

CONFERENCE PROGRAM

The 2nd Australasian Conference on Particle Approaches and Applications in Fluids (ACPAAF2026)

The University of Sydney, 9-11 February 2026



THE UNIVERSITY OF
SYDNEY



AUSTRALASIAN
FLUID
MECHANICS
SOCIETY



ACKNOWLEDGEMENT OF TRADITIONAL OWNERS

We acknowledge the tradition of custodianship and law of the Country on which the University of Sydney campuses stand. We pay our respects to those who have cared and continue to care for Country.



Foreword

It is a pleasure to welcome you to the 2nd Australasian Conference on Particle Approaches and Applications in Fluids (ACPAAF2026), hosted at The University of Sydney, Australia, from February 9th to 11th, 2026.

Building on the success of the inaugural conference held at the Queensland University of Technology (QUT) in 2024, which welcomed over 40 participants and featured 31 technical presentations, we hope this second gathering will establish a strong ongoing series for advancing particle-based methods and applications in the Australasia region. With over 50 registrants and 36 presentations scheduled for this occasion, ACPAAF continues to serve as an important forum for researchers and practitioners to share developments in emerging experimental and numerical approaches. These methods show great promise in accurately simulating and measuring fluid flow across diverse applications, from microfluidics to large-scale macroscopic systems.

The 2026 program spans three full days and includes a rich schedule of technical sessions, networking opportunities, and social events. Beyond the technical sessions, we invite you to participate in the awards ceremony, lab tours, and our conference BBQ dinner hosted at the School of Civil Engineering.

We would like to express our gratitude to the Australasian Fluid Mechanics Society (AFMS) for their continued financial support, which has been instrumental in the success of this initiative. We also thank the local organising team and all participants for their contributions to this growing scientific community.

We hope your participation at the conference is scientifically fruitful and provides excellent opportunities for collaboration.

ACPAAF2026 Committee:

A/Prof Yixiang Gan (Chair)
Dr Michael Heisel
Dr Morgan Li
Prof Chengwang Lei

Local Organising Team:

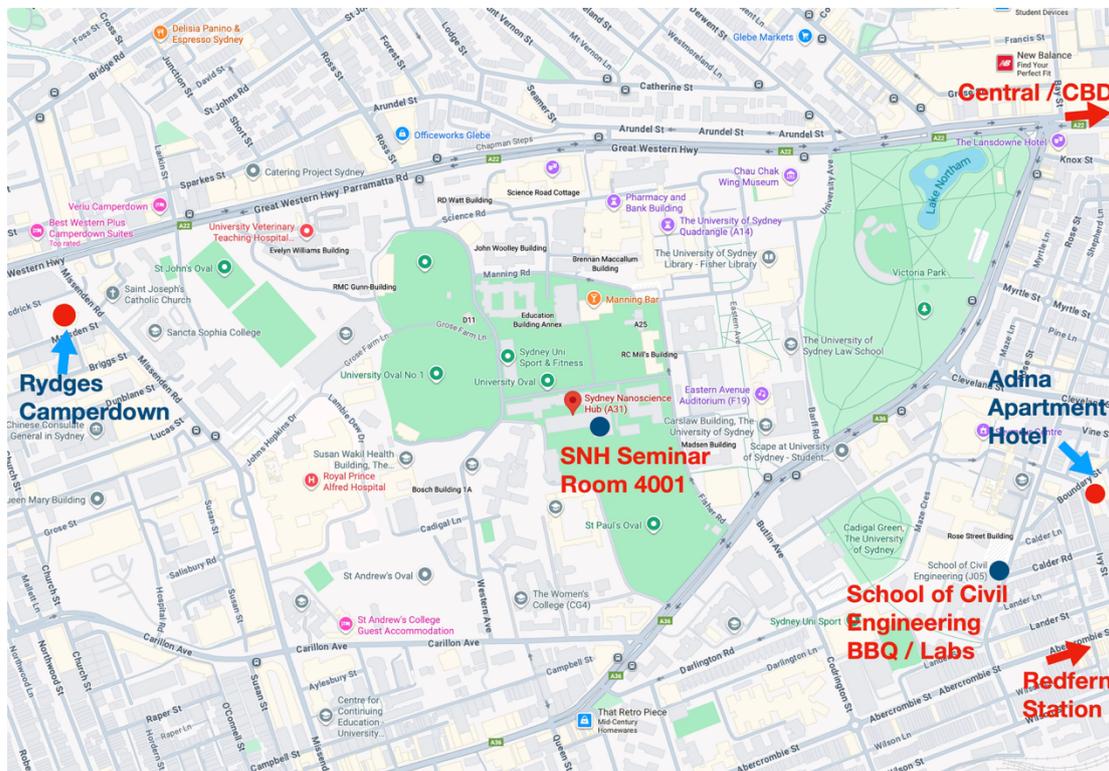
Ms Haiyi Zhong
Ms Jiayin Zhao
Mr Rico Chen
Ms Siyu Ji
Mr Tim Zhang

