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A new approach for failure criterion for sheet metals

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ABSTRACT

The interpretation of sheet forming simulations relies on failure criteria to define the limits of metal deformation. The common requirements for these criteria across a broad range of application areas have not yet been satisfied or fully identified, and a single criterion to satisfy all needs has not been developed. Areas where existing criteria appear to be lacking are in the comprehension of the effects of non-proportional loading, general non-planar and triaxial stress loading, and process and material mechanisms that differentiate between necking and fracture. This study was mainly motivated to provide an efficient method for the analysis of necking and fracture limits for sheet metals. In this paper, a model for the necking limit is combined with a model for the fracture limit in the principal stress space by employing a stress-based forming limit curve (FLC) and the maximum shear stress (MSS) criterion. A new metal failure criterion for in-plane isotropic metals is described, based on and validated by a set of critical experiments. This criterion also takes into consideration of the stress distribution through the thickness of the sheet metal to identify the mode of failure, including localized necking prior to fracture, surface cracking, and through-thickness fracture, with or without a preceding neck. The fracture model is also applied to the openability of a food can for AA 5182. The predicted results show very good agreement with the experimentally observed data.

1. Introduction

Materials may safely undergo plastic deformation up to finite strain, but ultimately material elongation is limited by one of many limiting phenomena. One example of these limiting phenomena is represented by the forming limit curve (FLC) or diagram describing the onset of local necking under linear loading in terms of the major and minor strains. The characterization of forming limits in terms of strain is not reliable for complex deformation processes since the conventional strain-based FLC is sensitive to strain-path effects. The most promising solution for dealing with strain-path effects in the FLC is to use a stress-based approach, as independently proposed by Kleemola and Pelkkikangas (1977), Arrieux et al. (1982), Stoughton (2000), and Stoughton and Yoon (2005). These authors have shown that the stress-based FLC, calculated directly from the strain-based FLC under conditions of proportional loading, is not affected by, or at least considerably less sensitive to changes in strain path that occur frequently in metal forming processes used by industry and in product applications.

Although strain-based and, more recently, stress-based forming limit diagrams have made significant contributions characterizing forming severity over the last 40 years, a general integrated solution to predict and differentiate other modes of metal failure beyond the onset of necking, and the dependence of all modes of failure on the stress/strain gradients and loading history has not been realized. In particular, the relationship between necking and fracture limits, which involves

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