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A generalized spherical velocity field for bi-metallic tube extrusion through dies of any shape

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ABSTRACT

In this paper, an upper-bound approach is used to analyze the extrusion process of bi-metallic tubes through dies of any shape with moving cylindrical shaped mandrel. A generalized kinematically admissible velocity field using spherical coordinate system is developed to evaluate the internal power and the power dissipated on frictional, velocity discontinuity surfaces and the total power. The extrusion process is also simulated using the finite element code, ABAQUS. Analytical results are compared with the results given by experiments of other researchers and also by the finite element method. These comparisons show a good agreement.

1. Introduction

Exact solutions are not available for many metal working processes and several attempts have been made to propose approximate methods, which could be adopted for estimating the loads required to cause plastic deformations. Among various methods of solution for many metal working processes, the upper-bound technique as an analytical method and finite element method has been widely used for the analysis of the extrusion process effectively. One of the limitations of most of the current FEM solution schemes for metal forming is that they do not provide parametric analysis. Hence, any parametric investigation is usually done manually by changing one FE model to another until a feasible solution is obtained. Even though the finite element gives detailed information, it takes considerable CPU time. Using the upper-bound technique has the merits of saving computer's CPU and it appears to be a useful tool for analyzing metal forming problems when the objective of such an analysis is limited to prediction of deformation load and/or to study metal flow during the process.

A considerable amount of investigation has been done on axisymmetric extrusion of bi-metallic rods/tubes [1] using fixed and moving straight mandrels [2]. Bi-metallic tubes have useful applications in various industries where service conditions demand different requirements in the core of tube from those on its outside surface. Hartley [3] proposed a kinematically admissible velocity field for tube extrusion, which reduces to a kinematically admissible velocity field for solid rods extrusion in the limit as the mandrel diameter goes to zero. Avitzur et al. [4] summarized the factors, which affect simultaneous flow of layers in extrusion of a bimetal rod. Some of these factors include percentage reduction in area, semi-die angle, friction factor between sleeve and die wall and ratio of core to sleeve radii. Chitkara and Aleem [5,6] theoretically studied the mechanics of extrusion of axisymmetric bi-metallic tubes from solid circular billets using fixed mandrel with application of generalized upper-bound and slab method analyses. They investigated the effect of different parameters such as extrusion ratio, frictional conditions, shape of the dies and that of the \mandrels on the extrusion pressures. Hwang and Hwang [7] investigated the plastic deformation behavior within a conical die during composite rod extrusion using the stream functions. Momeni et al. [8] experimentally investigated the effect of die profile on extrusion load in bi-metallic tube extrusion process, using a moving straight mandrel.

Utilizing the finite element method in analysis of bi-metallic rod/tube extrusion, Tayal and Natarajan [9] and Alcaraz and Sevillano [10] tried to obtain stress and strain contours during the axisymmetric extrusion process of bi-metallic rods and tubes, respectively.

Khosravifard and Ebrahimi [11] analyzed the extrusion of Al/Cu bi-metal rod by FEM using ANSYS LS-DYNA and studied effect of extrusion parameters in creation of interfacial bonds.

The purpose of this paper is to develop a velocity field that can be used in an upper-bound model for flow of bi-metallic tube during extrusion through dies of any shape. Based on this model, the optimum die length and extrusion force is derived. FEM simulation on the extrusion of a bi-metallic tube composed of a copper sleeve layer and an aluminum core layer is also conducted.

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