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A simple theory helps identifying which different rheological properties can result in the same IDDSI syringe flow test performance

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Abstract

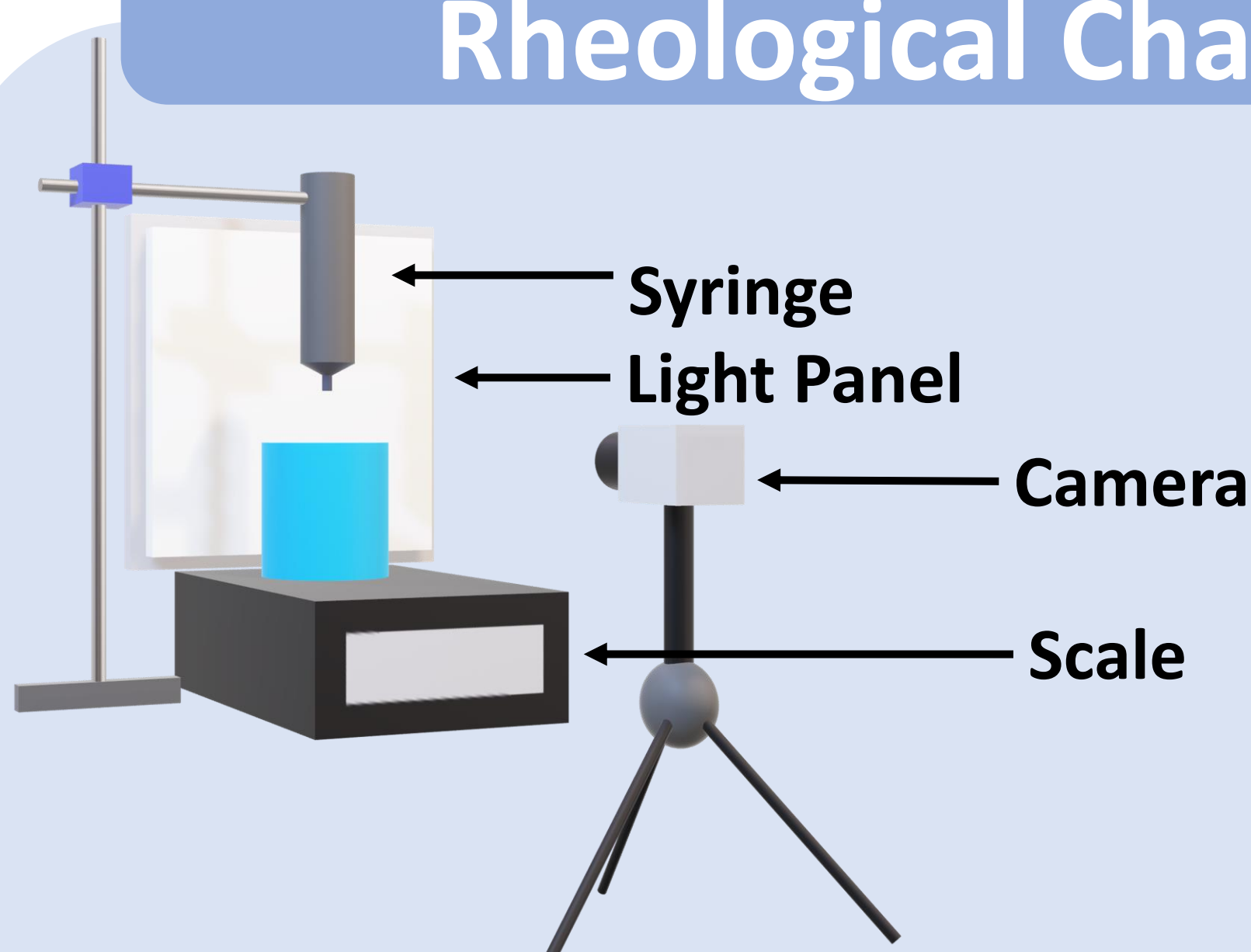
IDDSI tests¹ are **easy to use**, **inexpensive** and widely available thanks to the use of **syringes**, forks and spoons.

