Study of flow balance over a press cycle with HyperXtrude

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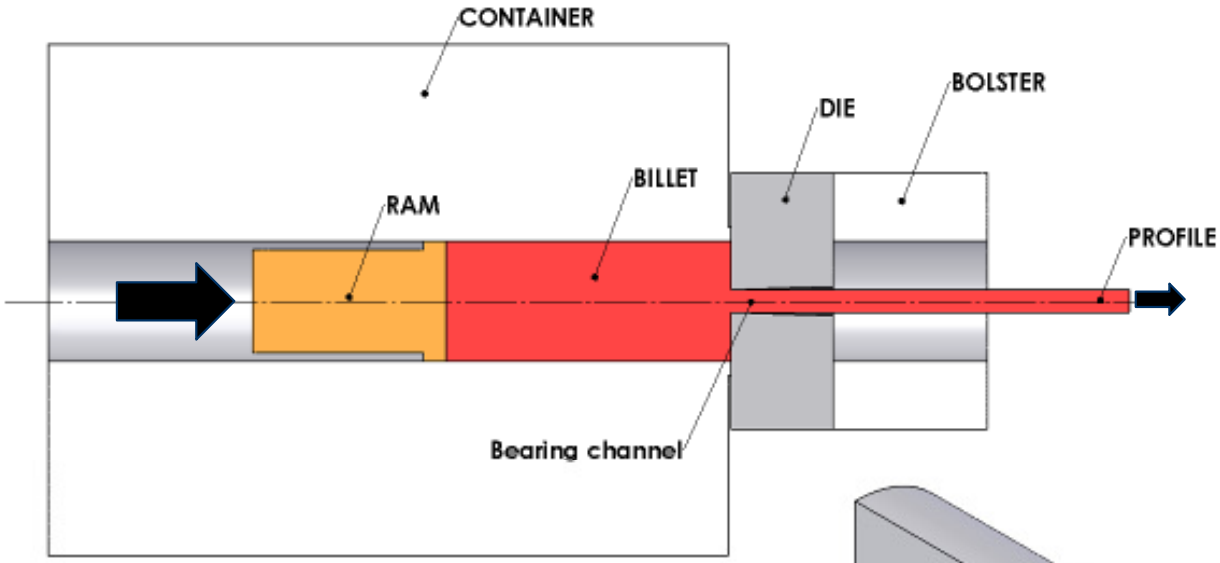
Abstract: In this work, flow balance in extrusion of aluminium has been studied. The aim of the study is to find how process parameters influence extrusion flow balance. This is done by investigating the influence of billet taper, billet temperature and ram speed on the relative run-out velocity from two separate cavities. The finite elements software used in this study is Altair HyperXtrude.

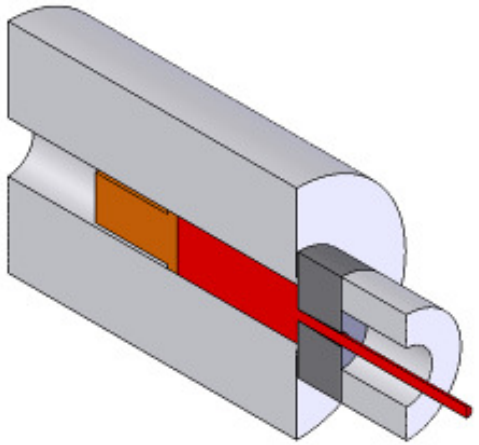
Outline

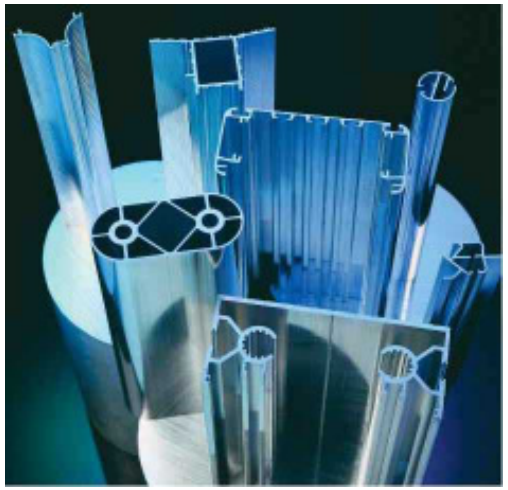
- Motivation
- FEM Modeling
- General linear model
- Conclusion

Extrusion press sketch

- Aluminium extrusion is a forming process where hot aluminium is forced through a die with a specific shape opening in order to form sections with a desired cross-sectional shape.