Conference Information

Conference location: Sydney Nanoscience Hub (SNH A31) Seminar Room 4001, The University of Sydney, NSW 2006, Australia

BBQ location: School of Civil Engineering (J05), The University of Sydney, NSW 2006, Australia

Lab tours: Fluids Lab, Wind Tunnel, Particles and Grains Lab, School of Civil Engineering (J05)



Schedule

Day 1, Monday 9 February 2026

8:50-9:00	Opening (Prof Stuart Khan , Head of School of Civil Engineering, USYD)
Session 1 (Chair: Zhongzheng Wang)	
9:00-9:50	Timm Krueger (Edinburgh) , Lattice-Boltzmann modelling for complex flow simulations - an overview [Keynote]
9:50-10:10	Ryan Huang (QUT) , Immersed Boundary-Lattice Boltzmann Method and Its Applications for the Fluid-Structure Interaction: From Blood flow to Insect Flight
10:10-10:30	Alireza Khoshnood (QUT) , Numerical Stability of Coupled Thermal-Fluid Simulations Using Double-Distribution and Hybrid Lattice Boltzmann Approaches [*]
Coffee Break	
Session 2 (Chair: Adnan Sufian)	
11:00-11:40	Christopher Leonardi (UQ) , Stochastic quantification of relative permeability in rough fractures using the phase-field lattice Boltzmann method (Invited)
11:40-12:10	Zhongzheng Wang (QUT) , A pore-resolved interface tracking algorithm for multiphase flow in porous media (Invited EMCR)
12:10-12:30	Howard Young (UNSW) , Carotid Artery Stenosis: A Haemodynamic Investigation [*]
Lunch	
Session 3: (Chair: Michael Heisel)	
13:30-14:20	Ha Bui (Monash) , Recent Advances in Particle-Based Modelling of Multiphase Flow and Large Deformation in Porous Media [Keynote]
14:20-14:40	Gholamreza Kefayati (UTAS) , A Lattice Boltzmann Method for Two- and Three-Dimensional Velocity-Vorticity Formulations of Generalized Newtonian Fluids in Non-Porous and Porous Media
14:40-15:00	Vedad Dzanic (QUT) , Bridging Elastic and Active Turbulence with a Hybrid Lattice Boltzmann Method
Coffee Break	
Session 4: (Chair: Ryan Huang)	
15:30-16:00	Lu Jing (Tsinghua) , How grain shape matters in granular flow [Invited EMCR]
16:00-16:20	Adnan Sufian (UNSW) , Particle-scale observations of internal erosion using transparent soil imaging
16:20-16:40	Shivakumar Athani (USYD) , Scale dependence of segregation patterns in the filling of silos
16:40-17:00	Mingrui Dong (USYD) , DEM Study of An Irregular-Shaped Intruder in Granular Media

