29th Scottish Fluid Mechanics Meeting
20th of May 2016

University of Strathclyde Engineering

Flow behaviour of vitreous humour biofluid during saccadic eye movements

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James Weir Fluids Laboratory

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Transport Phenomena Research Center

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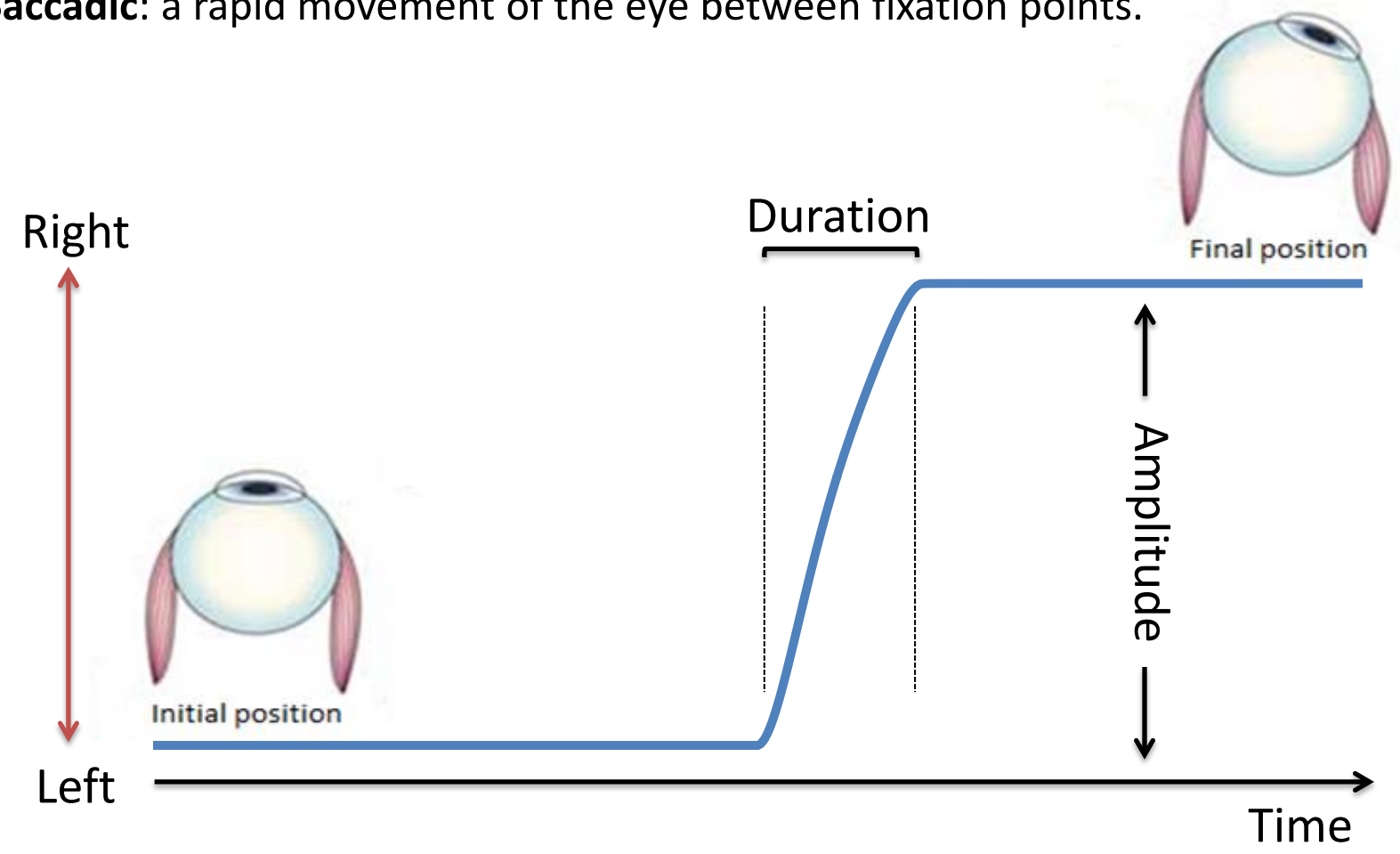
Outline

- Background;
- Motivation;
- Experimental part:
  - Experimental methodology;
  - Experimental results;
- Numerical part:
  - Numerical methodology;
  - Numerical results;
- Conclusions.

Background

Saccadic: a rapid movement of the eye between fixation points.



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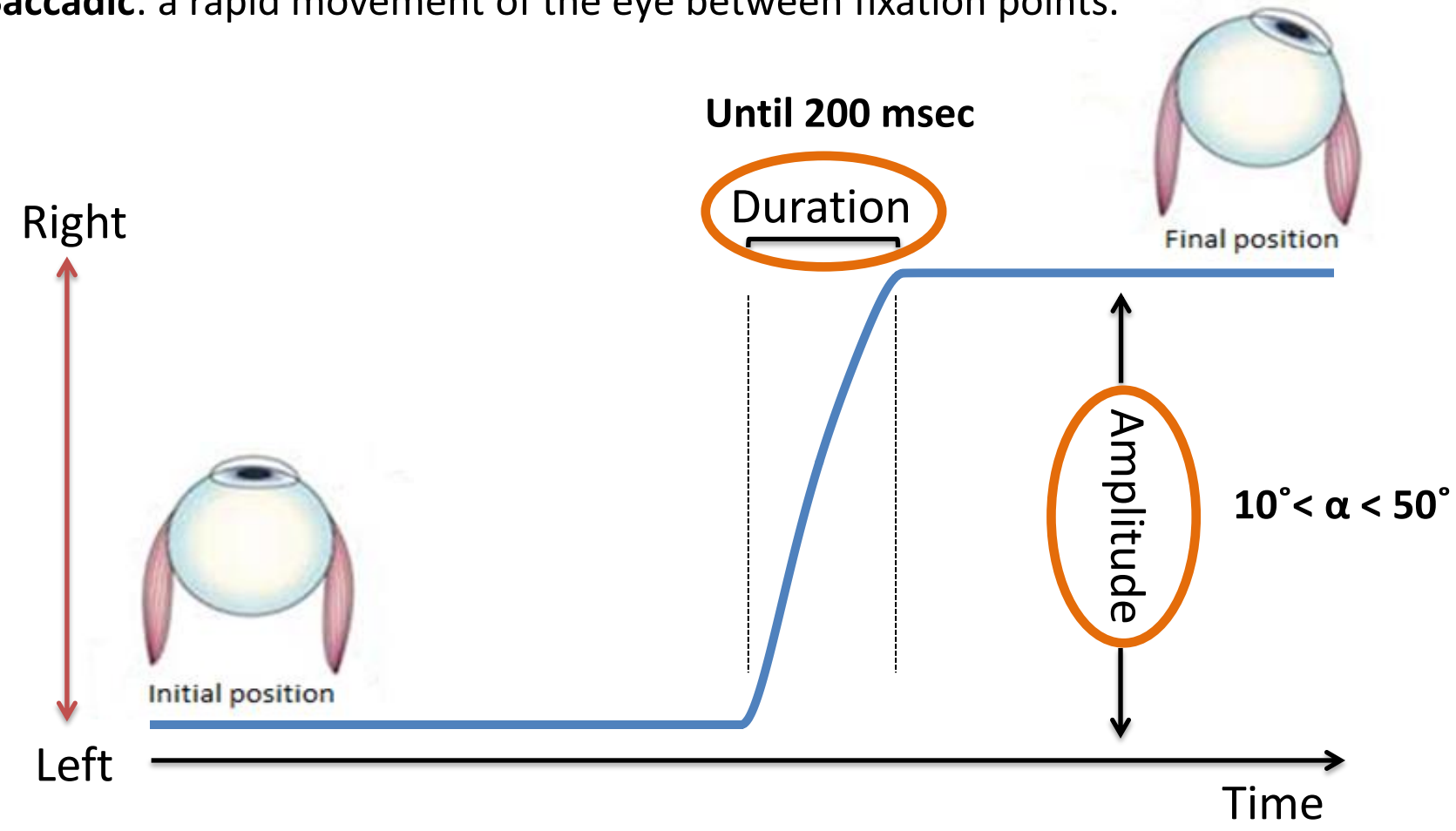