The aim of this study is to propose a model to predict the **transient flow** during the **IDDSI syringe flow test**. Unlike previous approaches, the simple theory developed in this study does not require the use of any simulation software³ and predicts IDDSI flow test considering the **complete flow curve** of the fluid, rather than considering arbitrarily the viscosity at a single shear rate⁴.

Material

This study considers : distilled water and **glycerol (N - Newtonian)** ; Vittel water thickened with **xanthan gum (XG - Shear thinning)** ; Vittel water thickened with a starch-based commercial thickener, **Resource Thicken Up (TU - Shear thinning)**.

IDDSI Flow Test and Rheological Characterisation



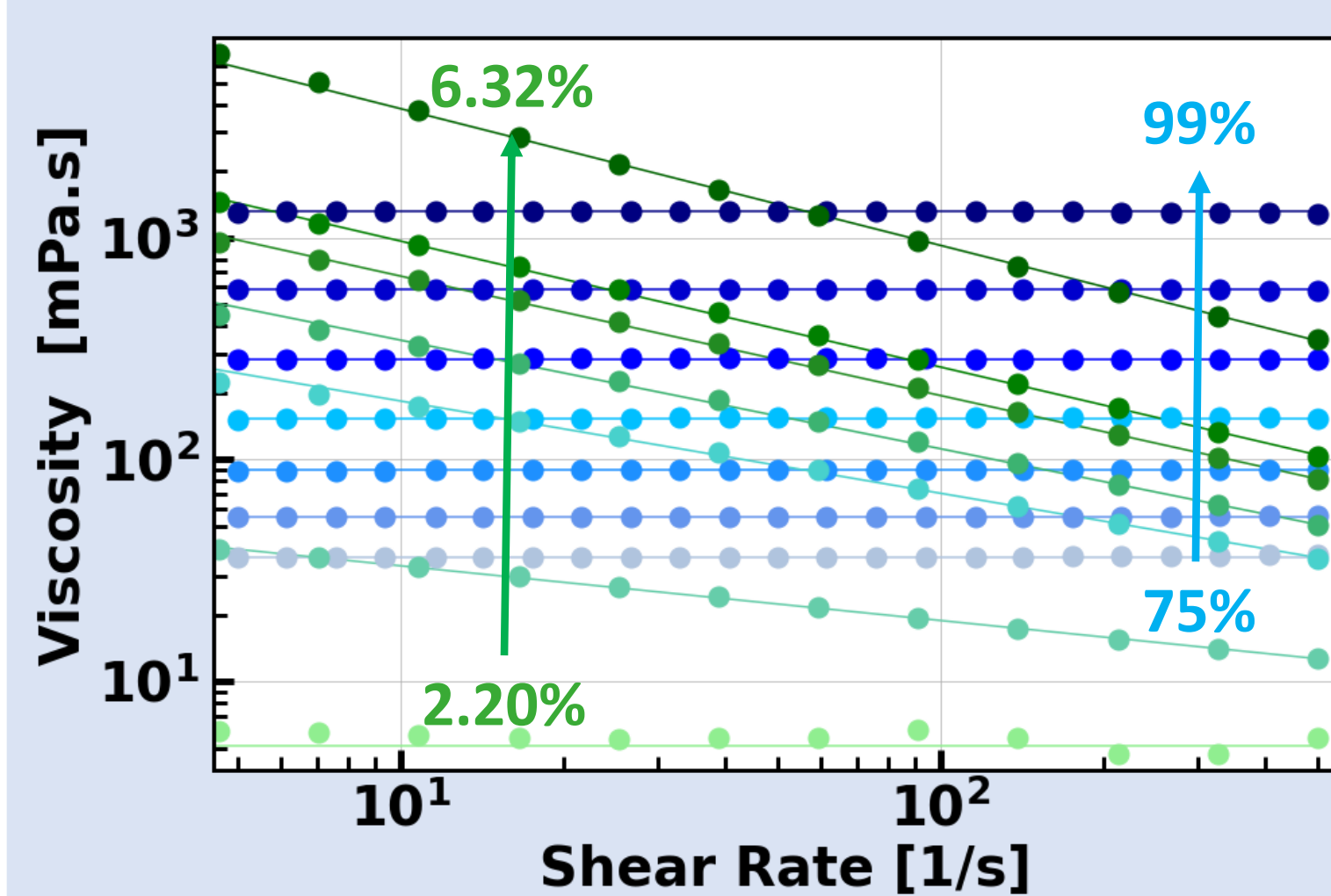
The IDDSI Flow Test is performed in a syringe recommended by IDDSI², and recorded with a camera at 25fps

