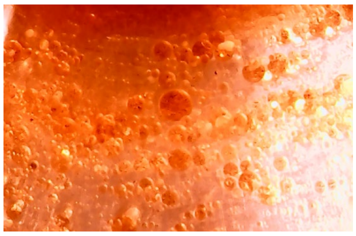
# Non-Newtonian Club, 17th September 2021

## Rheology of Multiphase Systems: Bubbles, Drops and Particles

Organised by Mónica Oliveira, Konstantinos Zografos, Paul Grassia and Mark Haw at the University of Strathclyde and hosted virtually on Zoom platform on Friday 17th September.





The Non-Newtonian Club (NNC) is an informal rheology discussion group, which provides half-day or one-day meetings with the aim of bringing together experienced and not-so-experienced rheologists from industry and academia. PhD students with an interest in rheology are particularly encouraged to attend, as it is you who are the future of our discipline.

### Meeting programme

### Morning Session

**09:50 – 10:00 Welcome & Intro**

**10:00 – 10:40 Ari Jäsberg and Tuomo Hjelt --** VTT Technical Research Centre of Finland Ltd
Rheology of the foams used in foam aided chemical addition on a paper machine

**10:40 – 11:20 Isabelle Cantat –** University of Rennes
Visco-elasticity of foam films - Local scale experimental study

**11:20 – 12:00 Nathanael Inkson --** Siemens Digital Industries Software
Multiphase Rheology in CFD

### Afternoon Session

**13:20 – 14:00 Anke Lindner –** ESPCI Paris PSL, Sorbonne Université, Université de Paris
Steering microscopic particles in viscous flows via shape and deformability

**14:00 – 14:40 Elizabeth Jamie --** Schlumberger Cambridge Research
Structure and rheology of a non-aqueous drilling fluid

**14:40 – 15:20 Adam Townsend --** Durham University
Microorganisms swimming through structured networks: from the point of view of the microorganism

**15:20 – 15:30 BSR Announcements and Closure**

*The British Society of Rheology (BSR) is a charitable society focused on the science of "the deformation of matter". The BSR's main objective is to promote the science and the dissemination of knowledge in the areas of pure and applied rheology to all.*

## Rheology of the foams used in foam-aided chemical addition on a paper machine

Hjelt Tuomo and Jäsberg Ari
VTT Technical Research Centre of Finland Ltd

The strength of pure fiber net is not enough for end-use application. For that reason, strength aids are needed in papermaking. Currently those chemicals are added before fiber network is formed. Strength aids are glues, thus they makes fibers to stick each other leading to uneven distribution of fibers in final paper. To overcome this problem we introduce method, where different chemicals can be added to the already formed wet web on the paper machine. This method also allows the control of the chemical penetration to the web. To be able to control the process we need better understanding of the foam rheology.

In this study, the rheological parameters for high-air-content foams generated by using polyvinyl alcohol (PVOH) as surfactant were quantified in a laboratory-scale pipe flow test environment. The measurements were carried out with solutions in thermal equilibrium with room temperature of ca. 21°C. The foam density was varied between 100 g/l and 300 g/l, and the concentration of the PVOH solution between 0.5% and 6.0%. Foam flow was established by injecting compressed air into continuous flow of surfactant solution in a high-shear flow inside a rotor-stator assembly of a commercial foam generator. At the outlet from the generator, volumetric flow rate, absolute pressure, and bubble size distribution of foam were measured with a magnetic flow meter, a pressure sensor and an online foam monitoring device, respectively. After the online measurement section, foam flowed into a horizontal pipe bank with three parallel 1.5 m long acrylic pipes with inner diameters 8, 12 and 19 mm. The viscous pressure drop was measured over a 1-meter span of pipe, after which the flow discharged to ambient room air pressure. The so-called slip velocity at the pipe wall was quantified by recording the foam motion in the pipe with a high-speed video camera. In the viscosity analysis, the apparent shear rate calculated from the volumetric flow rate and the resulting apparent viscosity were translated to real material viscosity data by applying the Weissenberg-Rabinowitsch correction. The results indicated that these foams can be described as shear-thinning power-law fluids where the detailed behavior depends on the foam density and PVOH concentration.