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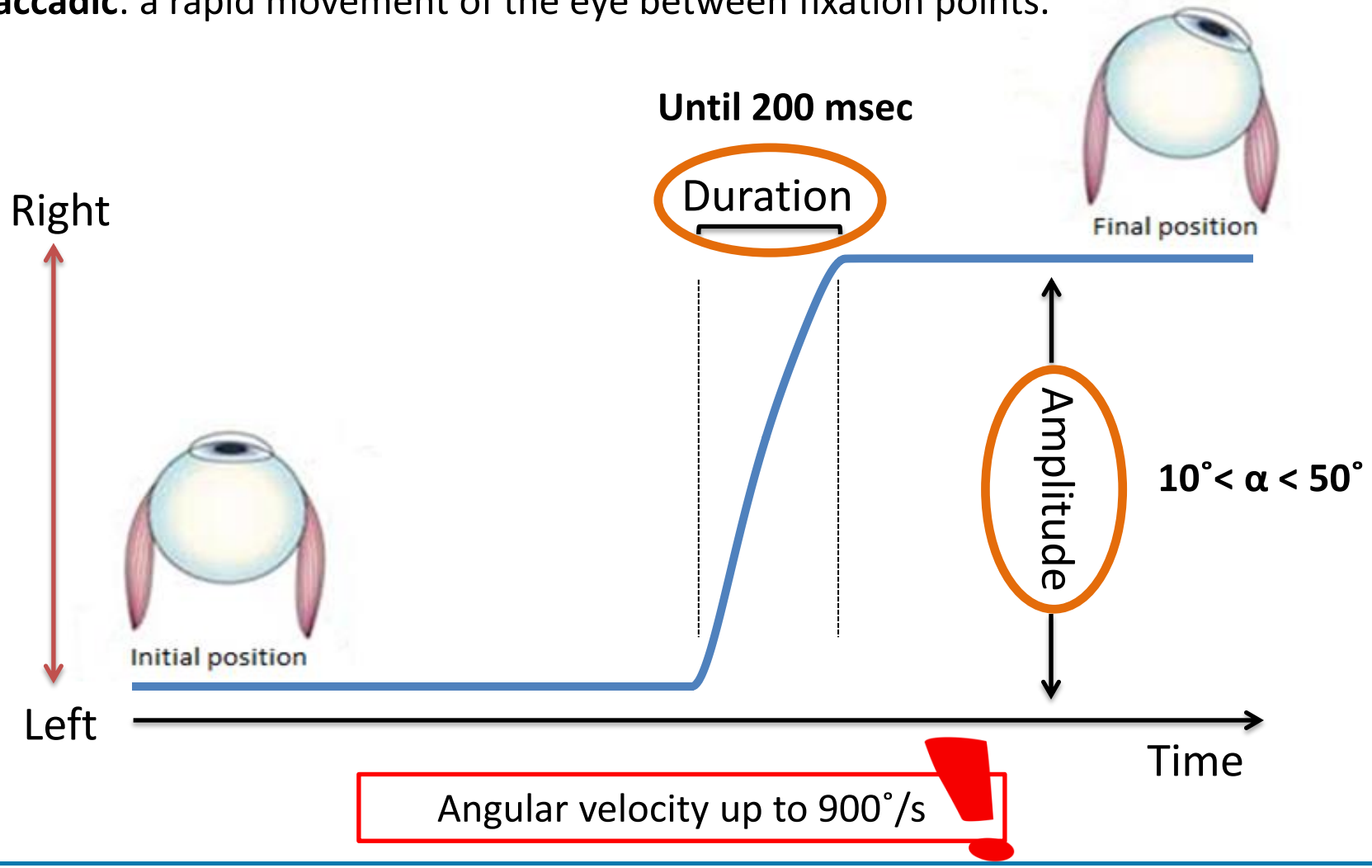

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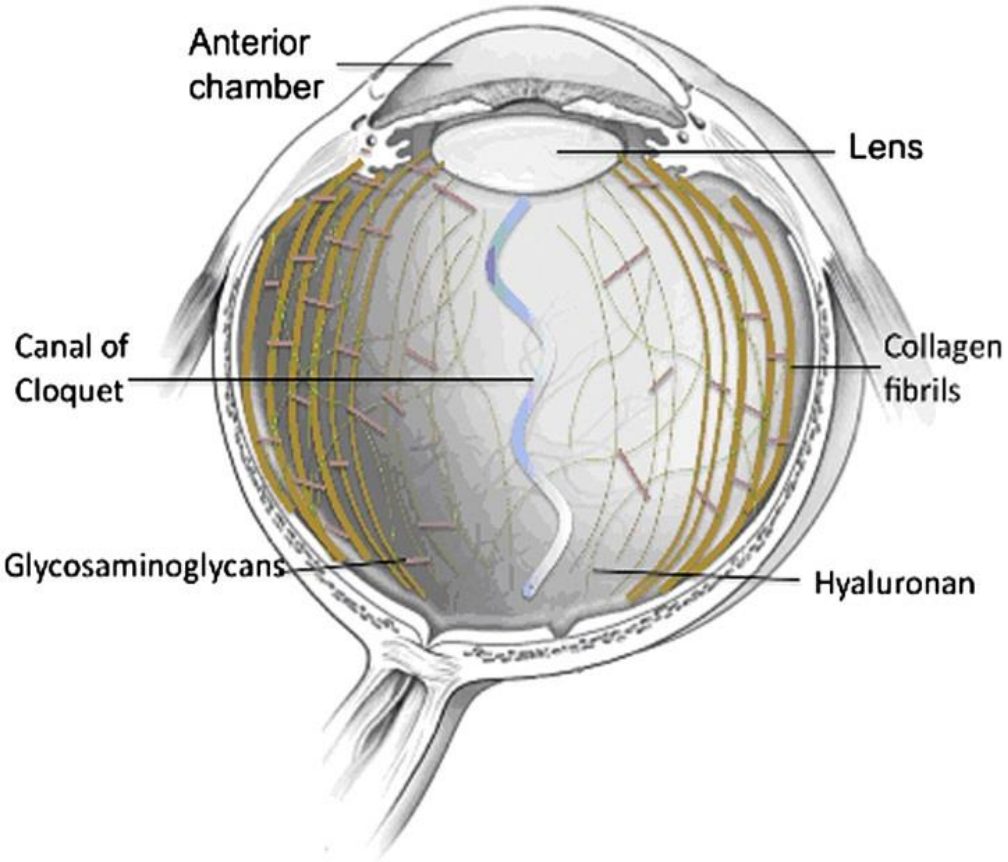

Laude, A., et al., Progress in Retinal and Eye Research, 2010. **29**(6): p. 466-475

