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Non-symmetric hollow extrusion of high strength 7075 aluminum alloy

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Abstract

A hollow extrusion process by varying pocket geometry in welding chamber and bearing length to obtain a uniform material flow is studied. Finite element analysis and Taguchi method are used to obtain a better porthole type extrusion die design. The research results show that the billet has the best uniform material flow and minimum dead metal zone in Double arc type, and the ramp load shows that R of 40 mm is smaller than 45mm. In addition, unequal bearing length makes metal flow more uniform. Finally, extrusion die with port-hole die structure has been manufactured and a successful extruding process has been conducted which proves the better design using the double arc pocket and unequal bearing length.

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keywords: AA7075; Porthole die; Hollow extrusion; Die design; Material flow

1. Introduction

Porthole die extrusion has a great advantage in the forming of hollow section tubes that are difficult to produce by conventional extrusion with a mandrel on the bridge. Because of the complicated structure of the die assembly, the extrusion of hollow section tubes has been investigated experimentally. Analytic approaches that are useful in profitable die design and in the improvement of productivity are inevitably demanded. Kim et al. (2002) have conducted finite element analysis on aluminum tube extrusion for AA3003 to obtain larger welding pressure than

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that of conventional porthole dies, and the effect of the improved porthole die on welding pressure has been investigated.

Design parameters such as billet temperature, bearing length and product thickness, are examined by Jo et al. (2003). The welding pressures are examined through 3D simulation of the non-steady state and compared with experimental results for AA7003 as billet material. The extrusion process of an aluminum AA1100 rectangular hollow pipe was simulated using finite volume method based software Msc/SuperForge by Wu et al. (2006). The simulation results indicate that the extruded work-piece has an uneven forepart, non-uniform deformation distribution and high load peak if using the original die design.

In order to investigate the effects of pockets in the porthole die on the metal flow, temperature at the die bearing exit and the extrusion load were contrasted with the traditional die design without the pockets in the lower die, two different multi-hole porthole dies with and without pockets in lower die for H-type solid extrusion of AA6061 were designed by He et al. (2010). The simulation results show that the pockets could be used to effectively adjust the metal flow and especially benefit to the metal flow under the bridges.

Multi-hole pocket dies are a type of extrusion tooling setup commonly used across the aluminum extrusion industry for efficient production of solid aluminum profiles. Fang et al. (2009) did the multi-hole pocket dies FEM simulation and extrusion experiments for AA6063 as the billet material, and found that multi-steps in die pocket could be effectively used to regulate the metal flow through multi-hole dies.

Aue-u-lan and Khansai (2012) focuses on the effect of the factors that could be caused of shorten die life, such as flow behavior, extrusion load, flow velocity, and temperature distribution. FEM was employed to simulate and investigate the effect of those factors on die stress for die material of AISI H-13. DEFORM 3D was used to simulate this hot extrusion process of AA6063 with square hollow profile. The simulation result of die stress was predictable and coherent with failure in real die that used to produce aluminum profile.

Low-temperature incipient melting and high deformation resistance of aluminum alloy AA7075 place extraordinary demands on extrusion die design and process optimization, especially when the shape of the extrudate is complex. Fang et al. (2009) studied on die design and process optimization for the alloy to manufacture a complex solid profile with large differences in wall thickness, by means of 3D FEM simulation and experimentation instead of the traditional trial and error approach. The effects of die bearing length and extrusion speed on extrudate temperature and extrusion pressure were predicted. The authors (Hsu et al., 2011 and 2012) have studied solid welding conditions and square tube extrusion process of AA7075. The proposed paper is a continue research extending to hollow extrusion of complex profile for high strength aluminium alloy 7075.

2. Porthole die design for non-symmetric hollow extrusion

A hollow extruded AA7075 product with complex cross section as shown in Fig.1(a), which can be used as structure part, is an industrial case for current study. The minimum thickness is about 3mm in rib and 5mm in web. A port-hole die configuration is needed to conduct the hollow extrusion process, where the upper die is to provide the divided flow of source material and restrict the inner geometry of product, and the lower die is to provide the welding chamfer and restrict the outer shape of product. The mandrel of upper die and orifice of lower die can be used to regulate the material flow.

Fig. 1(b) depicts the schematic configuration of porthole die for hollow extrusion including ram, container, billet, upper die and lower die. Fig. 1(c) depicts the upper die (10) and lower die (20) where the former includes billet flow in port (11), connect bridge (12), welding chamber (13), mandrel (14), and the latter includes welding chamber pocket (21), hole (22) and simple support beam (23).

The welding chamber pocket geometry is an important design for non-symmetric extrusion part. There are three different types (Original type, Cut edge type and Double arc type) of pocket are designed, as shown in Fig. 2(a)-(c). The original type pocket is a circle with diameter of 110mm. The cut edge type pocket has a cutting plane with a distance of 40mm to central point. The double arc pocket has another small arc labelled as *R* besides the original diameter of 110mm. There are two types of die bearing, namely: all 4mm equal type and unequal type of 4mm & 12mm considered in the present study for welding chamber with double arc type pocket, as shown in Fig. 2(d). For