Visco-elasticity of foam films - Local scale experimental study

Isabelle Cantat
University of Rennes

Liquid foam exhibits surprisingly high viscosity, higher than each of its phases. This dissipation enhancement has been rationalized by invoking either a geometrical confinement of the shear in the liquid phase, or the influence of the interface viscosity. However, a precise localization of the dissipation, and its mechanism at the bubble scale, is still lacking. To this aim, we simultaneously monitored the evolution of the local flow velocity, film thickness and surface tension of a five films assembly, induced by different controlled deformations. These measurements allow us to build local constitutive relations for this foam elementary brick. We first show that, for our millimetric foam films, the main part of the film has a purely elastic, reversible behavior, thus ruling out the interface viscosity to explain the observed dissipation. We then highlight a generic frustration at the menisci, controlling the interface transfer between neighbor films and resulting in the localization of a bulk shear flow close to the menisci.

A model accounting for surfactant transport in these small sheared regions is developed. It is in good agreement with the experiment, and demonstrate that most of the dissipation is localized in these domains.

The length of these sheared regions, determined by the physico-chemical properties of the solution, sets a transition between a large bubble regime in which the films are mainly stretched and compressed, and a small bubble regime in which they are sheared.

# Multiphase Rheology in CFD

Nathanael Inkson
Siemens Digital Industries Software

In computational fluid dynamics software, the approach of modelling viscoelastic fluids has traditionally been to take a "single phase approach", however with increasing powerful computers multiphase simulation has become an established practice and we are now exploring the combination of multiphase approaches with viscoelastic models.

We have modified multifluid Eulerian finite-volume code to enable an enhanced modelling of suspensions of particles in a fluid.

These models have been validated with experiments that demonstrate the phenomenon of shear-induced particle migration. We have also extended these models to suspension-like stabilised emulsions and shown that we can successfully predict the pressure drops in a pipeline of crude oil and water mixtures in both laminar and turbulent cases with a model of a low number of parameters. Selection of the correct turbulence model can ensure that the flow successfully relaminarises to ensure a physical result.

Steering microscopic particles in viscous flows via shape and deformability

Anke Lindner
ESPCI Paris PSL, Sorbonne Université, Université de Paris

Understanding and controlling the transport of microscopic particles in viscous flows stems from the fundamental question of fluid-structure interactions but has also important implications for separation processes or bacterial contamination. Using recent microfabrication techniques, we produce a variety of microscopic particles and control precisely their shape and material properties. Investigating the transport dynamics of these particles in representative microfluidic flows we demonstrate how shape, mechanical properties or even activity govern particle trajectories. Combining our experimental findings with numerical and theoretical modeling performed by our collaborators we elucidate for example the role of particle symmetry, chirality, deformability or activity.

## Structure and rheology of a non-aqueous drilling fluid

**Elizabeth Jamie** (co-authors: Andrew Clarke, Louise Bailey)
Schlumberger Cambridge Research

When drilling a wellbore, the drill-bit produces rock cuttings, which are removed continuously to the surface by a drilling fluid. This fluid is pumped down the drill pipe, through the bit, and returns up through the annulus. The formulation is designed to fulfil many functions over a wide operating range of temperatures and pressures. These functions include: cuttings transport, well-bore pressure and chemical stabilisation, hydraulic energy transfer, bit cooling and lubrication etc.

Non-aqueous drilling fluids are multicomponent systems containing at least oil, a brine emulsion and clay together with emulsifiers and dispersants. Through a range of rheological measurements, we believe these fluids behave as high volume-fraction attractive colloidal gels; they exhibit rheological aging together with a complex yielding process, the latter being indicative of the presence of multiple lengthscales within the system. In this talk we shall explore the microstructure of a model drilling fluid, then interpret our results in the context of recent academic literature that describes the structural evolution of non-equilibrium colloidal gels and glasses.

## Microorganisms swimming through structured networks: from the point of view of the microorganism

Adam Townsend
Durham University

Microorganisms swimming through viscoelastic fluids are a common feature in naturally-occurring fluids. Approaches to modelling this behaviour normally come in two flavours: a macroscale, course-grained approach where the fluid is modelled as a continuum; and a microscale, detailed approach where the anisotropic structure within the background fluid is specifically modelled. The former approach has the benefit of speed, but in this talk I will share my experience of attempting the latter using computer simulations, and show how these simulations suggest the physical structure of the viscoelastic fluid directly affects the microorganism swimming through it.