NON NEWTONIAN CLUB

British Society of Rheology Non-Newtonian Club Meeting

Wednesday September 6th, 2023, 10:30-3:00

Rooms F105/F106

School of Engineering

Corner of Library Road and University Road

University of Warwick, CV4 7AL

The British Society of Rheology

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.

NON NEWTONIAN CLUB

Non-Newtonian Club Meeting 6th September 2023, University of Warwick

10:30 - 11:00	Registration and Refreshments	
11:00 - 11:05	Welcome and introduction to the meeting	
11:05 - 11:30	Thomas John Department of Chemical Engineering University of Manchester	Viscoelastic fluid flow in a helical static mixer: A comparison between the sPTT and FENE-P constitutive models
11:30 -11:50	Hao Yuan WMG University of Warwick	Squeeze flow of carbon fibre sheet moulding compound in compression moulding
11:50 – 12:10	Petr Denissenko School of Engineering The University of Warwick	Coarse emulsions in turbulent flow: Phase dynamics and surface energy
12:10 - 1:30	Lunch	
1:30 - 2:00	Alisyn J Nedoma Department of Chemical and Biological Engineering The University of Sheffield	Elevating the humble binder–the surprising role of polymer additives in controlling the structure and properties of cathode slurries for lithium-ion batteries
2:00 - 2:20	Richard Watson School of Engineering The University of Warwick	Active (magnetorheological) fluids for investigation with acoustic metamaterials
2:20 – 3:00	Tour of the Engineering Build Space then closing of the meeting	

Viscoelastic fluid flow in a helical static mixer: A comparison between the sPTT and FENE-P constitutive models

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The sPTT-Linear and FENE-P models are both commonly used for the simulation of viscoelastic fluid flows in many different geometries. Despite the fact they are derived from different microstructural theories, these models can become identical to one another in steady and homogeneous flows if the model parameters, such as L^2 (the limit of extensibility in the FENE-P model) and ϵ (the rate of junction destruction in the sPTT model), are chosen correctly. However, in transient flows, it has been observed that the response of the FENE-P model differs from that of the sPTT model even with the aforementioned selection of parameters, as it exhibits strong stress overshoots in, for example, start-up flow[1]. The difference between the two models comes from a Lagrangian derivative term present in the FENE-P model, and so it would be expected that the models also respond differently in Lagrangian unsteady flows which might be Eulerian steady. The Lagrangian unsteadiness might come from the presence of a complex geometry.

In this study, we use Computational Fluid Dynamics (CFD) to simulate viscoelastic flows in a helical static mixer with the sPTT and FENE-P models in the laminar regime. The results show that, for both models, increasing elasticity has a detrimental effect on the mixing performance. This effect has previously been observed experimentally with Planar Laser Induced Florescence[2], however, we are able to show that this effect is caused by flow asymmetries at the element intersections. The results seem to strongly suggest that the observed asymmetry is caused in part by viscoelastic instabilities which are frequently studied in simpler geometries such as the cross slot[3] and channels with confined cylinders[4]. For a range of Wi, where Wi is the Weissenburg number defined as the product of the viscoelastic relaxation time and the characteristic strain rate, we have quantified the degree of asymmetry at the element intersections and correlated this with the mixing performance. As Wi is increased the direction of the asymmetry flips at a seemingly critical Wi for the FENE-P model, but this change in direction does not occur for the sPTT model.

Since the static mixer represents a flow which is Eulerian steady but Lagrangian unsteady, we also compare the response of the sPTT and FENE-P models in Large Amplitude Oscillatory Shear (LAOS), which represents a Lagrangian steady but Eulerian unsteady flow. There are stark differences in the LAOS response of the two models; the FENE-P model again exhibits strong stress overshoots which manifest as self-intersecting secondary loops in the Lissajous-Bowditch plots (the viscous projection). In steady shear flow, the response of the FENE-P model (and sPTT model with the aforementioned selection of parameters) scales with Wi/L. Although this can be proven analytically to be the case for steady shear flow, we show in LAOS that the sPTT model response also scales with Wi/L (or $Wi\sqrt{\epsilon}$). For the FENE-P model, however, the same universality is only observed for large enough values of L^2.