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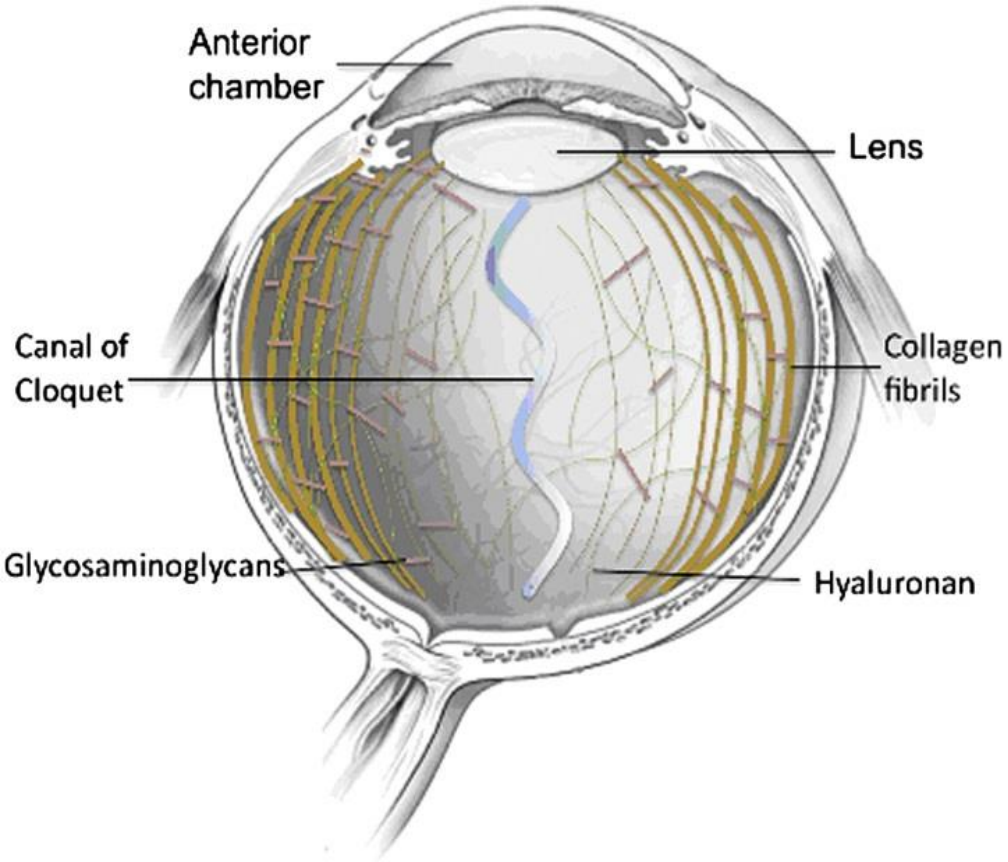

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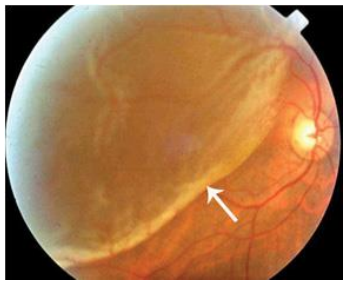
1. Vitreous Humour is only produced during the embryonic stage, and **becomes progressively liquefied** with age.

2. Just a few experimental and numerical studies about the rheology and the flow properties of the biofluid have been reported.

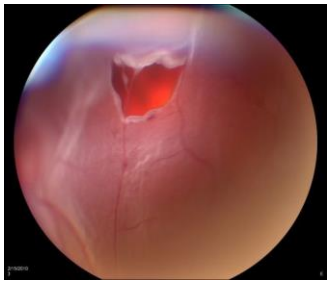
Motivation

Some of the eye diseases are related with changes in VH:

- Posterior vitreous detachment;
- Retinal detachment;
- Retinal tears;
- Floaters.



http://www.retinaeye.com/retinaldetachment.html



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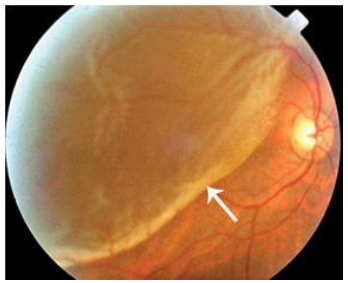

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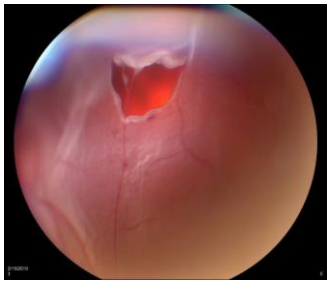

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Silicone oils

Densiron 68

To treat some of the diseases:

- Silicone Oils;
- Densiron 68.

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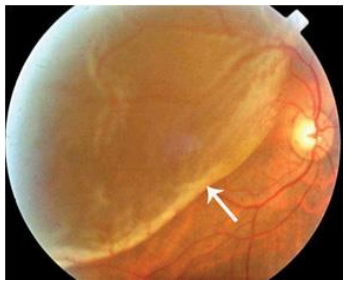

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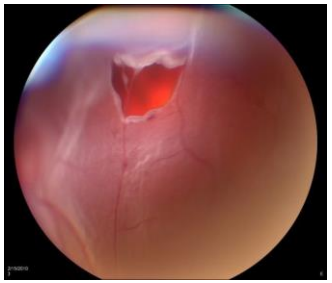

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Better understanding of the VH and pharmaceutical substitutes:

- Rheology;
- Flow dynamics.

Experimental methodology

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Pharmacological fluids samples

Silicone oils

Densiron 68

Experimental methodology

University of Strathclyde Engineering

Pharmacological fluids samples

Silicone oils

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Vitreous Humour samples

Specimen: healthy New Zealand white rabbit;
Age: 18 $\pm$ 3 weeks;
Weight: between 2.8 and 3 kg.

Experimental methodology

University of Strathclyde Engineering

Pharmacological fluids samples

Silicone oils

Densiron 68

http://sites.udel.edu/advani/facilities/

Temperature: 37˚

Vitreous Humour samples

Specimen: healthy New Zealand white rabbit;
Age: 18 ± 3 weeks;
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Pharmacological fluids

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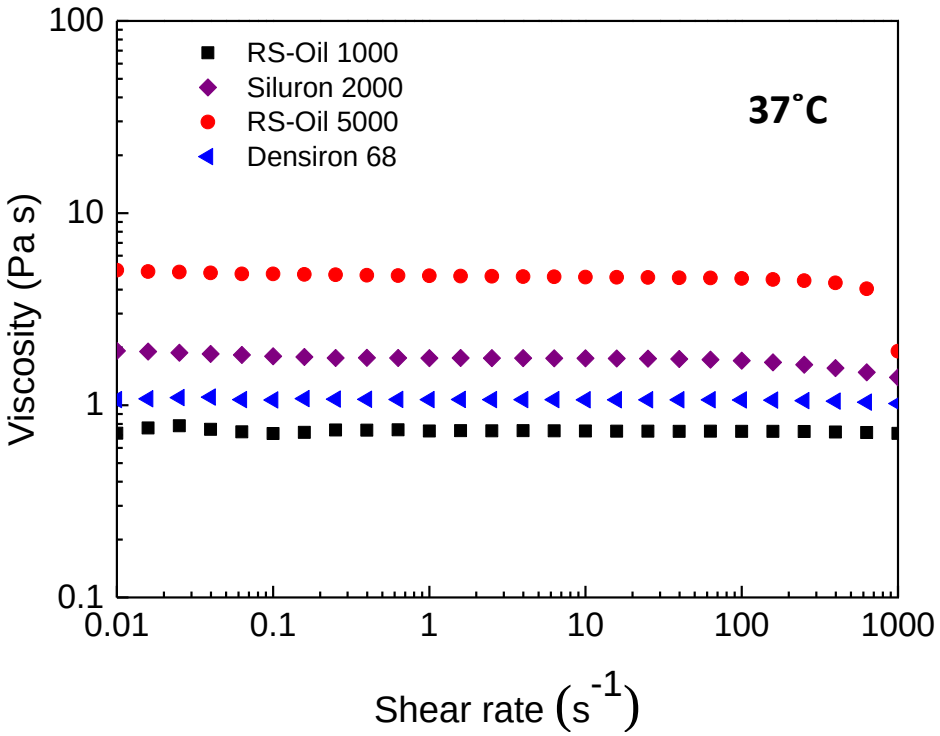

All the fluids behave as Newtonian fluids under steady shear, with constant viscosity.