[*] indicates presentations that are eligible for student presentation awards

Day 2, Tuesday 10 February 2026

Session 5 (Chair: Travis Mitchell)	
9:00-9:50	Emilie Sauret (QUT) , Numerically exploring inertialess multiphysics: from fundamentals to applications [Keynote]
9:50-10:10	Suvash Saha (UTS) , Inhalation Dynamics and Deposition of Cigarette-Derived Microplastics in a CT-Resolved Human Airway Model
10:10-10:30	Fangming Zhai (USYD) , Numerical Modelling of Bubbling Rayleigh-Bénard Convection Using OpenFOAM [*]
Coffee Break	
Session 6 (Chair: Suvash Saha)	
11:00-11:40	Travis R. Mitchell (UQ) , Lattice Boltzmann Modelling of Gas Diffusion Electrodes: Applications towards CO ₂ Electrolysis [Invited]
11:40-12:00	Sam Mallinson (Memjet) , Improving inkjet aerosol extraction
12:00-12:20	Yang Zhang (Monash) , Evolution of Droplet Size in Aerosol Jet Printing Processing [*]
12:20-12:40	Haiyi Zhong (USYD) , Performance of cyclic injections in soft granular media: Trapping efficiency and hysteretic behaviour [*]
Lunch	
Session 7 (Chair: Morgan Li)	
13:30-14:00	Shibo Kuang (Monash) , Modelling complex multiphase flow and reaction systems: Recent progress [Invited]
14:00-14:20	Benjy Marks (USYD) , X-ray radiography-based 4D particle tracking of heavy spheres suspended in a turbulent jet
14:20-14:40	Jiachen Zhao (QUT) , Transition between buoyancy- and Coulomb-dominated regimes in Rayleigh-Bénard convection with an additional side-heated wall and charge injection
14:40-15:00	Jiayi Wang (Monash) , Modeling of Particle Agglomeration in Flash Ironmaking Based on Natural Gas Combustion in a Mini-Pilot Reactor [*]
Coffee Break	
Session 8 (Chair: Benjy Marks)	
15:30-16:00	Fangbao Tian (UNSW) , Wall-modelled immersed boundary-lattice Boltzmann method and its applications [Invited]
16:00-16:20	Qian Wang (SJTU) , A 3D-PTV Algorithm for Characterizing Complex Vortical Flows Using Stereoscopic Shadowgraphy
16:20-16:40	Viet Khuyen Bui (USYD) , Anisotropy analysis of clay microstructure under shear using SAXS [*]
16:40-17:00	Xiaoyi Wang (Uni Melbourne) , A Gravity Modified Criterion for Particle Activity and Fabric Stability in Gap Graded Soils [*]
Conference Dinner (BBQ)	
17:30-19:30	School of Civil Engineering (Building J05)

[*] indicates presentations that are eligible for student presentation awards

Day 3, Wednesday 11 February 2026

Session 9 (Chair: Vedad Dzanic)	
9:00-9:30	Morgan Li (USYD) , Evaporation in humid air: A tale of two sprays [Invited EMCR]
9:30-9:50	Francois Guillard (USYD) , Insights from X-ray radiography and rheography for multiphase flows
9:50-10:10	Jiahuan Li (USYD) , A Novel HGD-CFD Framework for Efficient Simulation of Fluid-Particle Systems [*]
10:10-10:30	Yue Hu (Monash) , Reconstruction of the pressure field in dense granular flow using physics-informed neural network [*]
Coffee Break	
Session 10 (Chair: Francois Guillard)	
11:00-11:20	Isadora Bugarin (USYD) , A Hybrid Solid–Sink Approach for Canopy Flow Modelling with the Lattice Boltzmann Method [*]
11:20-11:40	Brendan Waters (USYD) , Validation of waLBerla for Atmospheric Transport and Dispersion in Urban Environments: JU2003 Oklahoma City [*]
11:40-12:00	Qiang Zheng (Monash) , Modeling powder agglomeration and biomass intraparticle temperature gradient in the industrial cement calciner [*]
12:00-12:30	Kapil Chauhan (USYD) , Higher order moments of scalar within a plume in a turbulent boundary layer
Awards ceremony (Prof Chengwang Lei)	
Lunch	
Lab visit / Social event / Theme discussion	
13:30-16:00	School of Civil Engineering (J05): Fluids Labs, Wind Tunnel, Particles and Grains Labs, DynamiX, Conference Room 438

[*] indicates presentations that are eligible for student presentation awards

Keynote Speakers



Prof Timm Krüger is Professor of Fluid and Suspension Dynamics in the School of Engineering at the University of Edinburgh where he is the Head of the Institute for Multiscale Thermofluids. For his PhD, Timm developed a particular blood flow model. After postdoctoral positions in Eindhoven and at UCL, he became a Chancellor's Fellow at the University of Edinburgh in 2013 where he has been working since. Timm enjoys doing computational research in the areas of microfluidics, blood flow and mass transport, bringing together experimentalists and modellers in the process.

Prof Emilie Sauret is Professor in the School of Mechanical, Medical & Process Engineering, Queensland University of Technology (QUT). She received her PhD degree in Turbulence Modelling from the University Pierre & Marie Curie, Paris, France in 2004. Prior to returning to academia in 2009, she spent 5 years in the automotive and oil and gas industry both in France and in Australia. She was awarded prestigious fellowships, including an ARC-DECRA in 2013 and a Future Fellowship in 2020. Her current research focusses on the development of advanced computational techniques to accurately simulate complex and non-ideal fluid flow behaviours that are critical for the rational design and robust optimisation of engineering applications and advancement of applied sciences. She currently conducts research to numerically unravel the complexities of inertialess viscoelastic instabilities and investigates intricate microfluidic behaviours and interactions in multiphase/multi-component fluid flows influenced by various physical forces, thermal effects, and complex geometries such as porous media.

