journal of materials processing technology 209 (2009) 1891–1900

journal homepage: www.elsevier.com/locate/jmatprotec

FEM simulation of aluminium extrusion through two-hole multi-step pocket dies

Gang Fang [1], *Jie Zhou* *, *Jurek Duszczyk*

Department of Materials Science and Engineering, Delft University of Technology, Mekelweg 2, 2628 CD Delft, The Netherlands

ARTICLE INFO

Article history:
Received 21 January 2008
Received in revised form
20 February 2008
Accepted 20 April 2008

Keywords:
FEM simulation
Extrusion
Die
Aluminium

ABSTRACT

Multi-hole pocket dies are a type of extrusion tooling setup commonly used across the aluminium extrusion industry for efficient production of solid aluminium profiles. Such dies are designed on the basis of experience and corrected after a number of trial extrusion runs before becoming usable. Computer simulation based on the finite element method (FEM) is in principle capable of predicting metal flow through the dies designed, but it is yet a huge technological challenge to simulate the extrusion process to produce profiles of industrial significance. The present research was attempted to investigate the effect of steps in the die pocket on metal flow to produce two chevron profiles with unequal thicknesses through two-hole dies, by means of 3D FEM simulation of extrusion in the transient state. The results showed that the pocket step could be effectively used to balance metal flow. Extrusion experiments validated the predictions of metal flow, extrudate temperature and the pressure required for extrusion through the pocket dies with three different designs. 3D FEM was demonstrated to be a powerful tool in optimising die design and decreasing the number of trial extrusion runs.

© 2008 Elsevier B.V. All rights reserved.

1. Introduction

Across the aluminium extrusion industry, multi-hole dies are extensively used to produce several solid profiles simultaneously for maximum productivity. A multi-hole die may sometimes also be used to avoid a high reduction ratio, if a single-hole die is used, which requires an excessively high breakthrough pressure. It is essential that the multiple extruded profiles coming out of the multi-hole die are straight (without distortions) and at the same velocity. Flow uniformity and synchronization are affected by the sizes and shape of the profiles and the number and layout of die orifices, in addition to operational parameters such as temperature and extrusion speed. These can, in principle, be achieved by adjusting the die bearing length and angle, which is delicate manual work of the die corrector. However, in practice, balancing metal flow is often quite difficult, especially when the thickness of the profile is not uniform and the layout of die orifices is not axi-symmetrical. A number of trial extrusion and corrections cycles are needed before the die can be put into use for extrusion production, which is costly and waste of production time.

In recent years, pocket dies have been increasingly used instead of flat dies, mainly because they allow billet-on-billet extrusion so that extrusion can be run in a semi-continuous fashion so as to maximise the throughput of extrusion operation. An additional advantage of using a pocket die is that the adjustment of metal flow may be achieved through adequate design of the pocket, which is desirable, because a single bearing die may then be used, favourable for die manufacturing and die correction. It is a challenging task of the die designer

* *Corresponding author*. Tel.: +31 15 278 5357; fax: +31 15 278 6730.
E-mail address: J.Zhou@tudelft.nl (J. Zhou).
[1] Present address: Department of Mechanical Engineering, Tsinghua University, Beijing 100084, China.
0924-0136/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.jmatprotec.2008.04.036

to achieve both flow uniformity and synchronization in the case of multi-hole pocket dies. At present, pocket design is based on the experience of the die designer who is uncertain about his design until the pocket die is manufactured and has undergone trial extrusion runs. In today's aluminium extrusion manufacturing, short lead-time is a must and thus zero die trial is desirable. For this, the die designer needs a reliable tool to predict the metal flow before his design is finalised.

