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Plastic propagation affected by linear material gradation in the pressurized thick-walled sphere

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Abstract

The elastoplastic behavior of the thick-walled inhomogeneous spherical container made up of metallic materials with through-thickness linear gradation in radial direction subjected to internal pressure is investigated. The equilibrium and compatibility equations as well as Hooke's constitutive relations are simplified for axisymmetric conditions in the spherical coordinate system. Since the natural or mechanical boundary conditions at inner and outer surfaces of sphere must be satisfied, the governing differential equations in the elastic and plastic regions are calculated in terms of the radial stresses. In the elastic zone the linear and in the plastic zone the elastic-perfectly plastic material behaviors are assumed. The von Mises yield criterion is employed. The shear stresses are vanished due to axisymmetric conditions; as result the coordinate parameters are principle axes. The elasticity modulus, yield stress and Poisson's ratio are assumed to be linear functions of the radius. The governing differential equation is solved via finite difference method (FDM) due to lack of analytic solution. The diagrams of stress field in the elastic and plastic zones as well as strain field in the elastic zone are illustrated. The through-thickness variations of elasticity modulus, Poisson's ratio and yield stress effects on required internal pressure for plastic zone propagation are investigated. The validity of the calculated results based on FDM is proved by introducing equivalent laminated FEM model in Abaqus software.

Key words: Elastoplastic analysis, Linear material gradation, Spherical reservoir, Plastic propagation, Finite difference method (FDM)

1. Introduction

The elastoplastic collapse limit models of coiled tubing under complex stress state are established based on the twin shear unified strength theory and a new analytical model is proposed to define the collapse limit of coiled tubing. The plastic collapse limit is the value of external pressure for which the entire wall thickness of coiled tubing becomes