The results from this study help us to understand the role that viscoelasticity, and the choice of constitutive mode, can play in fluid flows in complex industrial geometries. The findings can hopefully aid in the design of equipment and processes, particularly when it comes to choosing a particular viscoelastic constitutive model.

[1] M. Davoodi, et al., Phys. Fluids. 34, 033110 (2022)
[2] J. Ramsay, et al., Chem. Eng. Res. Des. 115, 310 (2016)

[3] R. Poole, et al., Phys. Rev. Lett 99, 164503 (2007)

[4] S. Varchanis, et al., Phys. Fluids. 32, 053103 (2020)

Squeeze flow of carbon fibre sheet moulding compound in compression moulding

Hao Yuan and Connie Qian

Warwick Manufacturing Group, University of Warwick

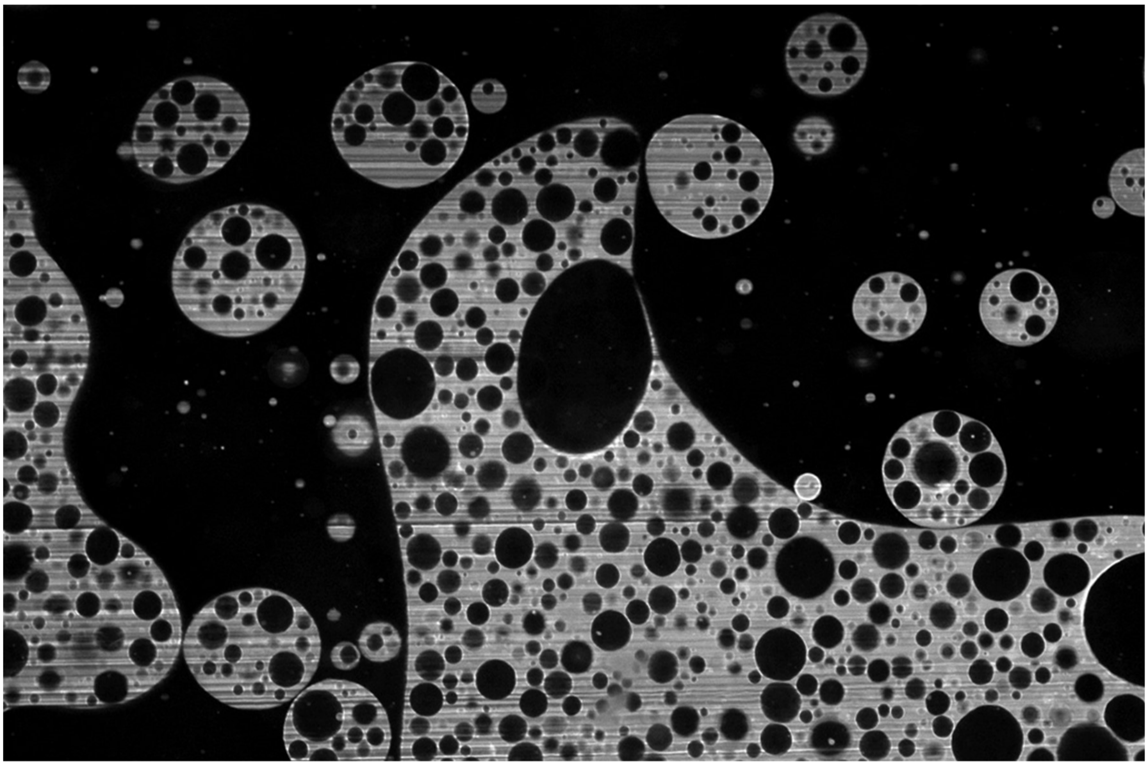
In recent years, carbon fibre sheet moulding compound (SMC) has been increasingly used in automotive applications as a low-cost alternative to conventional prepreg based composites. Due to its ability to flow under high compressive pressure (typically greater than 10 MPa), it offers great capabilities of manufacturing complex geometry while maintaining the material wastage at the minimum. Existing process simulation tools are developed from injection-moulding models which is far from the reality in the actual SMC compression moulding. This highlights the concerns over the inappropriate constitutive material models used in these packages.