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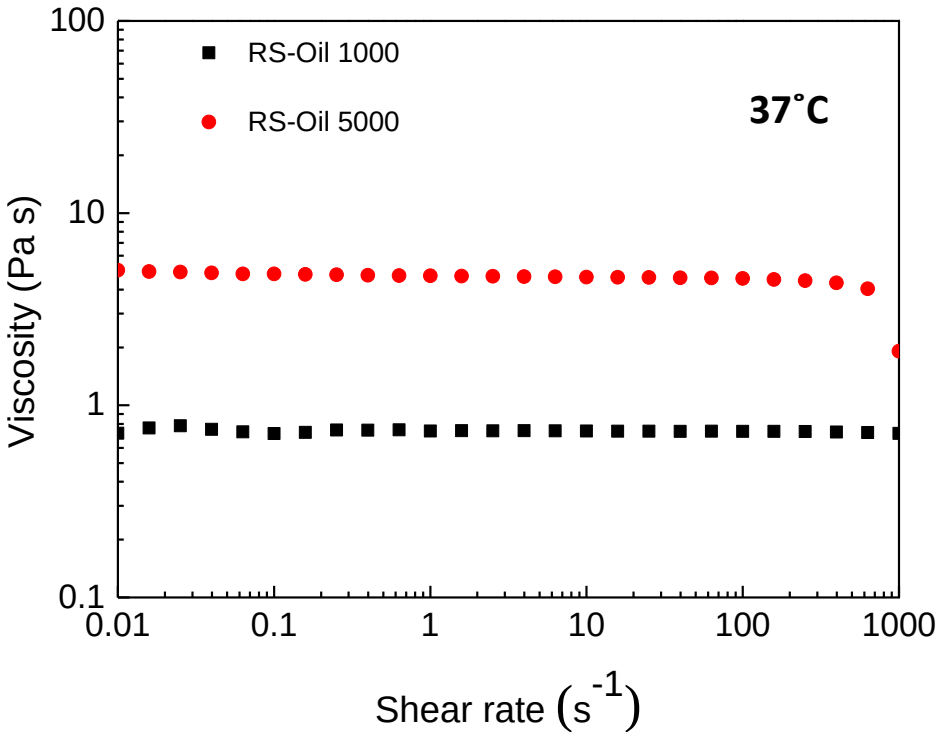

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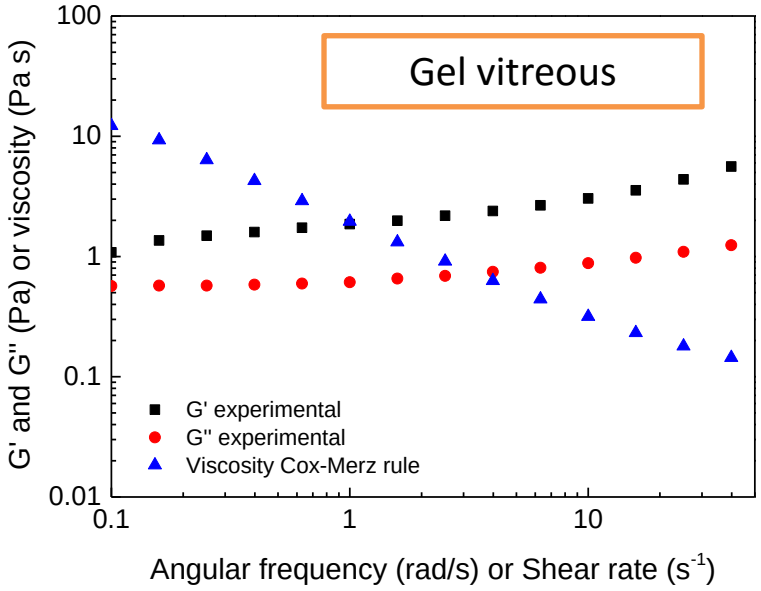
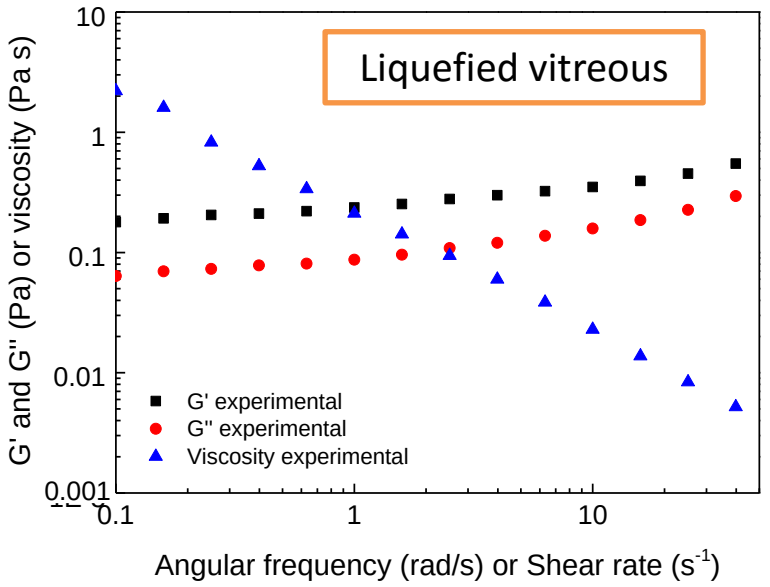
Experimental results

Vitreous humour





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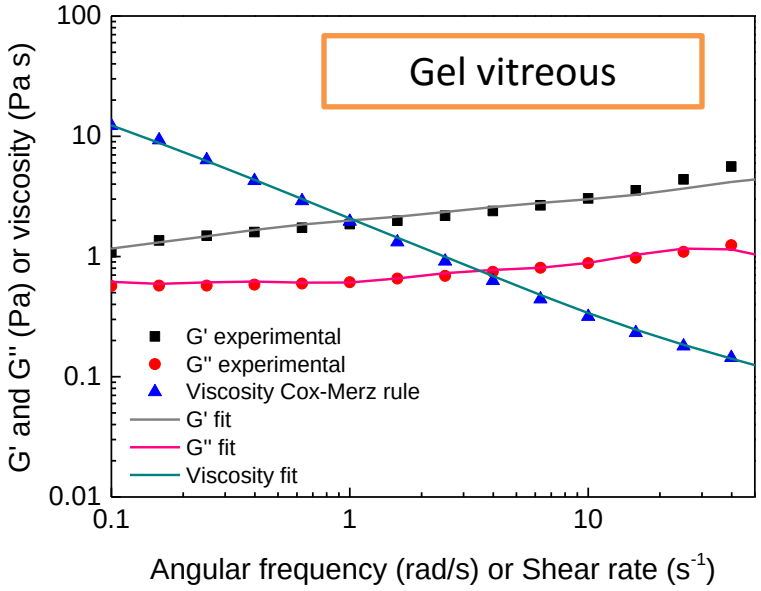
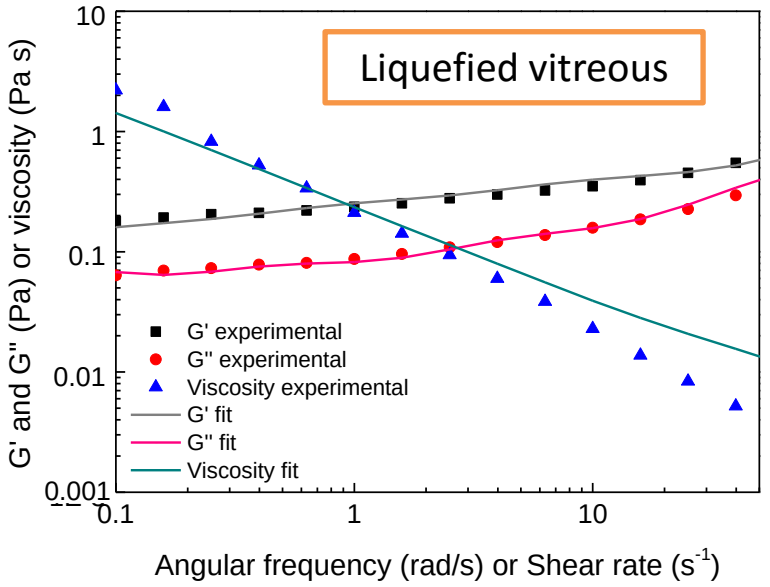




