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Approximate method formulating plastic potentials of porous sheet metals with non-quadratic anisotropy

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Abstract

In this paper, a new approximate method was proposed to formulate the plastic potentials of the porous sheet metals with non-quadratic anisotropic matrix. Theoretical and simulated results have indicated that the plastic anisotropy of the matrix could influence mechanical response and damage evolution of the ductile porous materials. Nevertheless, previous analytical approaches were mostly focusing on the porous plastic potentials with matrix obeying Von-Mises or Hill's quadratic yield criterion, which could not accurately describe the plastic behavior of some sheet metals exhibiting strong anisotropy. Other few works tried to formulate the plastic potentials with non-quadratic matrix by simply redefining the equivalent stress in the Gurson-type models without rigorous deductions. In this work, however, a first-order approximating method with optimizing analyses was introduced to establish the acceptable approximation of plastic potentials with non-quadratic anisotropic matrix. Based on this new approximating method, a planar porous model with non-quadratic anisotropy was proposed. In this model, the anisotropic constitutive relation of the matrix was characterized by the Yld2000-2d yield criterion, which has proved to be capable in modeling complex plastic behaviors of the anisotropic sheet metals. The formulating procedures were based on the rigorous micromechanics derivations with upper bound analyses. Afterwards, the proposed model was verified by comparing the theoretical predicted yield loci with the numerical simulated ones using the voided unit cell model. Furthermore, this model was then implemented into ABAQUS as user subroutine VUMAT to simulate the mechanical responses of the porous sheets with high strength DP steel matrices under uniaxial / biaxial tensile conditions.

Keywords**:** porous material; sheet metal; non-quadratic plastic anisotropy; finite element method

1. Introduction

For the common structural metals, the imperfection matrix surrounding the micro-voids and/or second phrase would generally provide strain concentration sites for void nucleation, growth and coalescence which leading to material failure. Therefore, modeling the mechanical behaviors of porous media is essential in predicting the damaging and ductile fracture of the metals. For decades, the micromechanical approaches for characterizing the porous media have been studied in great depth and consequently a number of porous models have been proposed. McClintock [1] firstly proposed a fracture model by analyzing the growth of the postulated cylindrical void in the infinite plastic matrix under biaxial stress conditions. Rice and Tracey [2], however, considered the isolated spherical void in the infinite matrix under the remotely uniform stress fields and concluded an exponential dependence of void volume growth rate on the hydrostatic component of the stress. Inspired by the previous works of McClintock, Rice and Bishop [3], Gurson [4] introduced the concept of representative volume element (RVE) with