In the past, a number of research efforts have been made to help the die designer to understand the metal flow through multi-hole dies by means of physical modelling and more recently numerical simulation. Dodeja and Johnson, for example, built some plain strain and axi-symmetrical slip-line fields to calculate the pressure and flow rate during extrusion to produce sheets (Dodeja and Johnson, 1957a) and rods (Dodeja and Johnson, 1957b) through multi-hole dies. Johnson et al. calculated the extrusion pressure needed to produce sheets of unequal sizes through three-hole dies using the slip-line methods and the velocities to indicate the obliquity of the emergent sheets (Johnson et al., 1958). The 2D models used to calculate these parameters in cold extrusion ignored some relevant process parameters, *e.g.* the friction between the billet and container. Nevertheless, the research contributed to the understanding of complex metal flow during extrusion through multi-hole dies. Keife used the upper-bound method to study the effects of bearing length and hole position on velocity difference during extrusion through a die with two holes of different sizes (Keife, 1993). Ulysse and Johnson evaluated the effects of die hole eccentricity and the centre distance between the holes on extrusion pressure, the exit angles and velocities of the emerging products during extrusion through an eccentric single-hole die and an unsymmetrical multi-hole die, also by using the plane-strain upper-bound method (Ulysse and Johnson, 1998). In recent 15 years, computer simulation based on the finite element method (FEM) has been increasingly applied to the aluminium extrusion process, which allows geometrical complexities to go beyond the capabilities of the conventional analytical methods. Tong, for example, developed an FEM program (PressForm) based on the mixed Eulerian–Lagrangian approach and applied it to extrusion through two double-hole flat dies to demonstrate velocity non-uniformity as affected by hole size and position (Tong, 1995). Van Rens developed another FEM model and demonstrated the possibility of revealing velocity fields in the case of extrusion through a two-hole flat die with varied bearing length (Van Rens, 1999). Peng and Sheppard used a commercial FEM program (FORGE3) based on the Lagrangian approach to study the effects of the number and distribution of die orifices on flow pattern, pressure requirement and temperature history during extrusion through multi-hole dies (Peng and Sheppard, 2004). In addition, the influence of pocket on metal flow and on the microstructure of the extrudate in multi-hole extrusion was investigated (Peng and Sheppard, 2005). Commonly used software packages based on different FEM approaches were compared in the case of extrusion through a multi-hole flat die. The differences between the predicted lengths of the extruded rods and those obtained from experiments appeared to be associated with the software and even with the user (Karadogan et al., 2005). All these previous studies on extrusion through multi-hole dies were restricted to relatively simple geometries of limited industrial significance, *i.e.* flat and round products. In recent years, the awareness of this restriction and the need of the die manufacturing industry have prompted the research on extrusion through multi-hole dies for commercial profiles. A multi-hole die with four L-shaped openings and different pocket shapes has recently been used to evaluate the capabilities of different FEM software packages. The results are quite encouraging, although further research with improved physical and numerical parameters is needed to achieve a better agreement between FEM predictions and experimental data (Shikorra et al., 2007). Notwithstanding this remarkable progress towards the industrial reality, the die designer still relies on his experience and intuition when it comes to the design of multi-hole pocket dies.

For a die designer, the transient state of the extrusion process when the extrudate emerges from the die exit is most interesting. With the fast development of computational technologies in recent years, FEM simulation of the real-life extrusion process in the transient state has become feasible (Zhou et al., 2003; Li et al., 2004; Flitta and Sheppard, 2005). With the updated Lagrangian approach in FEM, automatic remeshing during the simulation of extrusion involving large deformation largely solves the problems of mesh distortions and free surfaces, although a large number of meshes and a high remeshing frequency are needed. For simulation of extrusion throughout the whole cycle, the Arbitrary Lagrangian Eulerian (ALE) adaptive meshing method has shown its capabilities of predicting metal flow and the final shape of the product effectively and efficiently, although it is still under development (Kayser et al., 2008). It is convinced that FEM will soon become a predictive tool of the die designer and corrector to change the costly, time-consuming trial and error practice across the aluminium extrusion industry.

The present research was an attempt to apply FEM to simulate the extrusion process in the transient state to manufacture profiles of industrial significance through multi-hole pocket dies. It was focused on the design of pocket steps to investigate how metal flow could be influenced by changing the geometrical parameters of the pocket. FEM software DEFORM 3D based on the updated Lagrangian approach was used to run the simulations to produce two chevron profiles with unequal thicknesses simultaneously through two-hole dies with the pockets of three different designs. The predictions were verified by extrusion experiments.

2. Die design

Fig. 1a shows the chevron profile to be extruded in the present study. It has unequal thicknesses, thus presenting a challenge for the die designer. This is because the metal in the thicker section flows faster than that in the thinner section. If the velocities of metal at different locations are not equal, the chevron profile will be distorted, possibly leading to scrap. In the case of extrusion to produce two chevron profiles simultaneously using a two-hole die, die layout is an important consideration. The two orifices in the die may be positioned symmetrically, as shown in Fig. 1b. Such a layout makes the adjustment of flow uniformity and synchronization relatively

Download English Version:

https://daneshyari.com/en/article/798577

Download Persian Version:

https://daneshyari.com/article/798577

Daneshyari.com