The study considers shear thinning Power-Law fluids :

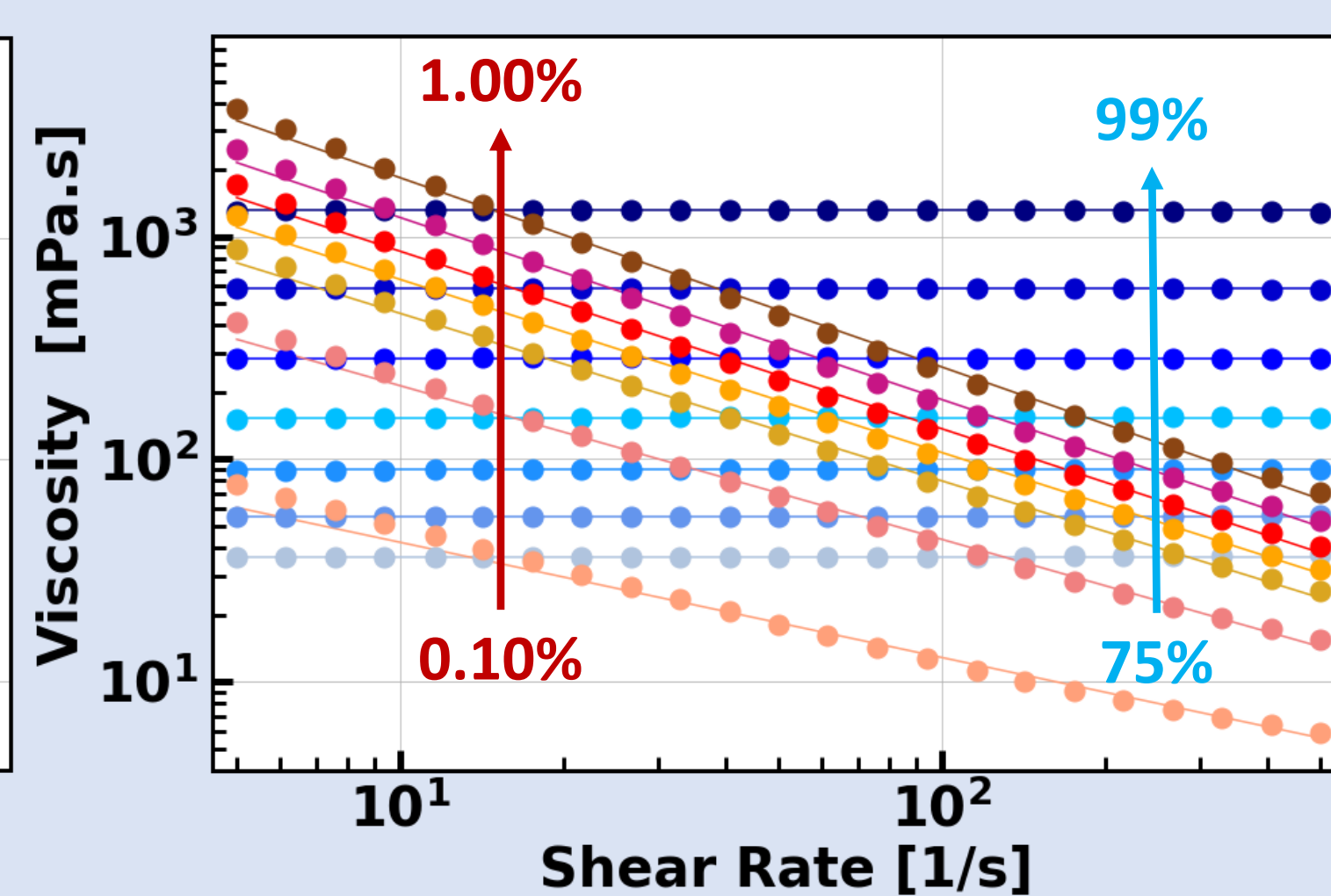
- K is the consistency index [Pa.sⁿ]
- n is the flow index