Prof Ha H. Bui is an ARC Future Fellow and Head of the Department of Civil and Environmental Engineering at Monash University. He is internationally recognised for pioneering particle-based and mesh-free computational methods, particularly Smoothed Particle Hydrodynamics (SPH), for modelling multiphase flow, large deformation, and failure in porous geomaterials. His work has advanced multiphysics modelling of geohazards and flow–deformation coupling. He is the founder of the GeoXPM SPH platform and an editor of two leading computational geomechanics journals, *Computers and Geotechnics* and *International Journal for Numerical and Analytical Methods in Geomechanics (IJNAMG)*.

Invited EMCR Speakers



A/Prof Lu Jing (Tsinghua University, Shenzhen) How grain shape matters in granular flow

Dr Morgan Li (The University of Sydney) Evaporation in humid air: A tale of two sprays

Dr Zhongzheng Wang (Queensland University of Technology) A pore-resolved interface tracking algorithm for multiphase flow in porous media

Invited Speakers

Shibo Kuang (Monash University) Modelling complex multiphase flow and reaction systems: Recent progress

Travis R. Mitchell (University of Queensland) Lattice Boltzmann Modelling of Gas Diffusion Electrodes: Applications towards CO₂ Electrolysis

Fangbao Tian (University of New South Wales) Wall-modelled immersed boundary-lattice Boltzmann method and its applications

Christopher Leonardi (University of Queensland) Stochastic quantification of relative permeability in rough fractures using the phase-field lattice Boltzmann method

Book of Abstract

Lattice-Boltzmann modelling for complex flow simulations - an overview

Timm Krüger

School of Engineering, Institute for Multiscale Thermofluids, University of Edinburgh, Edinburgh, UK.

Today's scientific and engineering challenges often involve complex flow scenarios, such as wind energy harvesting, multiphase and multicomponent flows, and flows in complex geometries and porous media. These problems typically involve effects such as turbulence, phase change, and fluid-structure interaction. Since experiments can be costly, time-consuming, or might not provide access to all observables of interest, simulations play an important role in understanding the underlying mechanisms and improving designs. While conventional CFD methods (such as finite differences, finite volume, spectral methods) have been developed for more than 60 years, particle-based methods in the context of fluid mechanics were explored several decades later. The lattice-Boltzmann method (LBM) is a particular example, as it combines advantages of lattice-based and particle-based methods. Since its first development in the 90s, the LBM has matured to a widely employed alternative to conventional CFD methods. In this presentation, I will give a short summary of the physical fundamentals of the LBM, followed by a discussion of its advantages and disadvantages. Finally, I will show how LBM has been successfully used to tackle the three challenges mentioned above.

Immersed Boundary-Lattice Boltzmann Method and Its Applications for the Fluid-Structure Interaction: From Blood flow to Insect Flight

Qiuxiang Ryan Huang¹ Jingtao Ma² Zhengliang Liu³ Li Wang, Fang-Bao Tian⁴
Zhiyong Li¹

¹ Queensland University of Technology, Brisbane, Australia.

² Aix-Marseille University, Marseille, France.

³ University of Electronic Science and Technology of China, Shenzhen, China

⁴ University of New South Wales Canberra, ACT, Australia

Fluid-structure interaction (FSI) problems ubiquitously arise in biological and engineering systems, yet their simulation remains challenging due to strong nonlinearity and complex coupling phenomena. The immersed boundary-lattice Boltzmann method (IB-LBM) offers a computationally efficient alternative by combining the geometric flexibility of immersed boundary approaches with the inherent parallelizability and explicit nature of lattice Boltzmann schemes. This work presents an in-house high-fidelity IB-LBM solver developed for two canonical applications: blood flow dynamics and insect flight aerodynamics. For blood flow, the method demonstrates superior robustness and computational efficiency compared to conventional CFD approaches. Specifically, we demonstrate the first full-domain numerical simulations of large-amplitude self-excited oscillations in collapsible blood vessels, validating the method's capability to capture complex FSI phenomena. For insect flight, the method effectively resolves the intricate interactions between flapping wings and surrounding fluid. The IB-LBM framework is highly extensible and shows strong potential for broader applications including red blood cell dynamics, non-Newtonian fluid flows, valvular hemodynamics, and integration with deep learning for predictive modelling. This presentation will discuss the methodological foundation of IB-LBM, demonstrate its accuracy and efficiency through representative case studies, and outline future directions for biomedical and engineering applications.

