

Shape prediction for complex profiles : the next step in aluminum extrusion die design

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Introduction

In aluminum extrusion (fig. 1) the die determines not only the cross-sectional shape but also the straightness of the profile. Currently, for complex profiles (fig. 2), a trial and error process is employed to determine the die design which renders the correct product. This process includes the designing and manufacturing of the die, and trial-pressing of a profile to assess the resulting shape. These steps are expensive ($\approx 10\text{kfl}$), time consuming ($\approx 2\text{ wks.}$) and difficult to automate.

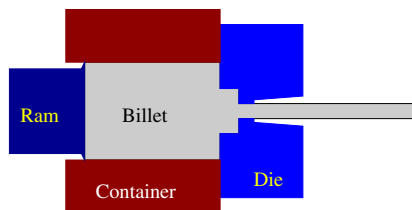


fig. 1 Extrusion

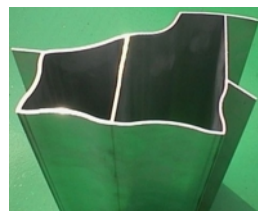


fig. 2 Complex profile

Objective

Replace the physical trial-pressings by FE (finite element) simulations and thus eliminate the manufacturing of incorrect die designs and the related trial-pressing.

FE simulation of extrusion

The aluminum is modeled as a fluid with a strain rate and temperature dependent viscosity. The die is assumed to be elastic. This renders the following coupled problems:

Coupled problems

- ▷ Aluminum flow problem (Stokes)
- ▷ Thermal problem (convection-diffusion)
- ▷ Die deflection problem (elastic)
- ▷ Free surface problem (convection)

Challenges for simulations

- ▷ Minimal effort required from die designer
 - Coupling between CAD and FE mesh
 - Tet Mini element to facilitate meshing
- ▷ Simulations should fit on workstation
 - Directionally refined meshes
 - New definition of normal on strongly curved edges
- ▷ Computations should be completed within days
 - Decouple problems
 - Dedicated solver for each problem

References:

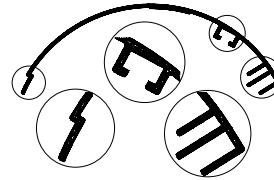
- [1] VAN RENS, B.J.E. *Finite Element Simulation of the Aluminum Extrusion Process* (PhD thesis, Techn. Univ. Eindhoven, 1999).

Results

Shape prediction for two profiles taken from practice:

Flat

Incorrectly designed die
→ profile curved



Hollow

Correctly designed die
→ profile straight

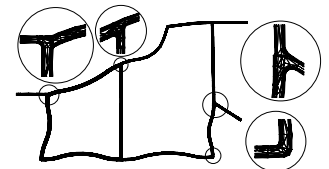


fig. 3 Directionally refined meshes for cross-sections

Computational information:

elements $\approx 260\ 000$

user input $\approx 20\text{ min.}$

simulation $\approx 2.5\text{ days}$

elements $\approx 320\ 000$

user input $\approx 30\text{ min.}$

simulation $\approx 3.0\text{ days}$

Temperatures:

Temperature should remain below the melting point

Min = $460[^\circ\text{C}]$ Max = $560[^\circ\text{C}]$

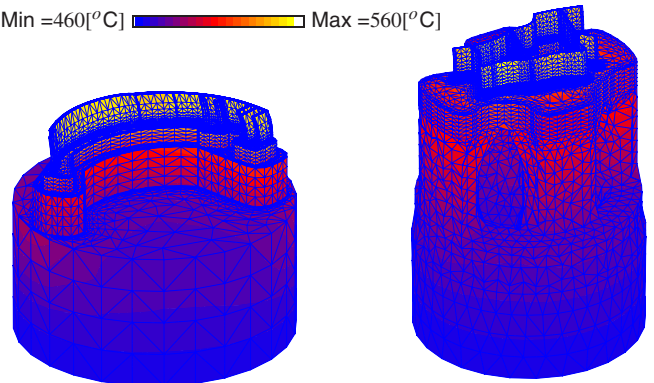


fig. 4 Temperatures and profile shapes

Exit velocities:

A uniform exit velocity results in a straight profile.

Min = $0[\text{m s}^{-1}]$ Max = $0.2[\text{m s}^{-1}]$



fig. 5 Die opening (outline) and cross-section (filled)

Conclusions

Simulations can replace trial-pressings

- ▷ Results correspond to trends from practice
- ▷ Simulations faster and cheaper
- ▷ Computational time and size acceptable