A novel material model specifically developed for SMC flow simulation has been proposed in this paper, where the experimental material characterisation is performed using the squeeze flow testing method. The model has been validated through simulation of the squeeze flow testing and the accuracy of the model is assessed by comparing the predicted compression forces against experimental data collected from the squeeze flow testing. The new material model has also been adopted to perform a full-component simulation using a flat plaque geometry. The proposed new model has demonstrated significant improvement in comparison to existing commercial models in both compression force and filling pattern predictions.

Coarse emulsions in turbulent flow: Phase dynamics and surface energy

Petr Denissenko, University of Warwick and Sergei Lukaschuk, University of Hull

Fluids with time-dependent viscosity include rheopectic and thixotropic fluids. Strain-stress relation of emulsions may have properties of both types and in general has complicated dependence on the history of the applied shear. We use laser induced fluorescence in index-matched emulsion of water and oil to experimentally investigate distribution of phases. In the flow stirred by two counter-rotating impellers, a setup commonly nicknamed French Washing Machine, we evaluate surface energy, and speculate on the energy distribution across scales, making analogy with turbulent energy spectra.



Elevating the humble binder–the surprising role of polymer additives in controlling the structure and properties of cathode slurries for lithium-ion batteries

Alisyn J. Nedoma, Department of Chemical and Biological Engineering, University of Sheffield

Lithium-ion batteries are poised to enable the widespread uptake of electric vehicles, but there are still improvements in battery capacity and lifetime required to overcome consumers' range anxiety. Researchers in the UK are developing thousands of new cathode chemistries each year, with lattice structures designed to hold more lithium, resist volumetric expansion, intercalate lithium quickly and maintain their integrity over thousands of cycles. Unfortunately, there is no straightforward way to test the electrochemical performance of these new materials because each one requires different formulation and processing conditions to behave optimally. Herein, we examine the liquid-phase formulation of cathode particles and carbon black (a conductive additive) suspended in an organic solvent with an added polymer binder. Varying the molecular weight of the binder over a decade of values, we find that the zero-shear viscosity of the polymer solution is the main factor determining whether cathode particles will settle, vertically stratifying the electrode films. The percolation of carbon black is evident in the strong elastic response of all the slurries; however it exhibits an unexpected maximum in slurries with an intermediate molecular weight binder. These highly percolated samples also exhibit the greatest hysteresis in their flow curves (ramping up the shear rate versus ramping it down), the highest conductivity and the smallest size of particle flocs. Drawing on knowledge from the field of polymer flocculants, we conclude that our observations are consistent with a kinetically trapped regime in which the viscosity of the liquid-phase slows agglomeration and is tensioned against the faster flocculation that accompanies binders of increasing molecular weight. These finding suggest that judicious selection of the binder can enhance the conductive pathways in the cathode slurry. Further work is required to establish whether conductivity in the slurry phase translates to conductivity in the dry electrode. Generally, we present several design rules for cathode slurry formulation that will improve the screening process for new battery materials.

Active (magnetorheological) fluids for investigation with acoustic metamaterials

Richard Watson, School of Engineering, University of Warwick

Active materials are a class of materials which respond to external stimuli and undergo changes in their properties, magnetorheological fluids are fluids that respond to an external magnetic field. These fluids are suspensions of magnetic micro or nano particles in a carrier fluid. Application of magnetic fields induces these magnetic particles to develop order along magnetic field lines changing the overall structure and rheological properties of the fluid. Control of the magnetic field results in variable properties of the fluid.