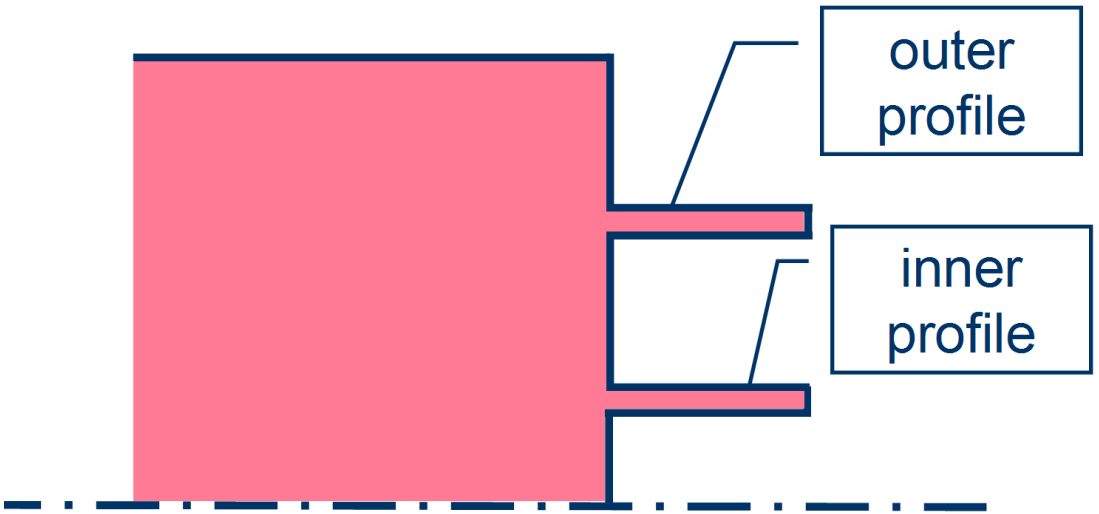
Motivation

- Important properties of extruded aluminium sections are:
  - Geometrical shape
  - Mechanical properties
- These are influenced by
  - Flow balance (velocity distribution across the section)
  - Temperature distribution
- Failure to meet specifications of shape and mechanical properties will result in scrap and customer claims.

Aim of the work

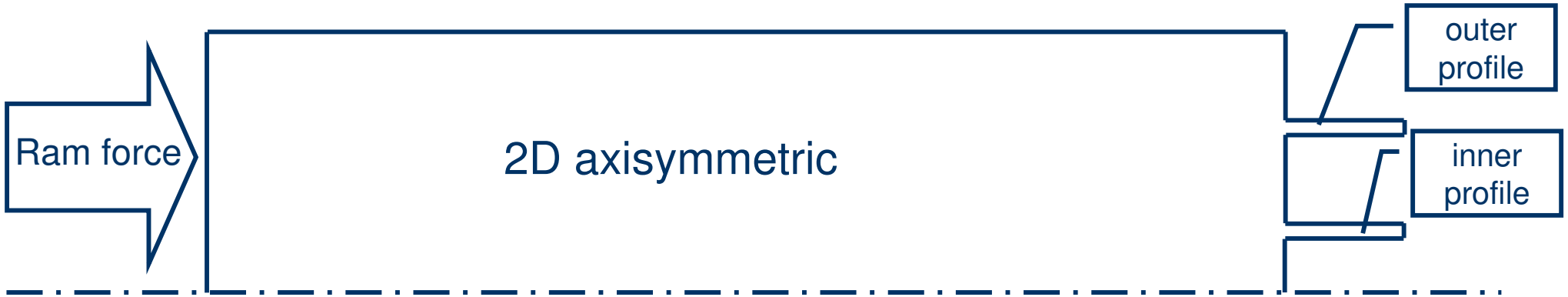
- The study is aimed at understanding mechanisms for variations in exit speed and exit temperatures across the section, and how to reduce these variations.

- In this work, this is done for a simple generic 2D axisymmetric case, by studying variations in exit velocity and exit temperature between two outlets.