Numerical Stability of Coupled Thermal–Fluid Simulations Using Double-Distribution and Hybrid Lattice Boltzmann Approaches

Alireza Khoshnood*, Vedad Dzanic, Zhongzheng Wang and Emilie Sauret

Queensland University of Technology, Australia

The numerical stability of multiphysics thermal–fluid models remains an ongoing challenge, particularly in advection-dominated regimes. Moreover, selecting a stable and compatible temperature solver for coupling with LBM remains an open issue in multiphysics simulations. This study examines the numerical stability of coupled momentum and energy solvers employing various modelling strategies. For the hydrodynamic field, single relaxation time (SRT) and recursive regularised lattice Boltzmann (RR-LBM) collision models are employed. The results demonstrate that RR-LBM provides significantly improved flow stability compared to the conventional SRT model. To address the advection-dominance issue for the temperature solver, various double distribution function (DDF) lattice Boltzmann formulations for temperature, as well as hybrid finite difference (FD) approaches, are examined and compared, including the SRT and hybrid recursive regularised lattice Boltzmann (HR-LBM) schemes, and the KT and WENO5 finite difference methods. The stability behaviour of each coupled strategy is evaluated using three benchmark problems: a rectangular pulse, the double shear layer (DSL) problem, and natural convection in a Rayleigh–Bénard cavity (RBC). The results provide a systematic assessment of the stability characteristics of coupled thermal–fluid solvers, offering practical guidance for selecting robust numerical methods for multicomponent heat transfer simulations.

Stochastic quantification of relative permeability in rough fractures using the phase-field lattice Boltzmann method

Dmytro Sashko¹, Travis R. Mitchell¹, Łukasz Łaniewski-Wołk², and Christopher R. Leonardi¹

¹ School of Mechanical and Mining Engineering, The University of Queensland, St Lucia QLD 4072, Australia

² Institute of Aeronautics and Applied Mechanics, Warsaw University of Technology, Warsaw, 00-665, Poland

Two-phase flow in fractures is critical to numerous industrial processes, including oil and gas production, CO₂ sequestration, and geothermal energy production and storage. Robust prediction of two-phase fracture flow, such as water and gas transport in coal seam gas (CSG) reservoirs, requires reliable relative permeability data. Despite this, contemporary models for two-phase permeability often rely on oversimplified representations of individual fractures, which typically treat them as a homogeneous porous medium or smooth parallel plates. Such assumptions neglect the geometric randomness and multiscale roughness that govern real fracture behaviour and introduce cumulative errors in the prediction of flow at the scale of a single fracture, a fracture network, and a reservoir. This work presents a simulation-based statistical methodology to derive physically grounded estimates of two-phase flow in rough fractures. A three-dimensional phase-field lattice Boltzmann method [1] is employed to resolve immiscible fluid displacement while accurately representing wettability effects. Multiple wetting boundary condition formulations are validated, and a modified boundary treatment is introduced to mitigate the staircase artefacts associated with Cartesian fracture representations [2]. Comparison with available experimental observations demonstrates the accuracy and robustness of the developed boundary conditions and phase-field model. To support large-scale stochastic simulations, new metrics are introduced for assessing phase-field convergence, and the topological structure of steady-state phase distributions is analysed to construct reliable initialisation procedures across many fracture realisations. Using synthetic fractures generated from representative coal surfaces with varying correlation lengths and roughness statistics, stochastic permeability–saturation curves are produced and examined. The resulting permeability distributions exhibit multi-modal, non-Gaussian behaviour at fixed saturations, arising from the coexistence of different flow regimes, including phase entrapment and concurrent two-phase flow. The probability of phase trapping, and thus the shape of the permeability distribution, is shown to depend strongly on fracture roughness, correlation properties, capillary number, and wettability. Notably, increased surface wettability reduces mean gas permeability while enhancing flow-path tortuosity. In its totality, this work advances the understanding of two-phase flow in complex fracture geometries and provides a foundation for upscaling these insights to fracture-network and reservoir-scale models.

References:

[1] T. R. Mitchell, C. R. Leonardi, A. Fakhari (2018) Development of a three-dimensional phase-field lattice Boltzmann method for the study of immiscible fluids at high density ratios, *International Journal of Multiphase Flow* 107, 1-15.

[2] D. Sashko, T. R. Mitchell, Ł. Łaniewski-Wołk, C. R. Leonardi (2025) Phase field lattice Boltzmann method for liquid-gas flows in complex geometries with efficient and consistent wetting boundary treatment. *Computers & Mathematics with Applications* 186, 101-129.

