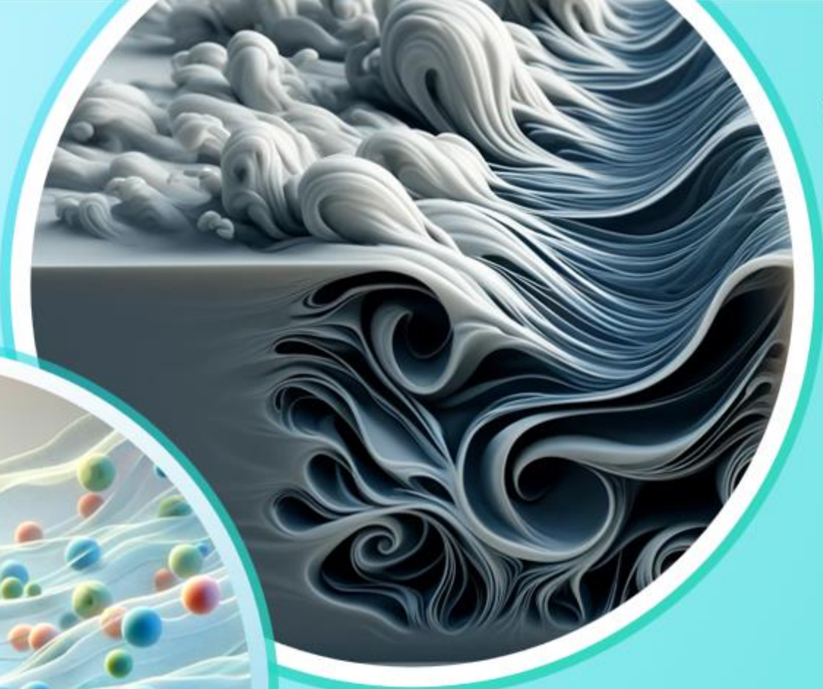
UNIVERSITY OF LEEDS



FLUID DYNAMICS SYMPOSIUM

University of Leeds
School of Electronic and Electrical Engineering
Rhodes Lecture Theatre

13 JUNE 2024
10AM - 4.15PM

LIFD
Leeds Institute for Fluid Dynamics

UKRI Engineering and Physical Sciences Research Council

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09:00	10:00	Registration
Session 1 – Chair: Robin Furze		
10:00	10:55	Dea Wangsawijaya - University of Southampton **Investigation of high Reynolds number turbulent boundary layers under non-equilibrium conditions**
10:55	11:20	Eric Won Keun Chang - University of Oxford **Experimental investigation of hypersonic flows using high-enthalpy ground test facilities**
11:20	11:50	Break
Session 2 – Chair: Girindra Ramgobin		
11:50	12:15	Tushar Srivastava - University of Leeds **Moving droplet-particle collisions**
12:15	13:10	Lee Nissim - University of Bath **Numerical modelling of Protein Aggregation Lubrication in synovial joints**
13:10	14:10	Lunch + Poster Session
Session 3 – Chair: Andrea Sendula		
14:10	15:05	Suzanne Fielding - Durham University **Modelling the rheology of biological tissue**
15:05	15:15	Break
Session 4 – Chair: Peter Jimack		
15:15	16:10	Richard Hewitt - The University of Manchester **Katabatic flows: an asymptotic view**
16:10	16:15	Closing Remarks

Investigation of high Reynolds number turbulent boundary layers under non-equilibrium conditions

Dea Wangsawijaya

University of Southampton

A non-equilibrium turbulent boundary layer (TBL) encompasses many flow phenomena in aeronautics and aerospace engineering, as well as energy harvesting. Under non-equilibrium conditions, the TBLs are perturbed by a combination of external factors. Understanding the impacts of non-equilibrium conditions (both individually and combined) for the purpose of flow, mass transport, noise, and thermal management is therefore critical in energy and transportation research, notably the two largest contributors of greenhouse gas emissions.

Various control mechanisms essentially introduce non-equilibrium conditions to the flow, altering the turbulent structures, as well as wall-shear stress, wall-pressure fluctuations, and scalar transport (mass and heat). The success of a control mechanism, quantified by either reduction or penalty, is determined by a large number of design & flow parameters, where the scaling of these parameters is still largely unknown. Moving towards control mechanism in compressible flow regimes presents another challenge: the incompressible flow analogy under non-canonical, non-equilibrium conditions, is still largely unknown.