The fluids are selected to display a large panel of behaviours :

$$\eta = K\dot{\gamma}^{n-1}$$



Flow curves of the glycerol (N) and TU solutions



Flow curves of the glycerol (N) and the XG solutions

• **Glycerol – Newtonian**

$$0.04 \text{ Pa.s} \leq \eta \leq 1.31 \text{ Pa.s}$$

• **Xanthan Gum – Range of K and n** $0.14 \text{ Pa.s}^n \leq K \leq 13.1 \text{ Pa.s}^n$ $0.15 \leq n \leq 0.48$

• **Thicken-Up – Range of K and n** $0.06 \text{ Pa.s}^n \leq K \leq 15.8 \text{ Pa.s}^n$ $0.38 \leq n \leq 0.75$

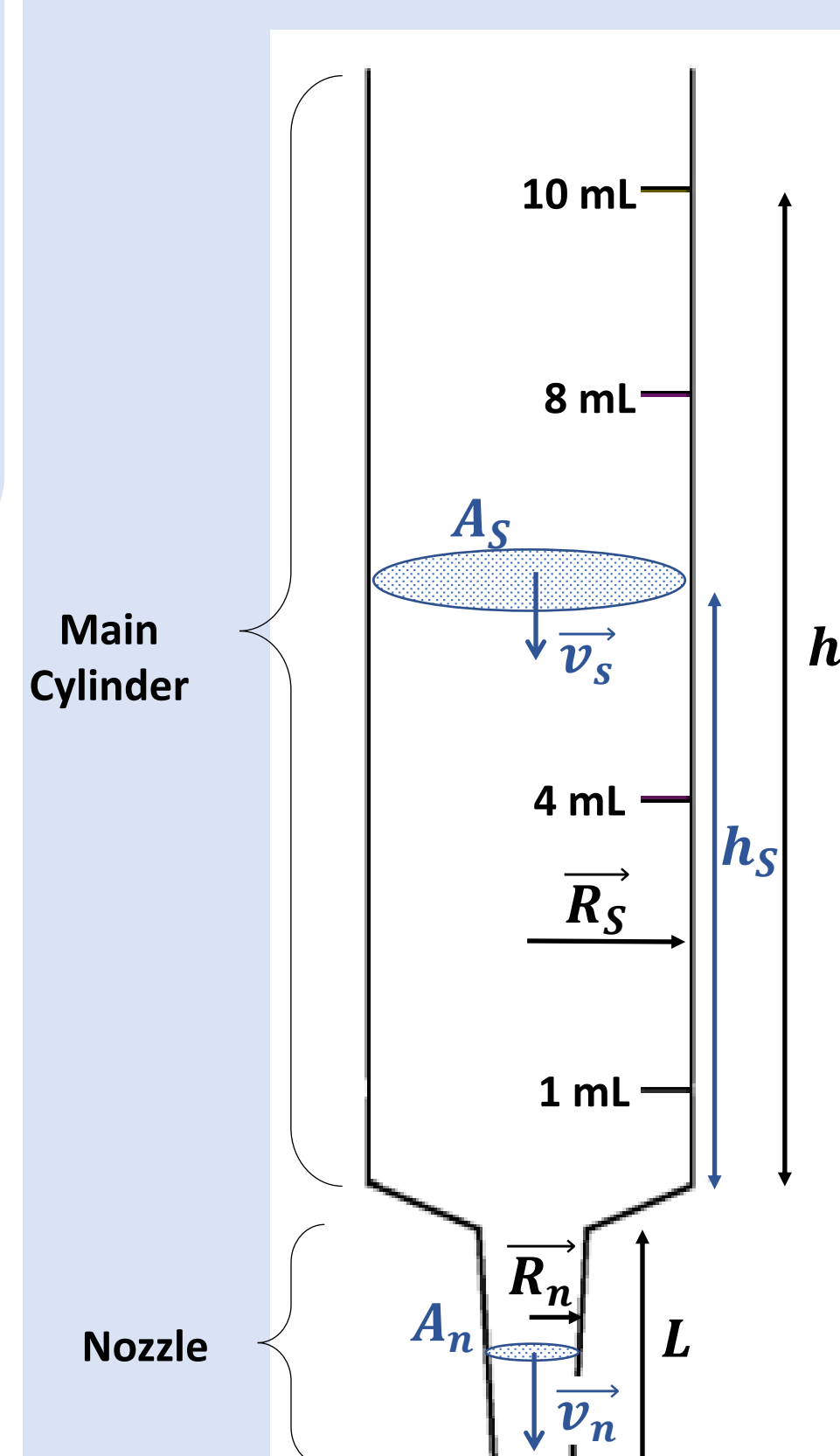
Final residue after 10s



Thickened liquids with very different shear rheology result in the same IDDSI level

Theoretical Model

$$\frac{d(m_n v_n)}{dt} + \frac{d(m_s v_s)}{dt} = \Delta P \pi R_n^2 - \tau 2\pi R_n L$$



The surface forces acting on the system, the fluid in the syringe :

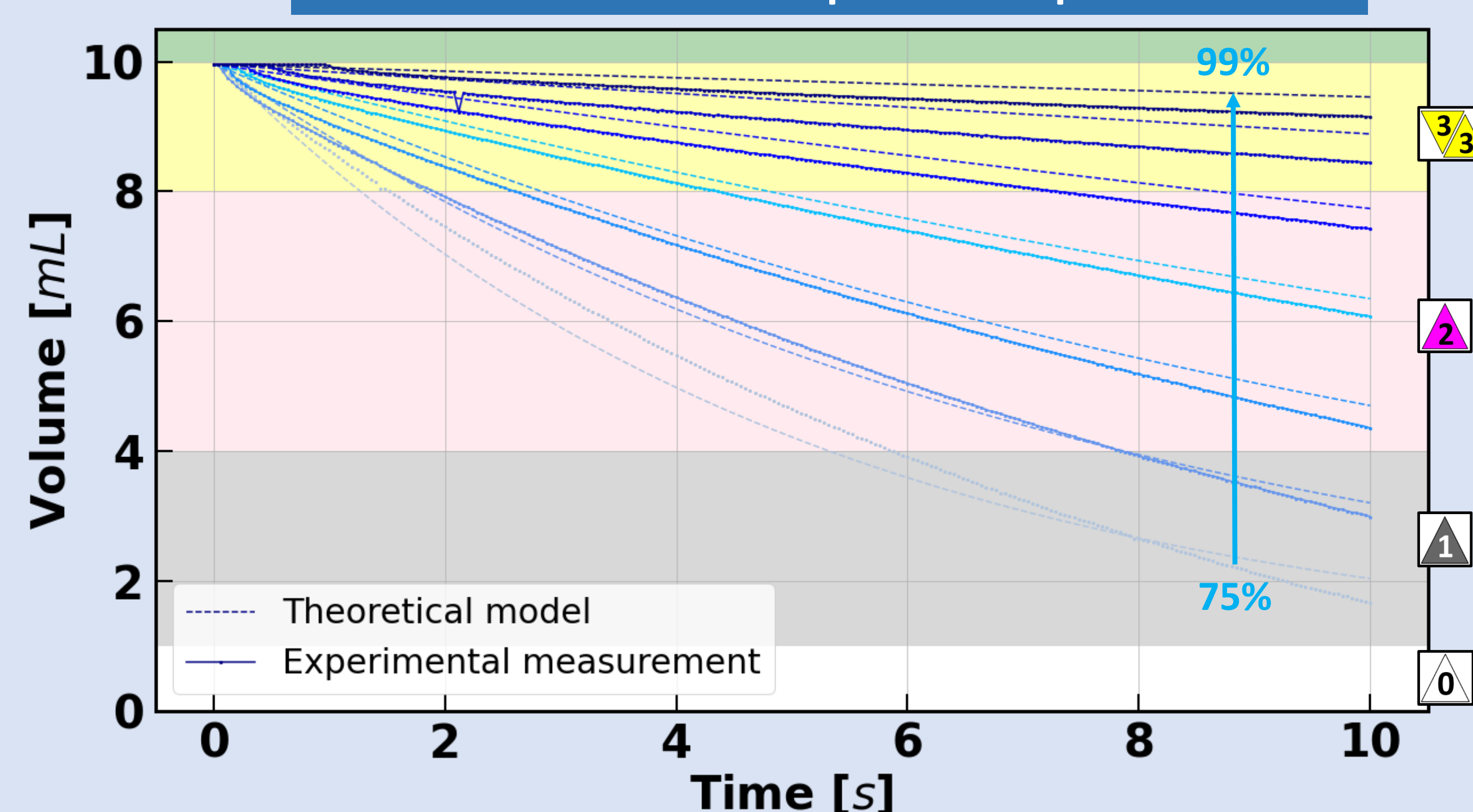
1. The pressure forces – **driving**
2. The viscous forces – **dissipating**