A pore-resolved interface tracking algorithm for multiphase flow in porous media

Zhongzheng Wang

School of Mechanical, Medical and Process Engineering, Faculty of Engineering,
Queensland University of Technology, QLD 4001, Australia

Understanding multiphase flow in porous media is important in many engineering applications, including carbon geo-sequestration, PEM electrolyzers, and microfluidic devices. In numerical simulations, it is essential to capture pore-scale physics to accurately predict the fluid transport process. However, conventional CFD methods are often computationally demanding. Here, we present a pore-resolved interface tracking algorithm (ITA) for simulating immiscible fluid displacement process in porous media. The algorithm is about two orders of magnitude faster compared with conventional methods, while producing consistent results. The algorithm thus provides a powerful computational tool for upscaling pore-scale results to continuum models in heterogeneous porous media, while also facilitating the design of artificial porous materials for precise control of fluid transport processes.

Carotid Artery Stenosis: A Haemodynamic Investigation

Howard Young, Tracie J. Barber, and Ramon L. Varcoe

School of Mechanical and Manufacturing Engineering UNSW Sydney

To better understand the relationship between haemodynamics and the risk of stroke for asymptomatic patients with carotid artery stenosis, a pipeline was developed, involving patient data collection, computational flow modelling, flow visualisation, and particle image velocimetry (PIV) experiment.

Segmentation of computed tomography (CT) scans collected from patients (ethics form HREC reference number 2024/ETH00544) allows a 3D reconstruction of the blood vessel, while ultrasound scans provide the flow boundary conditions of the artery. A patient-specific computational flow study can then be run, with wall shear stress (WSS) and oscillatory shear index (OSI) being the parameters of interest, which are known indicators related to disease progression.

An experimental study was setup, which involves flow of blood-mimicking fluid in a stenosis phantom, flowing at equivalent heart rates of 63 to 138 beats per minute. Using polyamide particles and a laser sheet, flow structures and trends in the computational model were replicated in the flow visualisation test.

This includes acceleration, which was estimated based on temporal streamlines traced by the particles. The maximum velocity occurred at the stenosis, as suggested by the computational model. 3D vortices were also captured downstream of the stenosis when examined frame-by-frame, as the computational model also suggested.

A PIV experiment is planned to quantify the flow parameters accurately. A study on endothelial cell behaviour due to flow dynamics is also planned. The end goal is to build a prediction tool that can aid in treatment planning for carotid artery stenosis patients.

Recent Advances in Particle-Based Modelling of Multiphase Flow and Large Deformation in Porous Media

Ha Bui

Department of Civil and Environmental Engineering, Monash University, Clayton,
Victoria 3800, Australia

Flow through porous media undergoing large deformation is central to many natural and engineered systems, including rainfall infiltration, internal erosion, debris flow initiation, and thaw-induced ground instability. These processes are governed by strongly coupled multiphase interactions between solid skeletons, pore fluids, and, in some cases, thermal effects and phase change, posing significant challenges for both physical modelling and numerical simulation. This talk presents recent advances in particle-based, mesh-free modelling of flow through deformable porous media, using a unified Smoothed Particle Hydrodynamics (SPH) framework. The approach enables seamless simulation of multiphase flow, solid-fluid interaction, and large deformation without the need for mesh remeshing or interface tracking. Novel formulations for unsaturated flow, internal erosion, and frozen-thawing porous media are introduced, allowing pore-scale and continuum-scale mechanisms to be captured within a consistent particle representation. Through a series of examples, including rainfall infiltration leading to slope failure, erosion-driven embankment collapse, and post-failure granular flow, the talk demonstrates how particle methods provide new insight into flow-deformation coupling, phase transitions, and evolving permeability in porous media. The results highlight the growing role of particle approaches in advancing predictive modelling of complex flow processes and supporting resilient infrastructure design under extreme environmental loading.

A Lattice Boltzmann Method for Two- and Three-Dimensional Velocity-Vorticity Formulations of Generalized Newtonian Fluids in Non-Porous and Porous Media

Gholamreza Kefayati

School of Engineering, University of Tasmania, Hobart 7001, Tasmania, Australia

This study presents a unified lattice Boltzmann framework based on the velocity–vorticity (V–V) formulation for simulating generalized Newtonian fluids (GNFs) in both non-porous [1] and porous media [2] under two- and three-dimensional conditions. Departing from the traditional pressure–velocity (P–V) formulation, the proposed finite-difference lattice Boltzmann method (FDLBM) eliminates the need for solving the Poisson equation for pressure, thereby improving computational efficiency and maintaining incompressibility more naturally.