Giesekus model

Viscosity

$$\eta = \eta_s + \frac{\eta_p (1-f)^2}{1+(1-2\alpha) f}$$

Elastic modulus

$$G' = \frac{\eta_p \lambda \omega^2}{1+(\lambda\omega)^2}$$

Viscous modulus

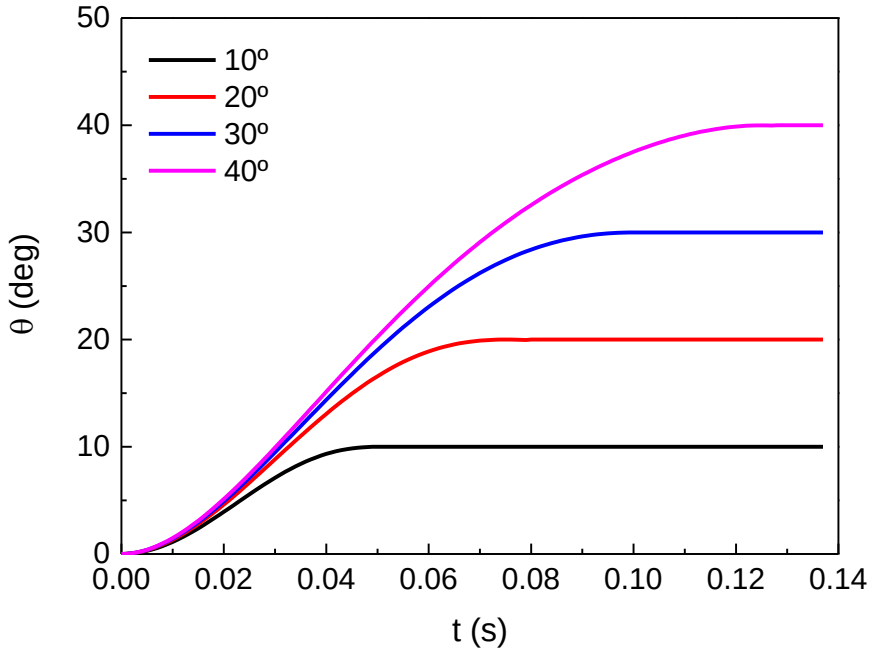
$$G'' = \eta_s \omega \frac{\eta_p \omega}{1+(\lambda\omega)^2}$$

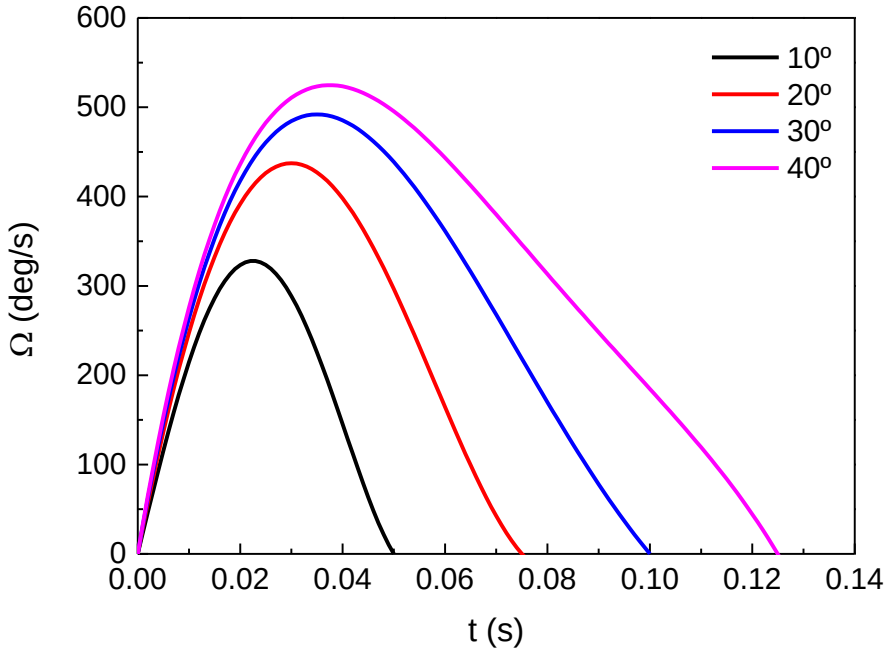
4 mode Giesekus model

Numerical methodology

Saccadic movements

$$\theta(t) = c_0 + c_1 t + c_2 t^2 + c_3 t^3 + c_4 t^4 + c_5 t^5 \quad ^{1,2}$$





[1] David *et al*. [Physics in Medicine and Biology, 1998, 43, 1385-99]
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Numerical methodology

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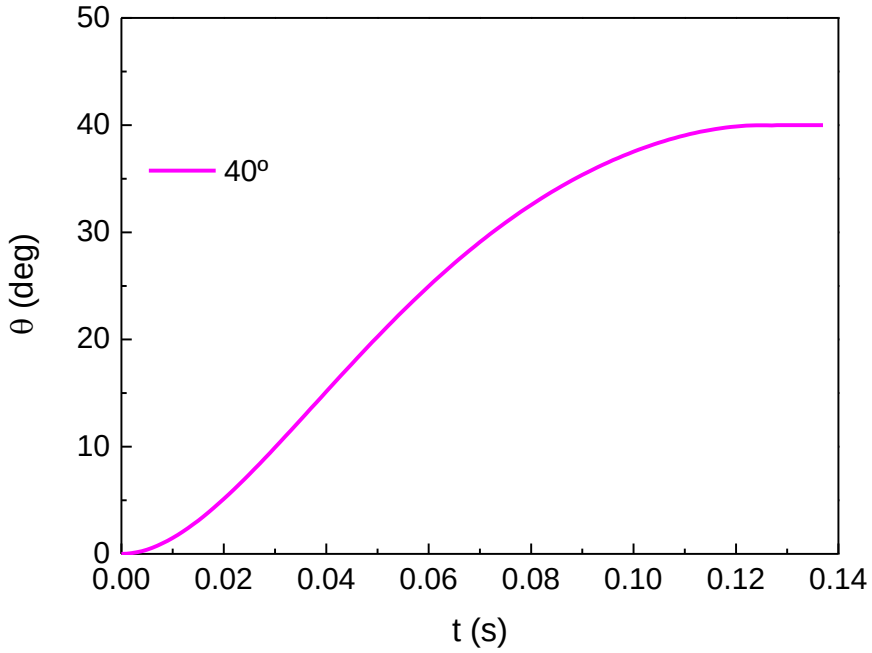
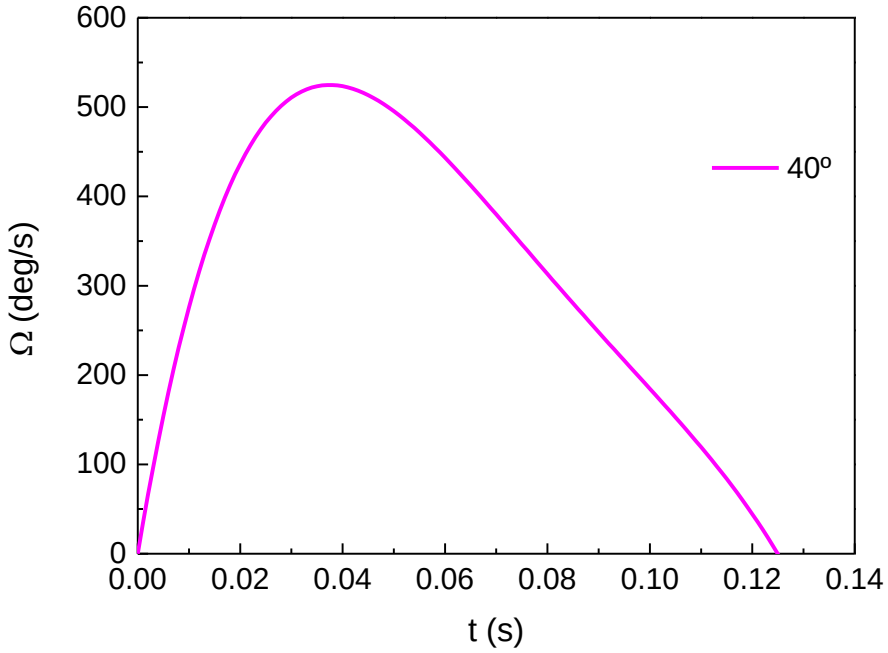
$$\theta(t) = c_0 + c_1 t + c_2 t^2 + c_3 t^3 + c_4 t^4 + c_5 t^5$$ [1,2]





