# Optimisation method of extrusion dies with a thin and complex shape*

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**ABSTRACT:** *Extrusion dies are usually manufactured with a rectangular pocket in front of the actual die opening. Finite element simulations demonstrate that curved or slant shaped pockets can assist in a more homogenous material flow in terms of velocity and shear stresses. An efficient optimisation algorithm has been developed for different pocket widths of slant die pockets. The algorithm incorporates finite element simulations to predict improvements in material flow. An example of a die with a great aspect ratio is presented and compared with experimental results.*

**KEYWORDS:** Extrusion; pocket design; die; finite element method (FEM); optimisation.

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## 1 INTRODUCTION

It is common industrial practice to manufacture extrusion dies for the production of aluminium profiles with a rectangular pocket in front of the die opening, which provides the shape for the work-piece. A rectangular pocket is relatively easy to machine and leads in general to a sufficient manufacturing result for many profiles. Nevertheless for complex parts and profiles with a great aspect ratio a standard pocket causes gradients in extrusion speeds, temperatures and shear stresses along all three dimensions. These gradients can have the effect of variations in the microstructures of the material of the finished product, which can lead to optical surface defects. These surface imperfections are usually referred to as flow lines, which are streaks in the extrusion direction of a width of a number of millimetres. They are very irregular in size, shape and position. According to the available literature (Muramatsu et al, 2005) it is a region of highest shear stress. A poor temperature and velocity uniformity inside the forming zone leads to a change in flow characteristics and layer distribution. In addition to flow lines there are also die lines present, which stem from surface defects and material build-up on the die orifice.

Various authors demonstrated the effect of the shape of pockets on the flow of material through a die. Li et al (2003a; 2003b) used finite element (FE) analysis to characterise the influence of the pocket angle $\theta$, which is the relation of pocket depth $d$ to pocket width $w$ in figure 1, on metal flow. They demonstrated an inverse linear relationship between the pocket angle and flow velocity when $\sqrt{d^2 + w^2}$ are constant, ie. a larger pocket angle reduces flow velocity and vice versa.

The influence of the relative position of the centre axis of the die to the centre axis of the extrusion channel on material flow was pointed out by Peng & Sheppard (2005), as well as the importance of the pocket widths $w_1$ and $w_2$. They considered geometry similar to figure 1 and ran several simulations by moving the centre axis position of the pocket towards and away from the centre axis of the die. In this study first they clearly demonstrated the necessity to use a pocket and the sensitivity of the pocket axis location relative to the channel axis. That is the sensitivity of the difference $w_1 - w_2$.

Yuan et al (2005) investigated a guiding angle in an effort to reduce surface defects. They demonstrated using a series of numerical simulations that the

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