In this talk I will discuss my past and current research, where I investigate the formation of turbulent structures under a non-equilibrium condition within the interface of aeronautics and astronautics engineering designs (high subsonic towards supersonic regimes) using a wide range of experimental techniques.

Experimental investigation of hypersonic flows using high-enthalpy ground test facilities

Eric Won Keun Chang

University of Oxford

Experiments in ground test facilities provide valuable data for understanding the complex aerothermodynamic phenomena encountered in hypersonic flight. This presentation will cover the fundamental operating principles of high-enthalpy facilities, including shock/expansion tubes and plasma wind tunnels. Emphasis will be given to hypersonic shock tunnel experiments on shock/boundary-layer interactions at flight-duplicated flow conditions, as well as expansion tube and plasma wind tunnel testing for atmospheric re-entry. Various flow diagnostic techniques and analysis methodologies for high-speed wind tunnel experiments will be introduced. The talk will also briefly overview the research conducted with the OPG plasma wind tunnel.

Moving droplet-particle collisions

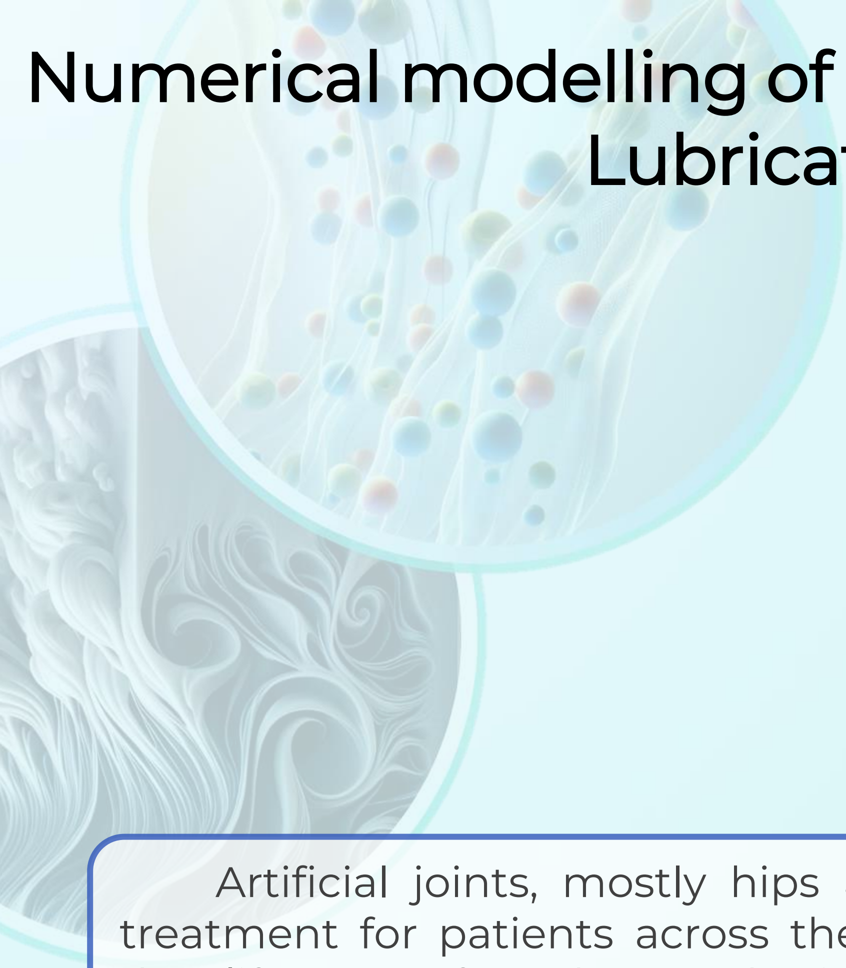
Tushar Srivastava

University of Leeds

Droplet-particle (D-P) collision is a ubiquitous phenomenon contributing to particle capture and agglomeration in applications such as spray drying, fluid bed cracking, and aerosol scavenging. The literature exploring the collision dynamics of moving D-P systems is limited, primarily due to the experimental challenges associated with small-sized droplets and particles.

This study investigates the collision dynamics of a moving D-P system using an in-house experimental setup that includes a droplet dispensing system, particle feeder, and two high-speed cameras. In the experiments, mono-sized water droplets with a 400-micron diameter were dispensed to collide with beads of 130-micron diameter released from the particle feeder. The droplet speed and collision angle were varied to change the Weber number. The two high-speed cameras captured front and side views of the D-P collisions, and the images were processed to determine the offset between the droplet and particle just before collision.