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Numerical methodology

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Eye Shape

Numerical methodology

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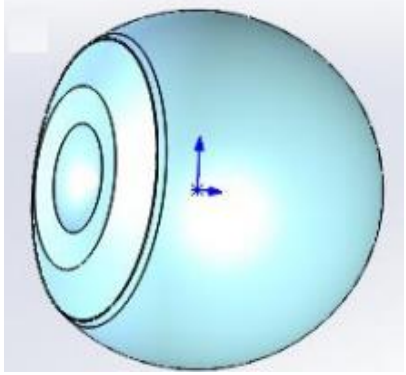
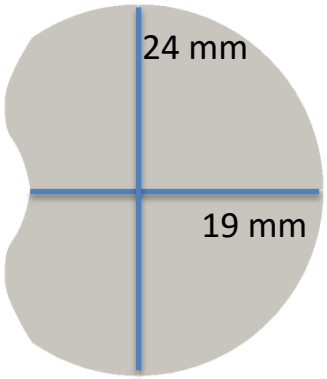
Eye Shape

Solidworks model



Main dimensions



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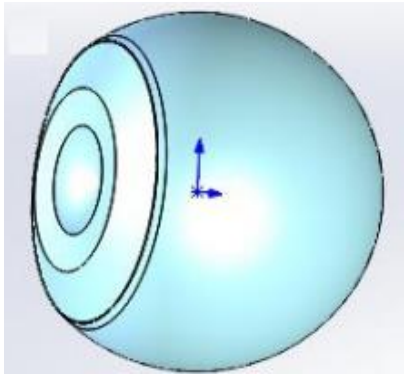

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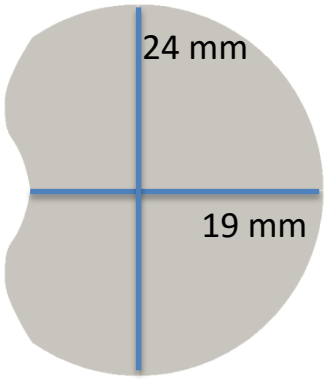
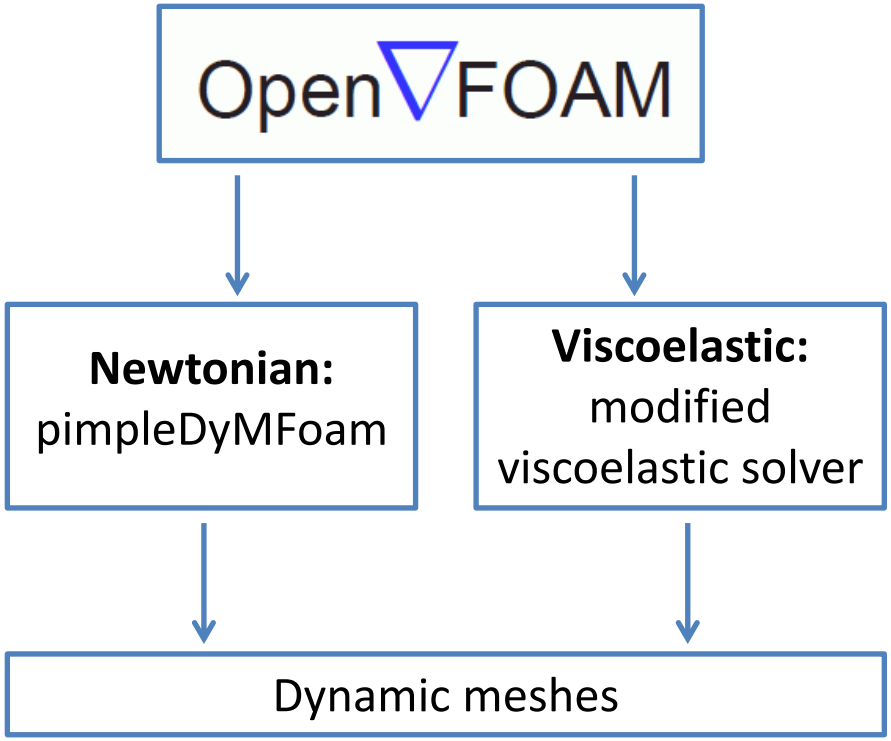
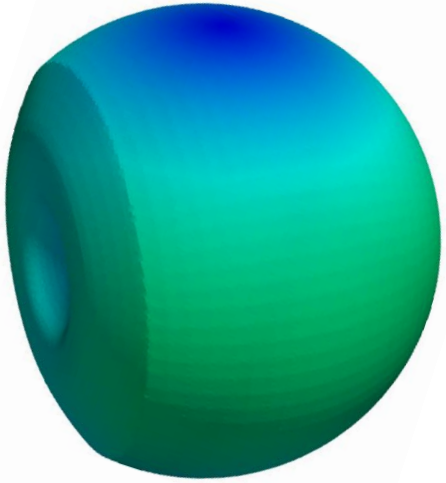


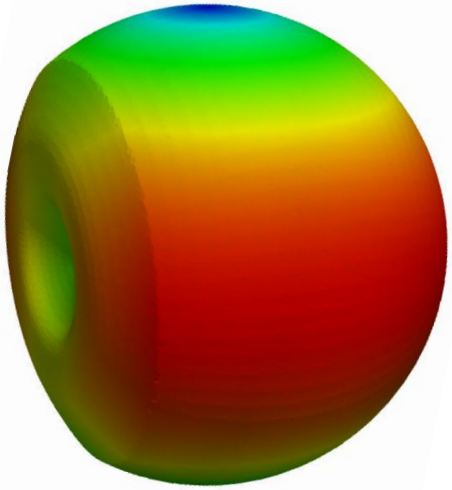


Numerical results

Applied velocity

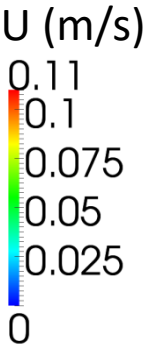


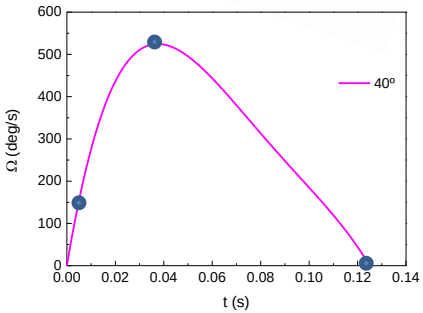
T= 0.05D = 0.0062 s



T= t_p = 0.0375 s

T= D = 0.1250 s





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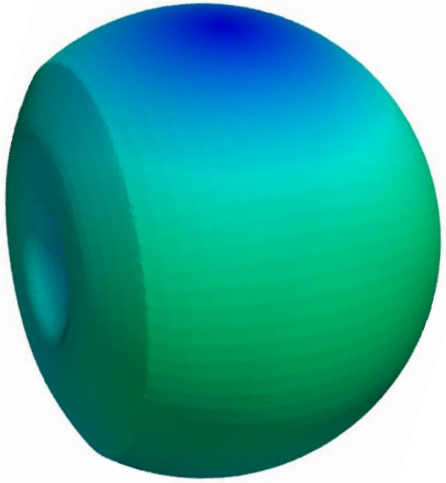

