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A Different and Effective Numerical method for Metal Extrusion

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Abstract

This study surveys and validates the novel numerical scheme to calculate the velocity, stress, strain, pressure and strain rate fields of metal plastic flow in direct extrusion processes by employing the finite volume method, FVM. Traditionally, the classical methods such as the upper-bound, slab, slip-line and more recently the Finite Element Method have been largely applied in metal extrusion analysis. However, recently the FVM has been applied and published by the authors for analysis of metal plastic flow, concluding that direct extrusion of metals could be mathematically modelled by the plastic flow formulation similar to an incompressible non-linear viscous fluid. Tannehill et al. suggested that viscous fluid flow can be numerically simulated by FVM, obeying the mass, momentum and energy conservation equations and boundary conditions. Hence, the governing equations of metal plastic flow in Euler approach were discretized by FVM, using the Explicit MacCormack Method in structured, fixed and collocated mesh. SIMPLE method was applied to attain the necessary pressure-velocity coupling. This new numerical scheme was applied to the analysis of direct hot extrusion process of Al 6351 and Al 6060 aluminium alloys. The velocity and other variables fields achieved fast convergence and a good agreement with experimental results from viscoplasticity tests by the grid stripe pattern technique and Forge 2008 software. The MacCormack Method applied to metal extrusion revealed consistent results without the need of artificial viscosity as required by the compressible fluid flow simulation approaches. Therefore, present numerical results confirm that FVM with MacCormack method together with Euler formulation approach and SIMPLE method can be applied satisfactory in the solution of metal forming processes.

Key words: Strain rate field, Plastic flow formulation, Viscous fluid flow, Extrusion, Artificial viscosity

Introduction

Generally, extrusion of metals is a thermo-mechanical processing at warm and high temperature by which metallic alloys billets are transformed into simple bar, rod, profiles or bars of complex cross sectional shape. The successful operation, direct or back extrusion, involves the knowledge of the mechanics of metal flow (velocity, pressure, stresses and deformations fields), heat transfer, friction and the metallurgy of microstructure evolution (grain size, phase, porosity, damage, etc.), to manufacture the