet metals occurs by localized necking along a narrow band whose width is comparable to the sheet thickness. Under plane stress conditions, the critical conditions for the onset of localized necking can be obtained using either a bifurcation analysis [1] or an imperfection band approach [2]. However, both approaches have well-known limitations, such as the inability of the bifurcation approach, when used with conventional plasticity models, to predict failure under biaxial tensile strains, and the sensitivity of the imperfection band approach to the choice of initial imperfections. In this study, we show that realistic predictions of the forming limits can be obtained using a recently developed multi-surface plasticity model, based on the micro-mechanics of void growth to coalescence, over the entire range of biaxial plane stress loading paths [3]. The predictive capability of the model is demonstrated by comparison with experimental forming limit diagrams for aluminum sheets subjected to pre-straining along various loading directions [4]. It is shown that the model is able to predict the evolution of the shape of the FLD as a function of the pre-strain history, in good agreement with the experimental data. The effects of plastic anisotropy and thickness imperfections in the sheet metal as a result of manufacturing tolerances are also investigated.

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