Results revealed that the Weber number and the offset significantly affect the collision outcomes, specifically particle capture or separation. Additionally, the material properties of the beads determine whether the particles penetrate the droplet or are captured at the interface. The findings of this study are crucial for developing a unified model based on fundamental principles to predict collision outcomes in various scenarios.



Numerical modelling of Protein Aggregation Lubrication in synovial joints

Lee Nissim

University of Bath

Artificial joints, mostly hips and knees, are a common treatment for patients across the UK and the globe. Often, the lifespan of such prosthetics (15-20 years) limits the treatment to those patients of a more advanced age due to the reluctance of clinicians to replace the joints for a second time. Replacements of replacements do not generally fair well.

Increasing the lifespan of these medical devices, such that they become available to more patients, and at earlier stages, relies on a thorough understanding of the lubrication and wear of the contact surfaces. The lubricating fluid for such joints is synovial fluid, a protein-rich and complex biofluid that exhibits interesting non-Newtonian properties. As such, lubrication mechanisms beyond those well studied in the field of machines are experimentally observed, including that of Protein Aggregation Lubrication (PAL).

This talk will discuss PAL, and efforts to simulate this lubrication mechanism, to both better understand the underlying physics and to progress toward the potential for full life-cycle simulations and optimised designs.

Modelling the rheology of biological tissue

Suzanne Fielding
Durham University

The deformation and flow properties of biological tissue are important in processes such as embryo development, wound healing and tumour invasion. Indeed, processes such as these spontaneously generate stresses within a living tissue via active process at the single cell level. Tissues are also continually subject to external stresses and deformations from surrounding tissues and organs. The success of numerous physiological functions relies on the ability of cells to withstand stress under some conditions, yet to flow collectively under others. Biological tissue is furthermore inherently viscoelastic, with a slow time-dependent mechanics. Despite this rich phenomenology, the mechanisms that govern the transmission of stress within biological tissue, and its response to bulk deformation, remain poorly understood to date. Simplified vertex models of confluent tissue monolayers have uncovered a spontaneous liquid-solid transition tuned by cell shape. In this talk, I shall review some recent progress in modelling the rheology of biological tissue.

First, I shall discuss work predicting a strain-induced stiffening transition in a sheared tissue. Second, I shall discuss how the interplay of external deformations applied to a tissue as a whole with internal active stresses that arise locally at the cellular level, is predicted to lead to a host of fascinating rheological phenomena such as yielding, shear thinning, and continuous or discontinuous shear thickening. Third, I shall discuss the formulation of a continuum constitutive model that captures several of rich linear and nonlinear rheological phenomena noted above.

Katabatic flows: an asymptotic view

Richard Hewitt
University of Manchester

Katabatic flows arise on cooled slopes in a stratified ambient fluid. They typically occur as a sloping terrain cools during the night, leading to a thermally-driven down-slope ('katabatic') flow. In theoretical models, a maximum downstream flow arises near the slope surface, but also a weak return flow develops at larger distances from the surface. So, whilst the net mass flux is in the down-slope direction, the velocity profile and the buoyancy profile are oscillatory in the slope-normal coordinate -- we will see that this feature has some significant theoretical consequences both for the problem formulation and stability of the resulting flow. If the slope is unbounded and the surface buoyancy constant, there is a well-known idealised solution due to Prandtl. This is a straightforward linear, 'parallel' reduction of the problem. Instead, we will construct a nonlinear bi-directional parabolic system under the assumption that the flow is driven by non-uniform surface conditions but remains shallow compared to the downstream length scale. This surface non-uniformity gives a nonlinear problem, with entrainment into and detrainment from the down-slope flow.

We will solve the leading order 'boundary layer' problem computationally and use it to contextualise some of the known similarity reductions to this problem. Using this same system we then examine the mechanisms for linear instability observed in recent DNS results, which highlight how vortex/roll instabilities and propagating waves can be associated with inflectional buoyancy and velocity profiles. Throughout I'll try to stress how the use of asymptotic scaling helps us to interpret this system.

POSTER COMPETITION

Posters will be displayed during the lunch break in the foyer. Please vote for the best poster using the QR code or link below. A prize for first place and runner up will be awarded at the end of the day, sponsored by NAG.

https://forms.gle/mT5CWVi2RFrj3btQA