For non-porous domains, the macroscopic equations governing momentum, energy, and concentration are developed for Newtonian, power-law, and viscoplastic fluids. The corresponding LBM accurately reproduces these macroscopic equations and demonstrates strong agreement with benchmark results while substantially reducing computational time compared to earlier models. The method is further extended to porous media using the representative elementary volume (REV) scale formulation, where the velocity–vorticity transformation simplifies the governing momentum equations into a convection–diffusion type. This modification results in a linear equilibrium distribution function and significant time savings without compromising accuracy. For the three-dimensional case [3], the method is extended by employing a modified equilibrium distribution function distinct from that used in the two-dimensional formulation. The vortex stretching term, inherent to three-dimensional velocity-vorticity dynamics, is incorporated through a newly introduced quadratic relation.

References:

- [1] G. Kefayati, Implementing vorticity–velocity formulation in a finite difference lattice Boltzmann method for two-dimensional incompressible generalized Newtonian fluids, *Phys. Fluids* 36 (2024) 013128. (Editor’s Pick) doi.org/10.1063/5.0230926
- [2] G. Kefayati, Integration of vorticity–velocity formulation in a lattice Boltzmann method for porous media, *Phys. Fluids* 36 (2024) 043607. (Editor’s Pick) doi.org/10.1063/5.0196973
- [3] G. Kefayati, Three-dimensional vorticity–velocity formulation in a lattice Boltzmann method, *Phys. Fluids* 36 (2024) 093121. (Editor’s Pick) doi.org/10.1063/5.0230926

Bridging Elastic and Active Turbulence with a Hybrid Lattice Boltzmann Method

Vedad Dzanic

Queensland University of Technology, School of Mechanical, Medical, and Process Engineering, Faculty of Engineering, QLD 4001, Australia.

Chaotic flow states can arise even in the absence of inertia when internal microstructural stresses dominate the dynamics. Two prominent examples are elastic turbulence in viscoelastic fluids composed of deformable polymers and active turbulence in active nematic systems, such as bacterial suspensions and epithelial cell layers. Both systems have previously been thought of as two separate distinct phenomena. In this talk, I present a hybrid lattice Boltzmann framework that bridges these two classes of inertialess turbulence. By establishing a continuum-level mapping between polymer constitutive equations and active nematic hydrodynamics, I show that stretched polymers can be interpreted as a deformable, contractile active medium with an effective, spatiotemporally varying activity. Numerical simulations of Kolmogorov flow reveal the emergence of the well-known traveling arrowhead structures in elastic turbulence, which are accompanied by the formation of $\pm 1/2$ topological defects in the polymer director field—hallmarks of active turbulence. This unified perspective provides new physical insight into polymer-driven flows and offers a flexible computational framework for studying hybrid passive–active soft matter systems.

How grain shape matters in granular flow

Lu Jing

Institute for Ocean Engineering, Shenzhen International Graduate School, Tsinghua University, Shenzhen, 518055, China

Grains in nature and industrial environments are nearly always non-spherical, but our understanding of how the grain shape affects granular flow is largely primitive. Here we use inclined chute flow as an example and find a velocity scaling law that unifies experimental and simulation data across vastly different granular materials, consisting of grains with spherical, cubic, pyramidal, elongated, flat, angular, or realistic shapes (including natural sand). The scaling law is simpler than existing ones in that it relies only on a single, easily measurable physical bulk parameter of the granular material: the dynamic angle of repose. We discuss the microscopic origin of this apparent unification and point out possible gaps in existing granular flow theories. Finally, we extend the current work and present preliminary results of shape-induced segregation in size-monodisperse but shape-bidisperse granular mixtures.