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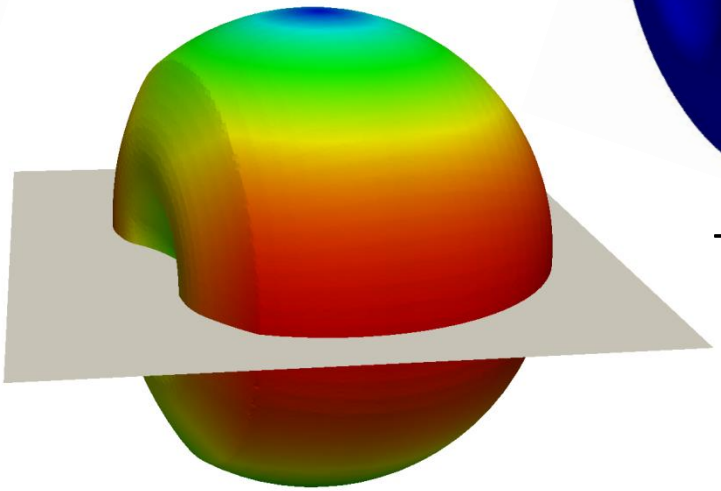

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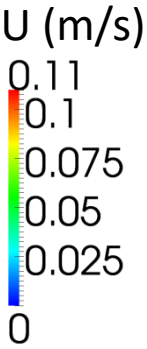

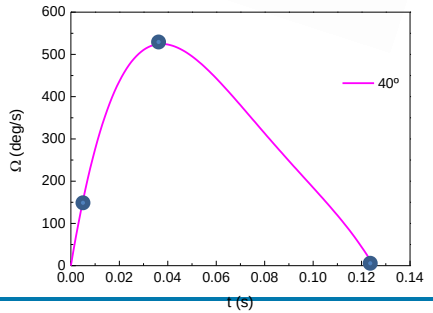

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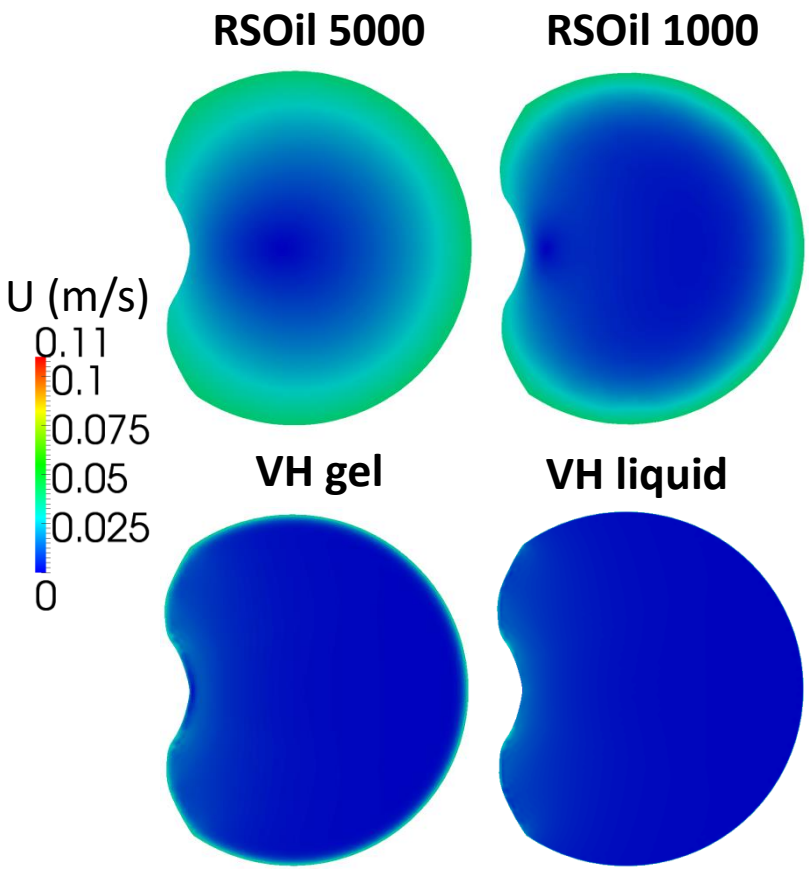
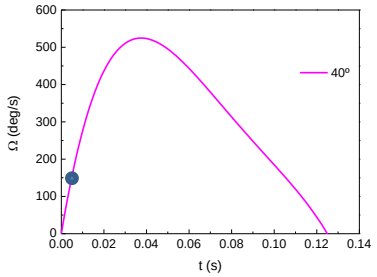
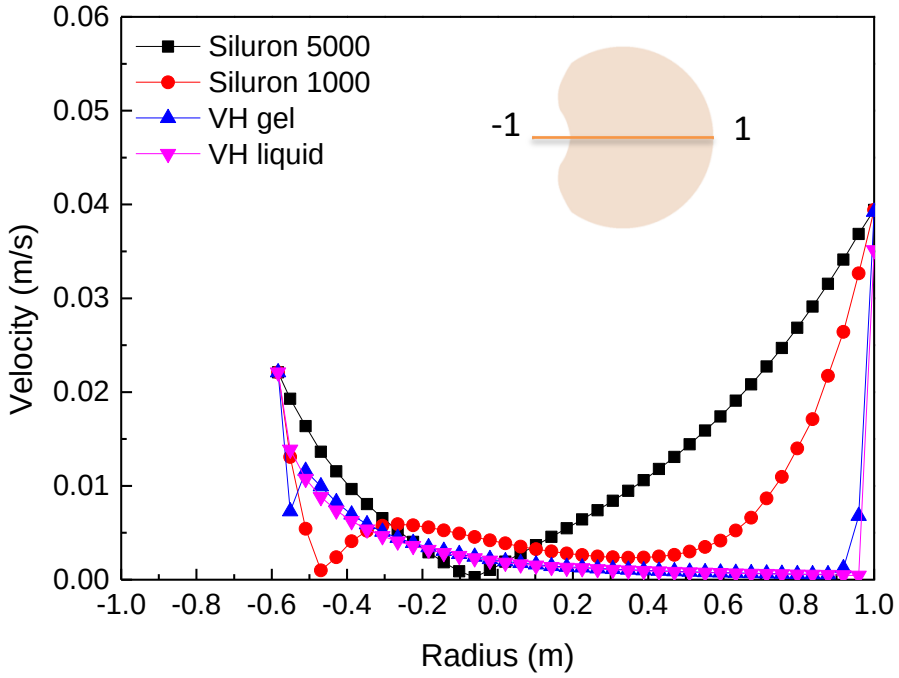
40˚: T=0.05D







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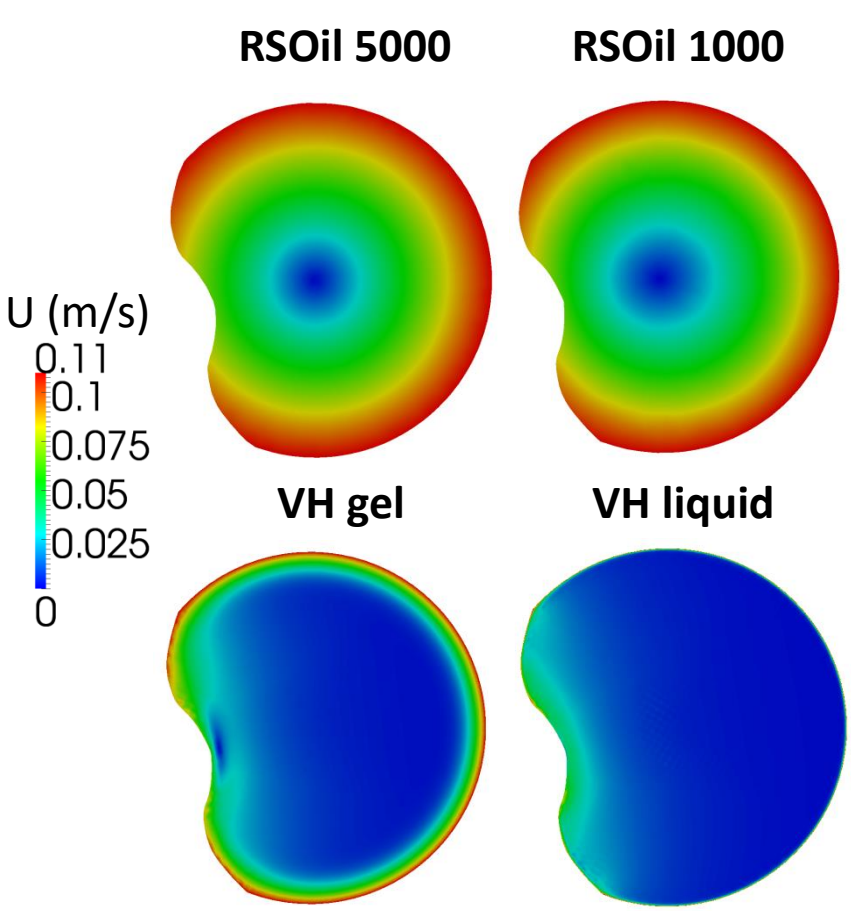

