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

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 asses the resulting shape. These steps are expensive (≈ 10kfl), time consuming (≈ 2 wks.) and difficult to automate.

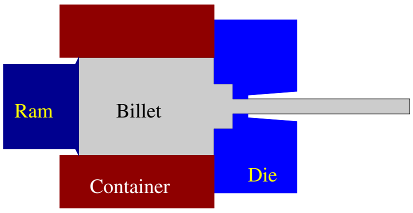

fig. 1 *Extrusion*

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

Results

Shape prediction for two profiles taken from practice:

Flat	**Hollow**
Incorrectly designed die	Correctly designed die
→ profile curved	→ profile straight

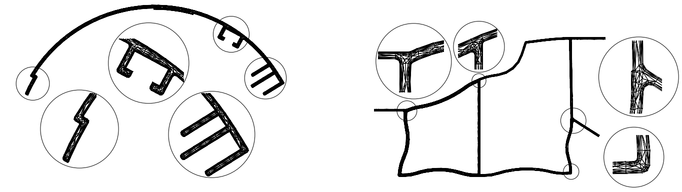

fig. 3 *Directionally refined meshes for cross-sections*

Computational information:

Flat	Hollow
elements ≈ 260 000	elements ≈ 320 000
user input ≈ 20 min.	user input ≈ 30 min.
simulation ≈ 2.5 days	simulation ≈ 3.0 days

Temperatures:

Temperature should remain below the melting point

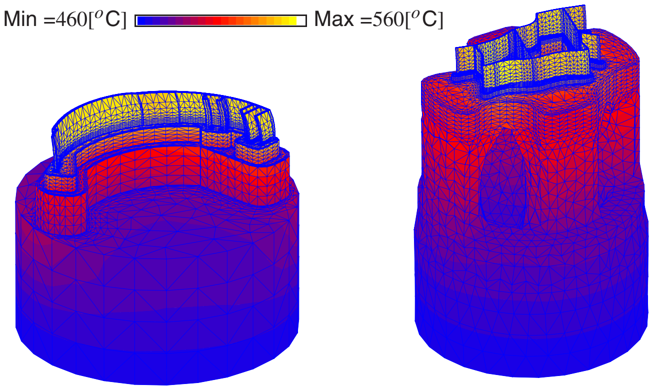

fig. 4 *Temperatures and profile shapes*

Exit velocities:

A uniform exit velocity results in a straight profile.

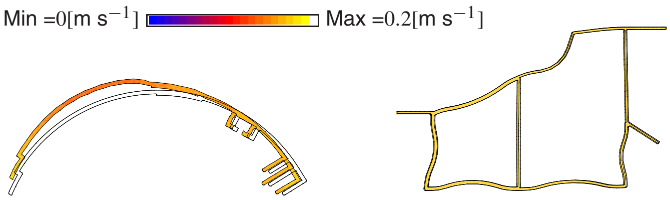

fig. 5 *Die opening (outline) and cross-section (filled)*

Conclusions

Simulations can replace trial-pressings

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

References:

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