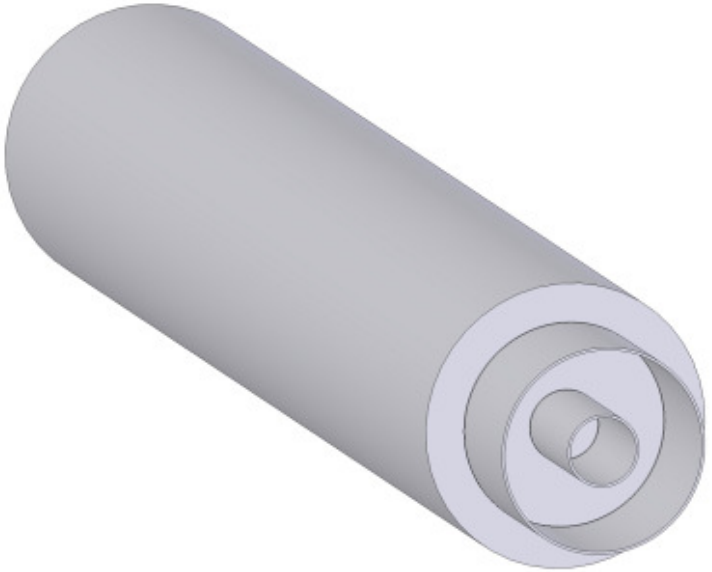


FEM model sketch

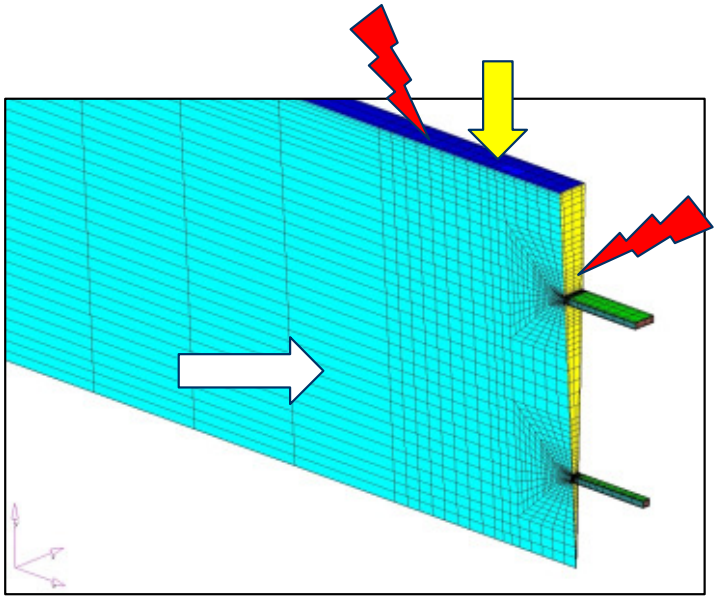
- **The generic section with 2 outlets, in 2D axisymmetry:**

