Abstract

In the present study, in-house experimental setups were fabricated to impart pre-strain along three distinct strain paths viz. equi-biaxial, plane strain and uniaxial, in different automotive grade sheet materials namely EDD, AA5052, and DP600. Uniaxial tensile tests and stack compression tests were conducted to evaluate the anisotropic coefficients and yield loci using Hill48-*r*, Hill48-σ and Yld2000-2d yield theories. The predicted evolutions of yield loci and both the yield strength and plastic strain ratio directionalities of as-received and pre-strained materials were successfully calibrated with experimental data. Additionally, the as-received and pre-strained sheet materials were stretch formed up to the onset of necking and further until the initiation of fracture. The failure limits were evaluated in principal strain space (ε_1 , ε_2) experimentally in terms of forming limit diagrams (ε-FLDs) and fracture forming limit diagrams (ε-FFLDs). The ε-FLDs and ε-FFLDs of as-received materials were theoretically predicted by Marciniak-Kuczynski (MK) model and Bao-Wierzbicki (BW) damage model, respectively. It was found that these two models predicted the necking and fracture strains very close to the experimental data when the calibrated Yld2000-2d yield theory was implemented. In case of pre-strained materials, the dynamic shifting of ε-FLDs and ε-FFLDs was recorded in principal strain space ($\varepsilon_1, \varepsilon_2$) depending on the type and amount of pre-strain. Hence, the polar effective plastic strain (PEPS) based necking limit (PEPS-FLD) and fracture limit (PEPS-FFLD) were estimated using Yld2000-2d anisotropy plasticity theory, and it was observed that the dynamic shift of the failure strains could be restricted successfully. The maximum absolute errors for prediction of necking and fracture dome height of pre-strained materials were within 5% and 6% respectively when PEPS based failure limits were used as damage model in FE simulation. Moreover, all the experimental fracture strains were converted into 3D stress triaxiality locus $\left(\eta, L_P, \overline{\varepsilon}_f\right)$ and it was concluded that the calibrated BW fracture loci had a good predictive efficiency for various forming tests. Moreover, the incorporation of Yld2000-2d yield model in FE simulation efficiently predicted the experimental limiting drawing ratio (LDR) and deep drawing behaviour in case of both as-received and pre-strained materials.

Keywords: Sheet metals; Anisotropy; Pre-straining; Forming limit diagram; Fracture forming limit diagram; Yield theories; Finite element simulation