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Development of an Advanced Rheological Tool (ART) for polymer melt characterisation



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Introduction

In the Advanced Rheological Tool, both experiments and numerical techniques are combined to characterise polymer melt flows in prototype industrial flow geometries.

Objective:

- Numerical simulations of visco-elastic flows in characteristic geometries under (industrial) processing conditions.

Problems:

- Reach convergence at high elasticity rates.
- Capture realistically the rheological behaviour.

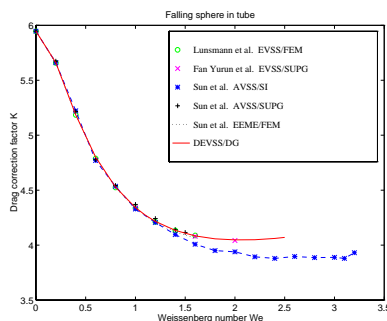
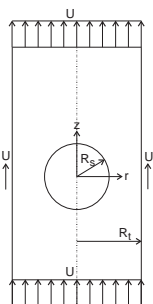
Numerical method

DEVSS/DG method [1]:

- Coupled visco-elastic method.
- Discrete Elastic Viscous Stress Splitting:
 - Split extra stress variable in elastic and viscous part: $\tau = \tau^e + \tau^v$.
 - Introduce a stabilisation term:
$$\bar{D} - \frac{1}{2}\{(\nabla\vec{u})^c + (\nabla\vec{u})\} = \mathbf{0}.$$
- Discontinuous Galerkin:
 - Discontinuously discretise τ^e in implicit/explicit scheme \Rightarrow solve τ^e at element level.

High Weissenberg Number Problem

- Benchmark problem: falling sphere in a tube.
Ratio $\chi = \frac{R_s}{R_t} = 2$.



Conclusion:

- Improve efficiency, robustness, stability and accuracy of the numerical technique.

Prototype Industrial Flow Geometries

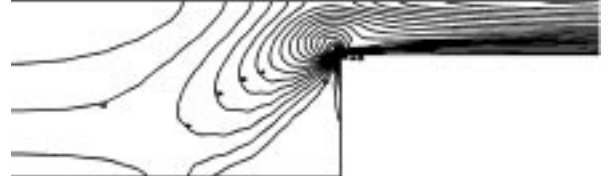
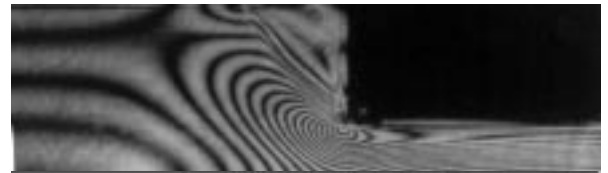
- Steady flow past symmetric confined cylinder [2]:
 $We = 12.1$, Giesekus model ($\alpha = 0.29$)



Upper half: Calculated isochromatic fringe patterns.

Lower half: Experimental isochromatic fringe patterns.

- Steady four to one contraction flow [3]:
 $We = 12.4$, exp. PTT model ($\varepsilon = 0.10$, $\xi = 0.09$)



Upper half: Experimental isochromatic fringe patterns.

Lower half: Calculated isochromatic fringe patterns.

Conclusions:

- Qualitatively experiments and numerical simulations agree.
- Quantitatively the constitutive models need improvement.

Future research

- 3D visco-elastic flows, both experiments and numerical simulations.
- Transient flows, both 2D and 3D.
- Investigate different solvers for the numerical technique.
- Implement new, more realistic constitutive models.

References:

- [1] F.P.T. Baaijens, S.H.A. Selen, H.P.W. Baaijens, G.W.M. Peters, and H.E.H. Meijer. Viscoelastic flow past a confined cylinder of a LDPE melt. *J. Non-Newtonian Fluid Mech.*, pages 173–203, 1997.
- [2] J. Schoonen and M. Winter. Experimental results, 1997. Eindhoven University of Technology.
- [3] M. Winter. Experimental and numerical analysis of the visco-elastic behaviour of a LDPE melt flowing into a four to one contraction. Master's thesis, Eindhoven University of Technology, MT97.016, 1997.