Hot Metal Extrusion

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Abstract. The paper focuses on the main scientific problems related to hot metal extrusion of thin walled tube, strip and sections, covering analytical approach, 2D- and 3D-numerical simulation and experimental validation. The main physical phenomena and parameter estimation related to thermo-mechanical constitutive equations, shear localization, bearing channel, dry hot friction and metal flow stability in extrusion is treated. The scientific, generic insight and knowledge of these extrusion phenomena should be considered as pre-competitive. In industry this knowledge must be integrated with practical experiences and skills in order to be able to predict and control dimensional, surface and microstructure variability during a press cycle, and inspire to innovations in the field of extrusion and its down stream processes such as tube drawing, cold forging, bending and hydroforming.

Keywords: Extrusion, thin-walled sections, metals, FEM, experiments.

1 Introduction

This Section gives a short overview of extrusion and drawing. Sub-Section 1.1 covers extrusion and drawing as technological forming processes presented in the ESAFORM papers in the Mini-Symposium “Extrusion and Drawing”. In Sub-Section 1.2 the focus is on hot metal extrusion of thin-walled strips, tubes and sections, with special attention to direct extrusion of aluminium alloys. This process is of special scientific interest because of the complex and strong interaction between metal flow, temperature, die displacement, interface phenomena, friction, localized shear and microstructural evolution.

1.1 Extrusion and drawing

Extrusion and drawing are material forming processes for manufacture of long lengths with constant cross-section. Extrusion transforms cast and homogenized billets to rods, open sections and hollow sections by pressing the billet in the container with a ram through a die in a hydraulic press. Rods are normally a semi-fabricated product, used as feedstock for cold drawing of long lengths or cold or hot forging and machining of components. In the case of hot aluminium extrusion thin-walled open and hollow sections can be made with very complex cross-sectional area. Hollow sections are produced with a mandrel that shapes the inner surface of the section. The mandrel is fixed to the die by
“bridges” so that the metal flow has to be separated and subsequently joined after passing the bridges, but before leaving the die outlet. These longitudinal welds are called “seam welds”.

At the ESAFORM Conferences, a mini-symposium Extrusion and Drawing was organized. Papers related to backward and forward extrusion of components, drawing of long lengths, joining of sections along its length by friction stir welding and even cold and hot rolling of steel, copper, aluminium and magnesium and their alloys, including super-alloys, were presented. A significant part of the presentations focused on extrusion of thin-walled open and hollow sections. In this chapter we will therefore treat basic thermo-mechanical problems related to hot semi-continuous extrusion of thin-walled sections of long length. The interaction between alloy microstructure, temperature distribution during the press cycle, metal flow field, shear strain localization, dry friction at high temperature, die distortion, flow stability, joining processes and final properties of the extrudate makes hot extrusion of thin-walled aluminium sections one of the most complex and fascinating processes in the big family of metal forming processes.

1.2 The basic scientific challenges of hot metal extrusion

In thin-walled extrusion, the metal has a tendency to flow faster out of the die in one part of the section than in other parts of the section. This is seen when observing the first metal extruded through the die, from the uneven cross-sectional front of the section. When some of the metal has been extruded the potential differences in outlet speed are manifested by building up of longitudinal stresses in the section. These stresses are transmitted backward into the die and die inlet and thereby cause incremental changes to the flow field so that the variation in outlet speed is reduced. This causes local thickening or thinning of some part of the section, cyclic waves or even cracks. Obtaining fundamental insight, knowledge and control of these phenomena is the main target of the generic, pre-competitive scientific research. The research results can be applied by the extruders in combination with their detailed practical experience and skills as a means to control thickness, shape, microstructure, surface properties and bulk properties of the extruded section, design optimal tools and dies with increased efficiency, precision and minimum variability. The vision is an innovative ideal continuous, steady state process with zero variations along the section length may be realized. Work related to the Conform extrusion process [1], the potential of producing curved sections[2], and integration of the process chain extrusion, quenching, shape calibration and hydroforming [3] may give directions of future innovations.

2 Application and validation of numerical methods

During the last thirty years numerical tools have enabled scientists and engineers to study complex physical phenomena and to solve practical engineering problems. In relation to aluminium extrusion and similar forming processes it is of special interest to further develop numerical tools in order to understand and model complex