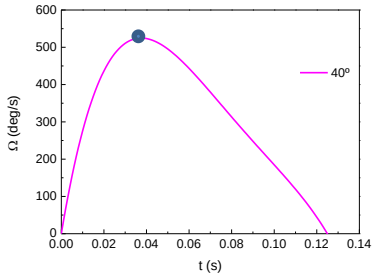

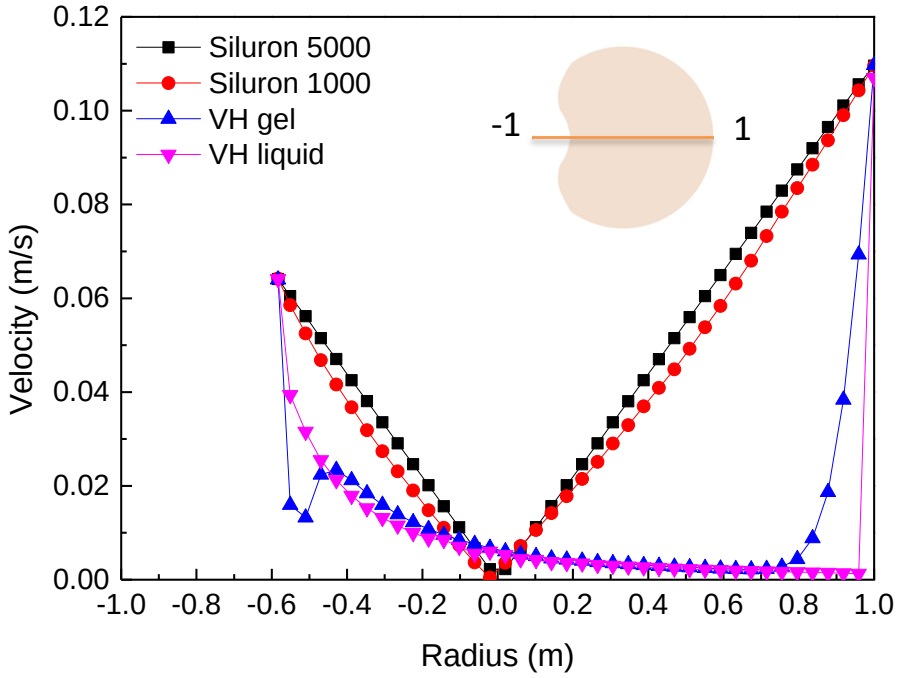

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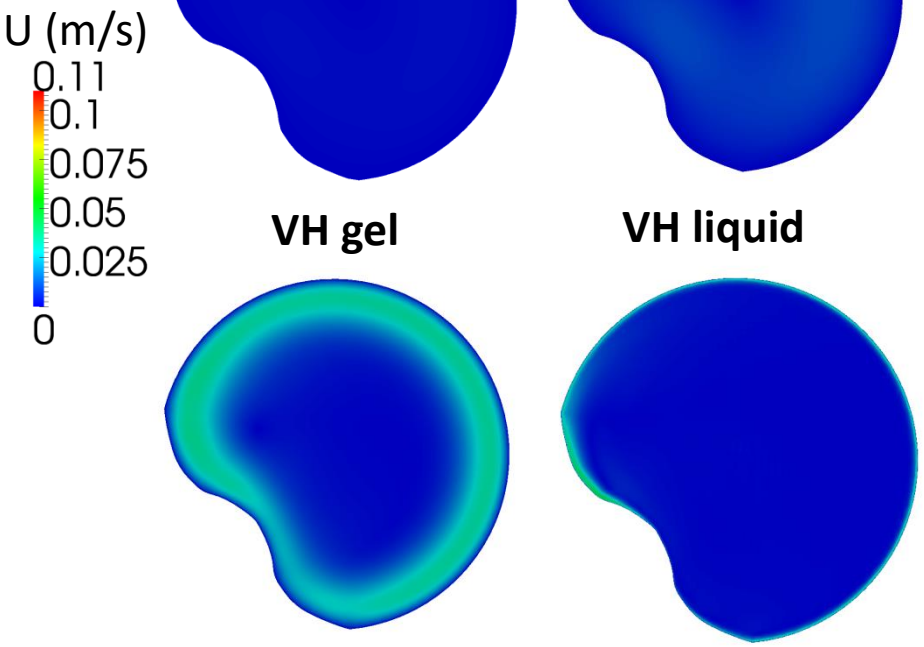

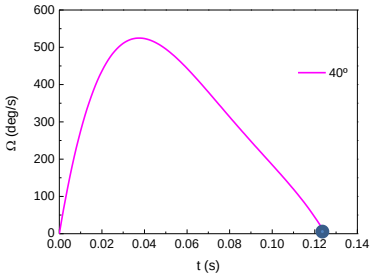

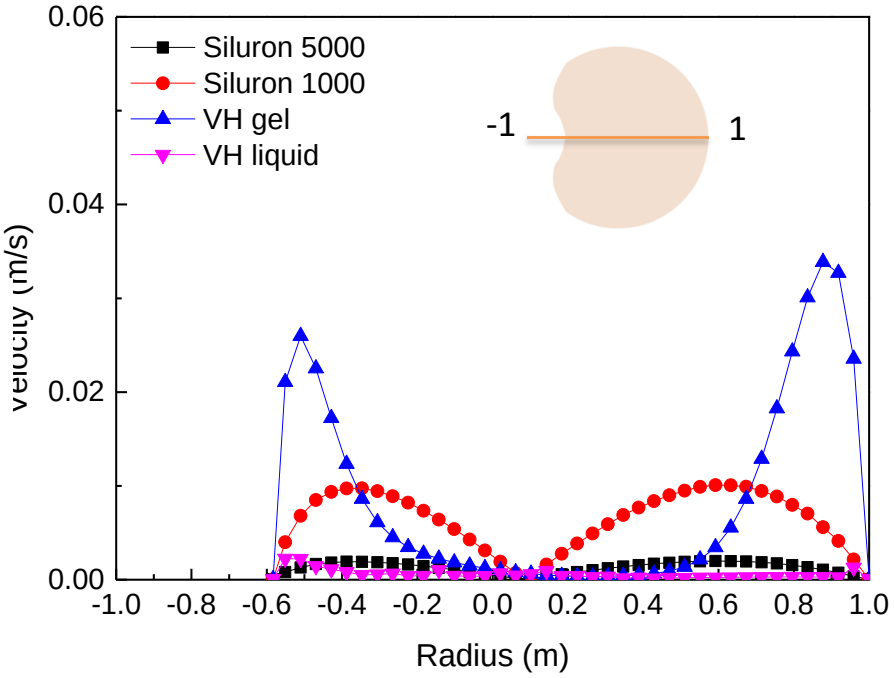

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- The pharmacological fluids used in eye surgery exhibit a constant viscosity;
- Vitreous humour, both gel and the liquefied phase behave as viscoelastic fluids;
- The flow dynamics of the biofluid in the eye cavity is strongly related with the viscosity of the fluid;
- Vitreous humour flow dynamic plays an important role to keep a stable biological structure of the major components of the fluid.

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Thanks for your attention

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