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 realisticly the rheological behaviour.

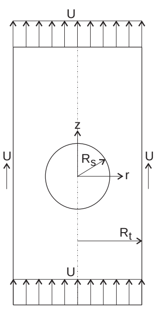
Numerical method

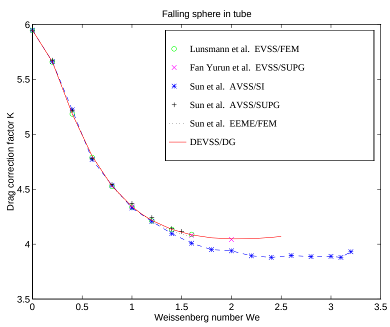
DEVSS/DG method [1]:

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

High Weissenberg Number Problem

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





Conclusion:

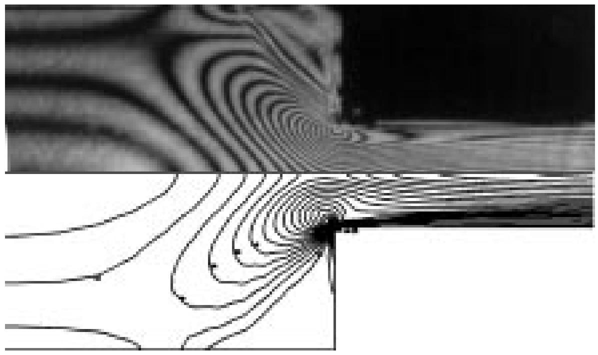
- Improve efficiency, robustness, stability and accuracy of the numerical technique.

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.