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Formability prediction of AL7020 with experimental and numerical failure criteria

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Abstract

The Formability of aluminum alloy sheet metal is a key issue in its design, analysis and operation of manufacturing processes. The conventional Forming limit diagram (FLD) which evaluates the principal strains at failure is often used to quantify the formability limits. Due to the sensitivity of the FLD to the strain paths, the forming limit stress diagram (FLSD) based on principal stresses is shown to be more efficient. In contrast, a fully coupled behavior-damage models are recently proposed, which allow to predict the strain localization and the failure occurrence based on appropriates fully coupled constitutive equations describing the main physical phenomena involved. In this work a fully coupled constitutive equations taking into account the mixed nonlinear isotropic and kinematic hardenings fully coupled with the isotropic ductile damage is used. The microcracks closure is added to affect the equivalent plastic strain at fracture in a large range of stress states. Various tests are conducted to test the formability of aluminum alloy AL7020. The three different methods (FLD, FLSD and the fully coupled model) are identified and validated separately. With the help of Nakazima tests and cross-section deep drawing tests, the quality of the three failure criteria for AL7020 are compared and demonstrated with the investigations of the simulation results.

Keywords: Formability; Forming limit curves; Constitutive equations; Ductile damage.

1. Introduction

Forming process is among the most important metal working operations for its important role in manufacturing, especially in the automotive industry. Many works have been performed to understand the process and predict forming limits or failure limits of various metal sheets.

The forming limit diagram (FLD) gives a useful concept on sheet metal formability characterization. Since the early 1950s, extensive work has been done to find an effective way to collate experimental forming limit data into a format that can help the user to evaluate material formability. Forming limit diagrams first described by Keeler and Backhofen (1963) meet that requirement. FLD gives an envelope of allowable forming limit curve that plots major strain versus minor strain below which failure should not occur, under proportional loading paths. Although the FLD method can be a useful tool in the analysis of forming safety, after lots of investigations, it has been found that the FLD definitely depends on the forming history and strain paths. Some multi-stage forming investigations of the mild steel, copper and brass have proven the shift or moving of the FLDs. The earliest experimental demonstrations like reported by Ghosh and Laukonis (1976), which have plotted the FLD of

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