SUMMARY

- The flow of a blood analogue solution past microfluidic hyperbolic contractions followed by abrupt expansions was studied.
- The shape of the constriction was chosen in order to provide a nearly constant acceleration of the fluid at the centreline and generate an extensional flow field [1].
- The flow of the blood analogue solution exhibits a complex behaviour distinct of that observed with a reference Newtonian fluid (DI-water).

FLUID CHARACTERISATION

- Fluid used in the experiments: xanthan gum 500 ppm (w/w) aqueous solution;
- Xanthan gum solution rheologically characterised using a shear rheometer (Anton Paar, Physica MCR-301);
- Steady shear measurements

<table>
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<tr>
<th>Maximum measurable torque</th>
<th>Newtonian ( \tau_0 )</th>
<th>Hamiled ( \tau_0 )</th>
<th>PTT mold</th>
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- Experimental data fitted using a PTT model with a Newtonian solvent contribution.

EXPERIMENTAL SET-UP

- Micro-channels fabricated in polydimethylsiloxane (PDMS) using standard soft lithography techniques.
- Visualisations of the flow patterns performed using streak line photography.
- Flow patterns investigated in different geometries with a hyperbolic contraction followed by an abrupt expansion

SUMMARY

- For all micro-geometries studied:
  - For low \( Re \) there is no flow separation;
  - Lip vortices appear downstream of the expansion and grow as the Reynolds number increases.
  - The critical \( Re \) for the onset of downstream vortices depends on \( \varepsilon_n \).

RESULTS

Newtonian Fluid Flow Patterns

- For low \( Re \) there is no flow separation;
- Lip vortices appear downstream of the expansion and grow as the Reynolds number increases.
- The critical \( Re \) for the onset of downstream vortices depends on \( \varepsilon_n \).

Xanthan Gum Flow Patterns

- Symmetric vortices appear upstream of the hyperbolic contraction;
- Increasing the flow rate (or \( De \)) leads to:
  - an initial growth of the upstream vortices (elastic effect);
  - followed by the onset and growth of downstream vortices (inertial effect);
- Eventually the flow becomes unstable with the upstream vortices varying in size asymmetrically.

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<th>( \varepsilon_n ) = 1.0</th>
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<th>( \varepsilon_n ) = 3.0</th>
<th>( \varepsilon_n ) = 3.7</th>
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- \( Q = 1 \text{ ml}^{-1} \cdot \text{h}^{-1} \), \( Re = 3.08 \), \( De = 33.0 \)
- \( Q = 1 \text{ ml}^{-1} \cdot \text{h}^{-1} \), \( Re = 3.47 \), \( De = 55.9 \)
- \( Q = 1 \text{ ml}^{-1} \cdot \text{h}^{-1} \), \( Re = 3.63 \), \( De = 1100 \)

| \( \varepsilon_n \) = 1.0 | \( \varepsilon_n \) = 2.0 | \( \varepsilon_n \) = 3.0 | \( \varepsilon_n \) = 3.7 |

- \( Q = 1 \text{ ml}^{-1} \cdot \text{h}^{-1} \), \( Re = 1.99 \), \( De = 17.1 \)
- \( Q = 13 \text{ ml}^{-1} \cdot \text{h}^{-1} \), \( Re = 46.3 \), \( De = 78.9 \)
- \( Q = 5 \text{ ml}^{-1} \cdot \text{h}^{-1} \), \( Re = 18.1 \), \( De = 98.8 \)
- \( Q = 3 \text{ ml}^{-1} \cdot \text{h}^{-1} \), \( Re = 11.0 \), \( De = 169 \)
- \( Q = 7 \text{ ml}^{-1} \cdot \text{h}^{-1} \), \( Re = 18.4 \), \( De = 249 \)

CONCLUSIONS

- Complex flow behavior of the blood analogue solution flowing through the micro-geometry is observed due to elastic nature of the polymeric solution (not usually observed at macro-scale);
- Increasing the flow rate leads to an increase of the vortices observed upstream of the hyperbolic contraction;
- Inertia leads to a decrease of upstream vortices and to the onset and growth of downstream vortices.
- For the Newtonian fluid flow, inertial effects promote the appearance of vortices downstream of the hyperbolic contraction. No flow separation is observed upstream of the hyperbolic contraction.

REFERENCES