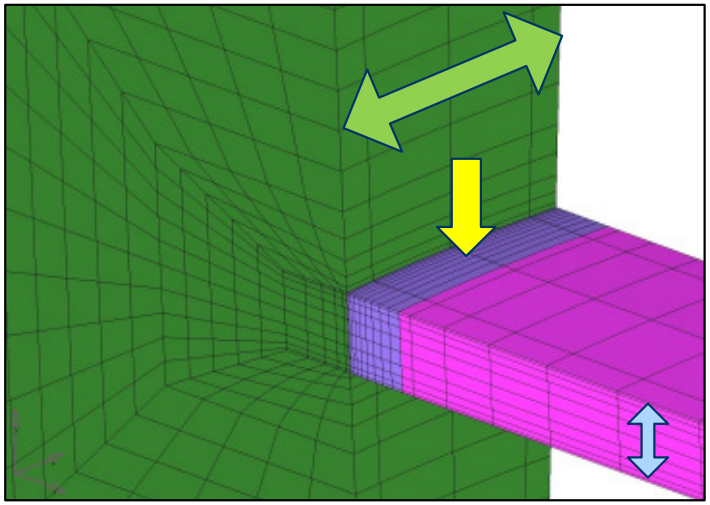


- **How this model would look like in 3D:**



FEM model, axisymmetric





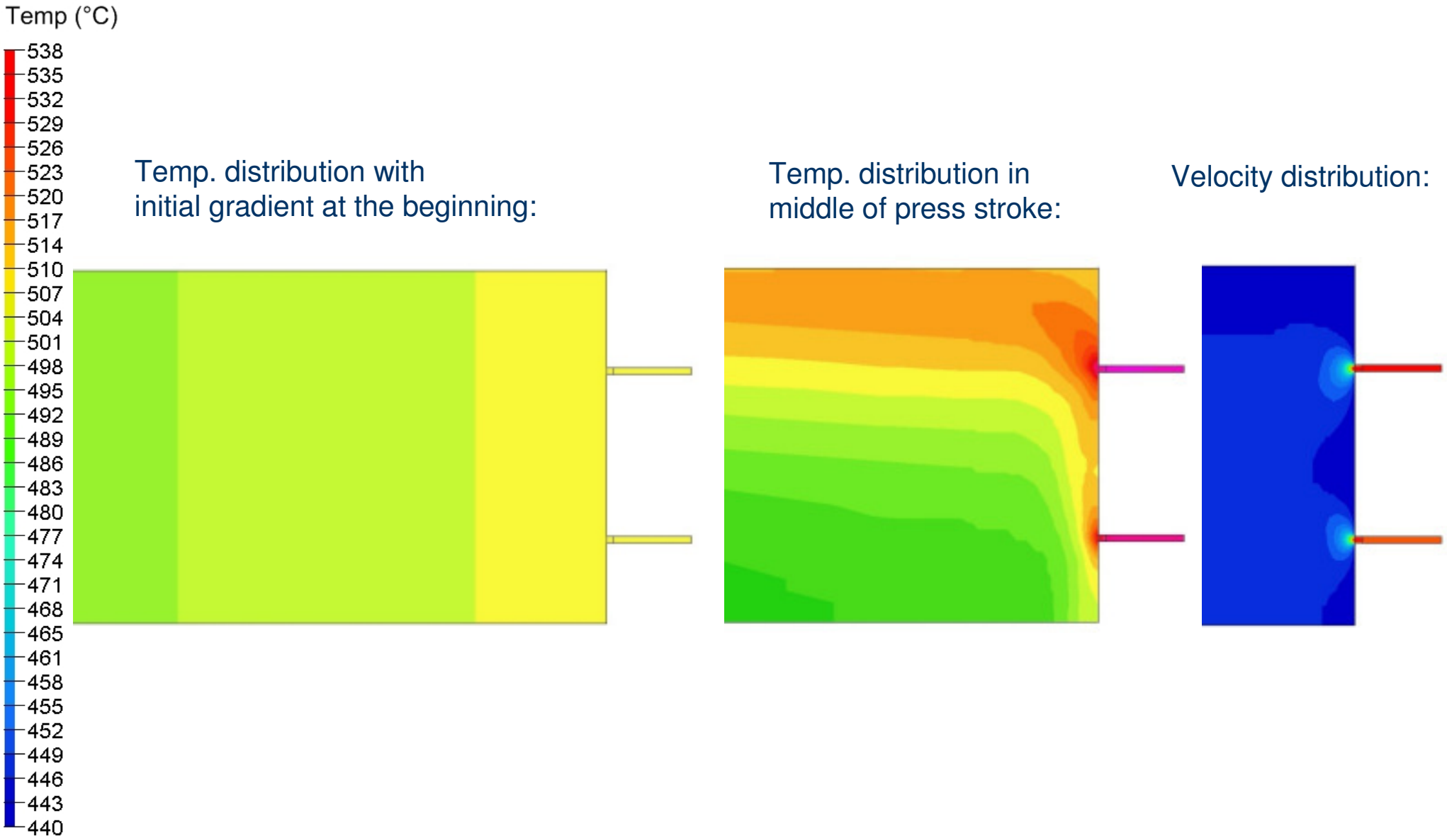
- **BCs**
  - Symmetry boundary condition on both sides of model
  - Full sticking friction inside the container and on bearings
  - Heat fluxes representing thermal interaction with die, container and ram all around the model
- **MESH**
  - 2 ½ D model.
  - ~ 15000 elements
  - 10 elements through thickness of the extruded section
  - 4 elements in the angular direction, in a 10° section
- **MATERIAL MODEL**
  - Temperature and strain rate dependent

    (for aluminium 6063 alloy)