Metamaterials are engineered materials which possess properties not found naturally. This is often achieved by use of multiple small identical units. In acoustic and ultrasonic metamaterials these are achieved by resonances in the structure, and these resonances result in frequency-specific properties for each design of metamaterial. The acoustic metamaterial resonance depends on the interaction between the metamaterial structure and the fluid with which it is surrounded, and which is needed to transmit the acoustic waves. This is controlled by differences in fluid and material acoustic impedances. Previous work at Warwick has investigated the manufacture and properties of acoustic metamaterials in water including negative refraction and subwavelength imaging[1,2]. Combining active magnetorheological fluids and acoustic metamaterials as an overall active system is the aim of this work, allowing investigation into control of the frequency response of metamaterial systems. Variable frequency responses of metamaterials may have applications in the filtering of sound, and the removal of transmitted excitation frequencies to allow low intensity signals at harmonics and subharmonics to be measured and recorded. Other applications could also be in the design of devices for frequency sampling. This would also allow the possibility for focussing of specific frequencies through metamaterial lenses for measurement and excitation at specific locations.

[1] Astolfi, L et al., 'Negative refraction in conventional and additively manufactured phononic crystals'. In: Proceedings of 2019 IEEE International Ultrasonics Symposium (IUS). 2019 IEEE International Ultrasonics Symposium (IUS), 06-09 Oct 2019, Glasgow, UK. IEEE , pp. 2529-2532, doi: 10.1109/ultsym.2019.8926236

[2] Lorenzo Astolfi et al., 'Holey-structured tungsten metamaterials for broadband ultrasonic sub-wavelength imaging in water', The Journal of the Acoustical Society of America 150, 74 (2021); doi: 10.1121/10.0005483

Getting to the School of Engineering at the University of Warwick

A map of campus is on the next page With Engineering, main entrance for cars and the bus station highlighted.

By car

There is parking available for visitors to campus. It is £7 per day. Payment is through APCOA who manage the university parking. (apcoaconnect.com) Parking is controlled by Automatic Number Plate Recognition cameras as you enter campus. Pleas log into the APCOA website and pay after arrival. Signs are posted in the carparks with details and the location code. More details on parking at Warwick in general are at the following link. https://warwick.ac.uk/services/carparks/general_parking

Details of the carparks on campus can be found on the following website, https://warwick.ac.uk/services/carparks/where

On the following page is a parking map so you can see where you can park. You can try the open (at ground level) physics carpark 9 & 10 or multi-story 15 as they are closest to engineering. The parking near the Junction building (old sports centre) is also close to Engineering. Kirby Corner and Lynchgate are more modern multi-storey parking structures with bigger spaces but significantly more of a walk to Engineering.

By Public Transport

Public transport to the University of Warwick is available and more details are available at the folowing web link. https://warwick.ac.uk/about/visiting/directions/

The main train station is Coventry (3.2 miles to campus) , buses to Campus from Coventry Station are the 12X, a direct fast service to the university. The 11 and 11U buses are also an option which travel through Earlsdon to the university but are slower.

Alternative train stations at Tile Hill (2.3 miles) and Canley (1.4 miles) are nearer to the university but are a walk or alternative means of transoprt is required to get to campus from these stations.


Individuals with accessibility requirements may contact the transport team on 02476522206 for a verbal description of the map and any other enquiries.
WESTWOOD CAMPUS
SCIENCE PARK
CENTRAL CAMPUS
Main Entrance
Engineering
LAKESIDE VILLAGE
Buses
CRYFIELD VILLAGE
GIBBET HILL CAMPUS
CAR PARKING KEY
P General | General users & staff payment portal
F Gibbet Hill general | Non-Gibbet Hill based staff payment portals are not valid here
W Sports & Wellness Hub | Pay on exit only; Staff & other site payments are not valid here
V Reserved visitor parking | Gibbet Hill campus visitors only at Gibbet Hill
B Gibbet Hill Staff | Gibbet Hill campus based staff & PGRs only
C Conferences | Scarman, Radcliffe & The Slate parking only; Staff & other site payments are not valid here
E Staff & visitors only | PGR, MBChB & students are not valid here
S Short stay | 20 minutes short stay only; does not apply to blue badge holders