$$\begin{cases} \frac{\delta h_s}{\delta t} = -v_s \\ \frac{\delta v_s}{\delta t} = \frac{\rho g h - 2\frac{\gamma_f}{R_n} - \frac{1}{4}\rho v_n^2}{\rho(h_s + L)} \left(\frac{R_n}{R_s}\right)^2 - \frac{2R_n L}{\rho R_s^2(h_s + L)} \tau_w - \frac{v_s^2}{(h_s + L)} \end{cases}$$

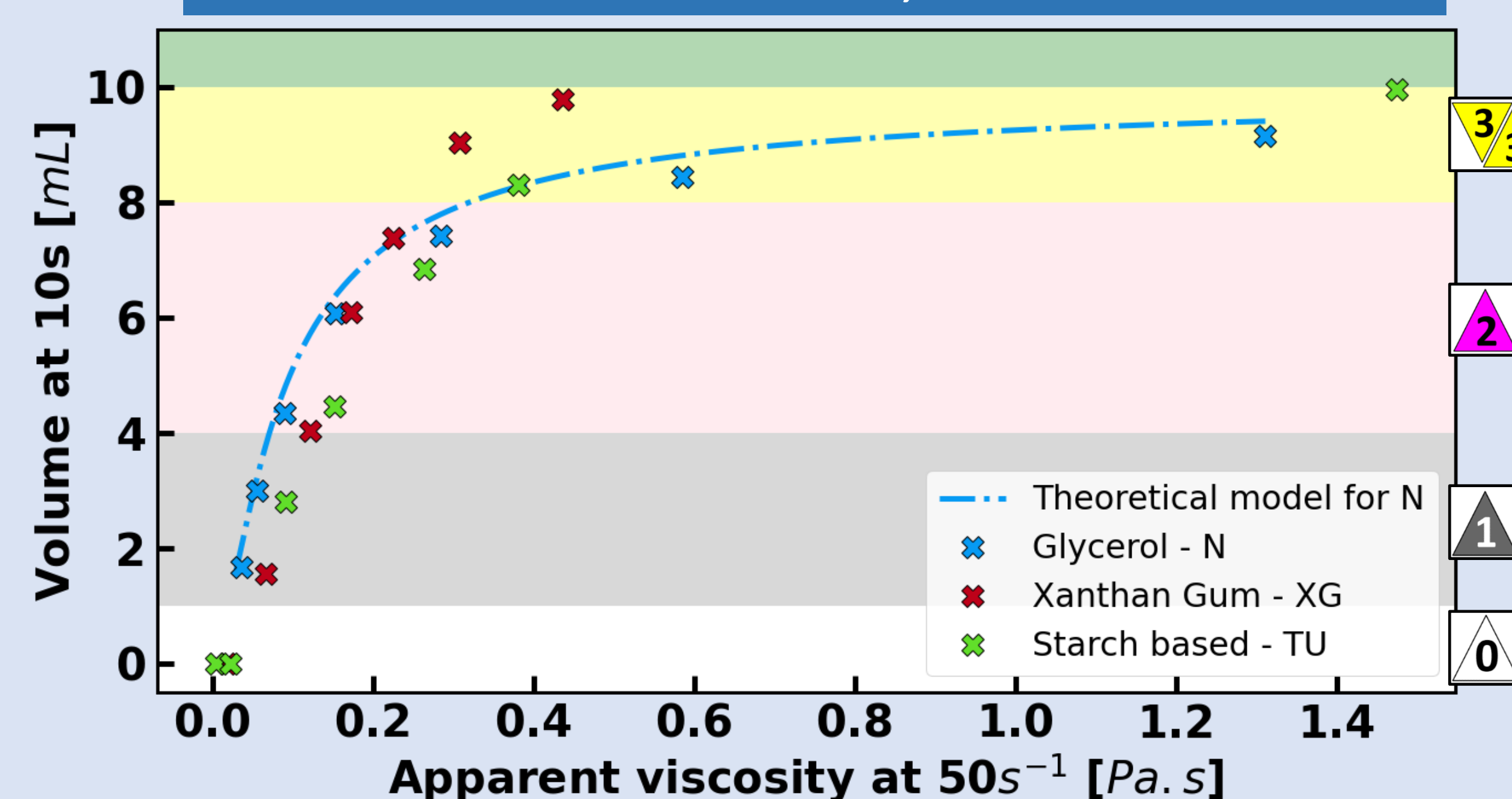
The main components are :

1. **Hydrostatic pressure**, driving the flow under its own weight
2. **Laplace pressure**, effect of the surface tension at the outlet
3. **Pressure loss** due to the contraction between the syringe barrel
4. **Shear stress at the wall** of the syringe, friction dissipating energy
5. **Inertia term**, coming from variation of mass in the syringe

Transient flow model compared to experience for N



IDDSI Flow Test results of N, TU & XG solutions



Conclusions

Thickened liquids with very different rheological properties result in the same IDDSI level, using the IDDSI syringe test. The simple theory presented in this study gives a good prediction of the IDDSI Syringe Flow Tests results for Newtonian liquids.

Perspectives

An extension of this model to more complex rheological properties, can help us identify which different rheological properties can result in the same IDDSI syringe flow test performance and orient future clinical trials to confirm the clinical relevance of this IDDSI "equivalence".

References

- ¹IDDSI Framework : www.iddsi.org , © The International Dysphagia Diet Standardisation Initiative 2019 @ <https://creativecommons.org/licenses/by-sa/4.0/legalcode>. Derivative works extending beyond language translation are NOT PERMITTED.
- ²BDs syringe for IDDSI Flow Test : [BD-Syringes-for-IDDSI-Flow-Test-International-Codes.pdf](https://www.iddsi.org/BD-Syringes-for-IDDSI-Flow-Test-International-Codes.pdf),
- ³Hanson et al.(2019). *ABE*, 47, 2296-2307.
- ⁴Matsuyama et al. (2020). *IJFST* 2020, 55, 2962-2969

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