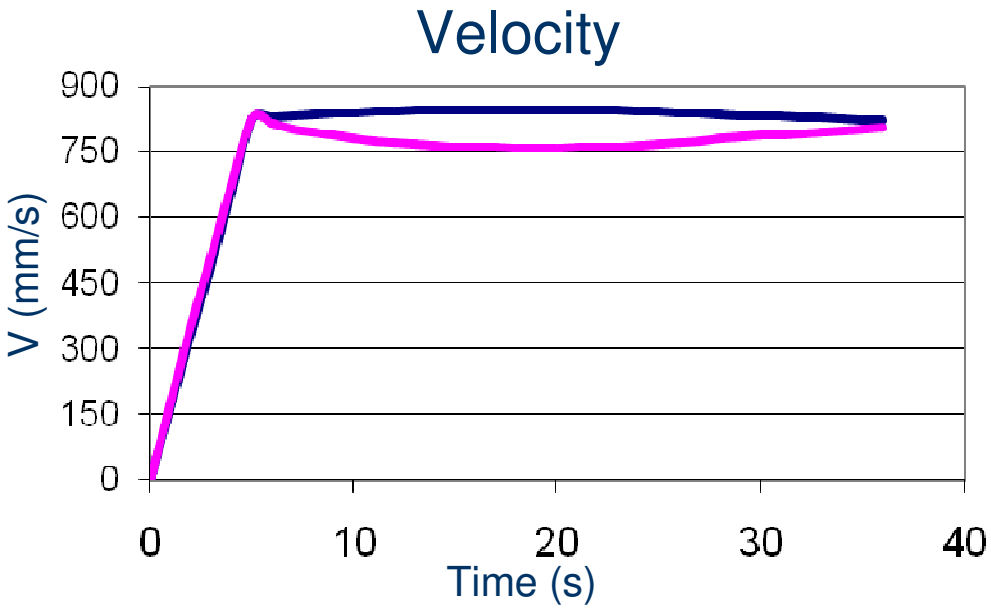
Design of experiments

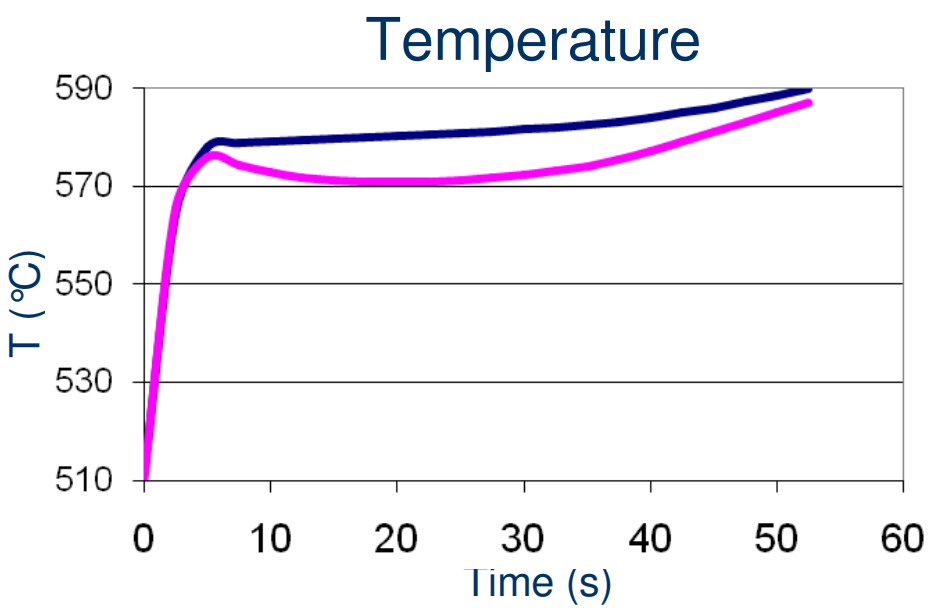
- Analysis of variance (ANOVA)
- 3 parameters
  - **Ram speed:** 10 , 20 , 30 (mm/s)
  - **Axial billet Taper:** 10 , 40 , 70 (°C)
  - **Front billet Temperature:** 450, 480, 510 (°C)
- 27 combinations.
- Two responses:
  - Standard deviation of V_i / V_o
  - Standard deviation of T_i / T_o

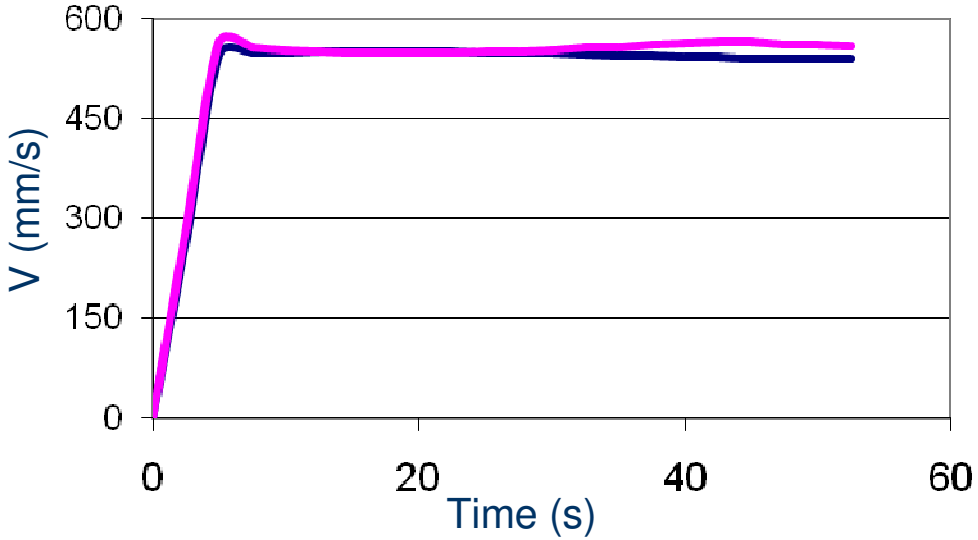
Results, examples

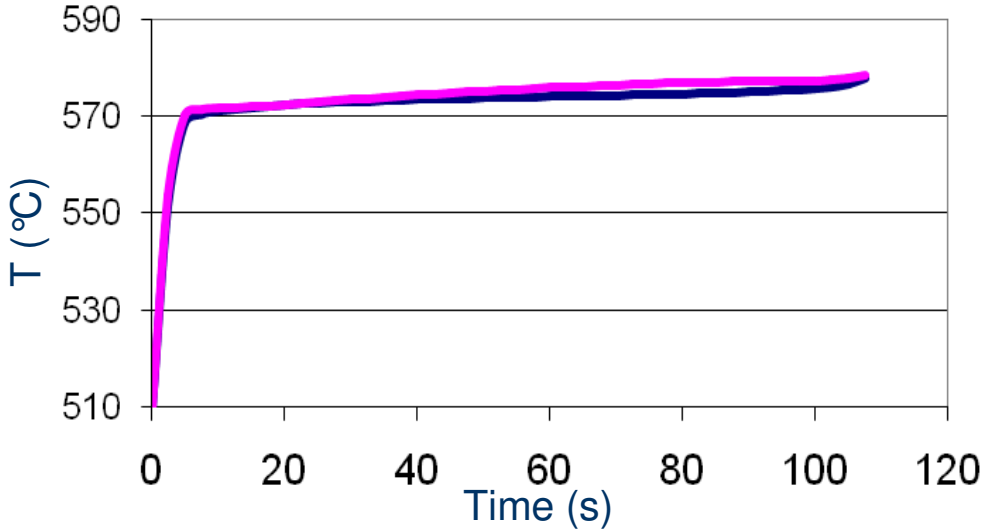


Results, examples

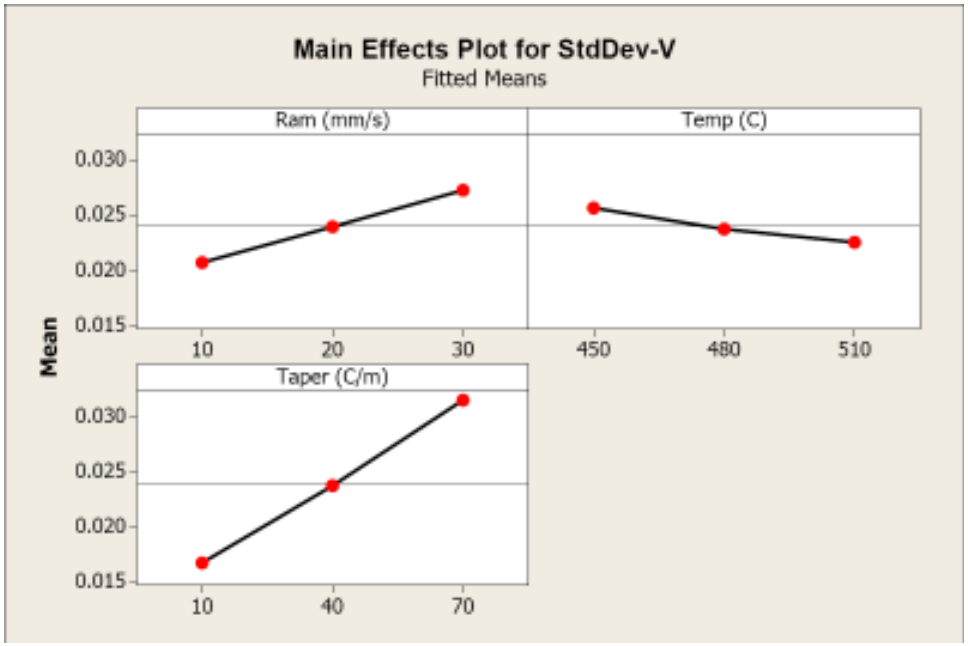


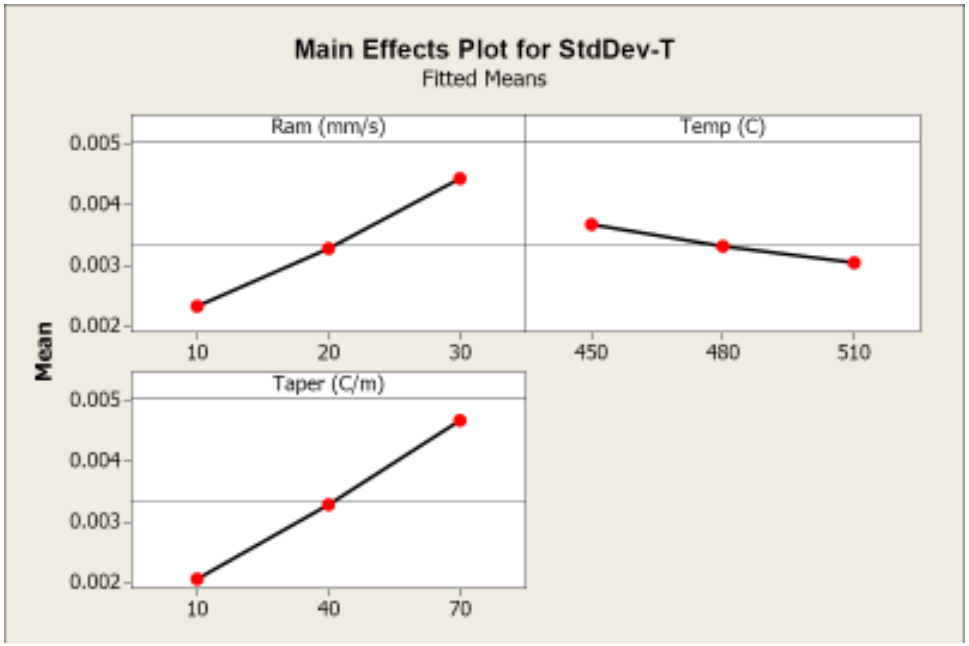






GLM results





- σ (V) = 0.0325 + 0.000327 Ram (mm/s) - 0.000052 Temp (℃) + 0.000246 Taper (℃)
  - R-Sq = 97.7%

- σ (T) = 0.00453 + 0.000105 Ram (mm/s) - 0.000010 Temp (℃) + 0.000043 Taper (℃)
  - R-Sq = 94.3%

Conclusion

- High values of ram speed and taper give high values of the standard deviation.
- Increasing the front billet temperature gives a reduction of the standard deviation.
- It is not desirable to reduce the ram speed much, since this means loss of productivity.
- Therefore a **high front billet temperature** and **low taper** are recommended in practice in order to achieve the best possible **flow balance** and stability of shape.

Further applications

- Running the model with multiple press cycles.
- Including die and container with heat exchange evolution.
- Running full 3D models to study temperature, and effect of container heating and cooling.


Thank you for your time ☺
Sognefjord, Norway

References

- **Sigurd Støren, Per Thomas Moe**, Ch. 8 of Handbook of Aluminum: Vol. 1: Physical Metallurgy and Processes
- **Douglas C. Montgomery**, Design and Analysis of experiments
- HyperXtrude user's manual, Altair HyperWorks™.
- MiniTAB™ user's manual.