Particle-scale observations of internal erosion using transparent soil imaging

Adnan Sufian¹ Yingyi Zhang^{2,3} Alexander Scheuermann³

¹ University of New South Wales, Sydney, Australia

² SMEC Australia, Brisbane, Australia

³ University of Queensland, Brisbane, Australia

Internal erosion is the detachment and transport of finer particles within a soil due to seepage. The internal erosion process is governed by particle-scale mechanisms which are challenging to observed experimentally. In this study, transparent soil imaging was used to make quantitative measurements of particle settlement and pore flow fields during internal erosion. Transparent soils are a refractively index matched combination of a solid and fluid phase which enabled optical accessibility within the internal sections of a sample. This study considered the combination of borosilicate glass beads and an oil mixture as the transparent soil and conducted experiments using a permeameter to investigate the filtration mechanism of internal erosion. The experiments considered different base-filter combinations that spanned from the no erosion to continuing erosion case and considered different rates of hydraulic loading. The particle-scale data extracted from the experiments were (i) particle displacement with the aid of a new particle detection algorithm based on image segmentation and RANSAC; and (ii) pore flow field using particle image velocimetry. Larger particle displacements were noted with increasing flow velocity and larger base-filter size ratios, while variability in displacements were correlated with local pore geometry structure. The time-averaged pore flow field where in good agreement with the macroscopic seepage velocity and a procedure was outlined to obtain an estimate of the local seepage velocity based on planar porosity obtained from the transparent soil images. These particle-scale observations provide insights into the internal erosion processes but also serve as useful data to calibrate numerical particle-based approaches for simulating internal erosion.

Scale dependence of segregation patterns in the filling of silos

Shivakumar Athani¹ Benjy Marks¹ François Guillard¹ Alistair Gillespie² Itai Einav¹

¹ School of Civil Engineering, The University of Sydney, Sydney 2006 NSW, Australia

² Rio Tinto, Brisbane, Queensland, Australia

Size segregation in granular flows is a well-known phenomenon: laboratory experiments consistently show that large particles migrate toward silo walls during filling, while smaller particles concentrate near the center. Paradoxically, field observations in large-scale industrial silos often report the opposite pattern, challenging these findings. We demarcate these patterns through a systematic experimental study spanning a range of dimensionless numbers relevant to bidisperse granular flows in quasi-2D silos under both dry and immersed conditions, varying container geometry and fluid viscosity. Image analysis reveals that the observed patterns are governed by two key dimensionless parameters: the slenderness of the silo and the Stokes number, which encapsulates the balance between particle inertia and viscous drag. Our results demonstrate the role of fluids on segregation dynamics and provide a unified scaling framework that reconciles laboratory- and field-scale observations in air.

DEM Study of An Irregular-Shaped Intruder in Granular Media

Mingrui Dong^{1,*}, Deheng Wei^{1,2}, Lu Jing³, Yu Chen¹, Yixiang Gan¹

¹ School of Civil Engineering, University of Sydney, Australia

² State Key Laboratory of Intelligent Deep Metal Mining and Equipment, School of Resources and Civil Engineering, Northeastern University, Shenyang 110819, China.

³ Institute for Ocean Engineering, Shenzhen International Graduate School, Tsinghua University, Shenzhen, 518055, China

* Presenting Author: mingrui.dong@sydney.edu.au

Granular drag, the resistance experienced by solid intruders moving through dense granular media is a fundamental problem in granular physics with relevance to geophysical processes, subsurface penetration, and granular locomotion. While granular drag has been widely studied for simple geometries, the influence of irregular surface morphology on drag behaviour and particle-scale dynamics remains less well understood, particularly in three-dimensional confined systems.

Here, we use three-dimensional discrete element method (DEM) simulations to investigate the drag experienced by irregular-shaped intruders moving laterally through a dense granular bed under constant confinement. Intruder geometries are generated using spherical-harmonic parameterisation, enabling systematic control of multiscale surface roughness while preserving intruder volume and characteristic length scales.

The simulations reveal distinct velocity-dependent drag regimes, including quasistatic, intermediate, and inertial regimes. Irregular intruders consistently experience larger drag forces than spherical intruders; however, when expressed in dimensionless form using the drag coefficient and Froude number, results for different morphologies collapse over a broad velocity range, indicating a secondary role of surface morphology outside the inertial regime.

Particle-scale analysis shows that increasing velocity is accompanied by a progressive reduction in contact durations, weakening of force-chain structures, and localisation of momentum transfer near the intruder through short-lived collisions. These results demonstrate a continuous evolution of force-transmission mechanisms with velocity rather than a sharp transition between regimes.

Numerically Exploring Inertialess Multiphysics: from Fundamentals to Applications

Emilie Sauret

Queensland University of Technology, Brisbane, Australia

Complex fluids play a central role in many modern engineering and scientific applications, from high-density working fluids in renewable thermodynamic cycles to viscoelastic and inertialess flows in microfluidic devices and biological suspensions. These systems are often governed by strongly coupled transport processes, such as multiphase transport, heat and mass transfer, and electrohydrodynamics, phenomena that are often challenging to model accurately with conventional continuum-based methods.

In this presentation, I will focus on the use of the lattice Boltzmann method (LBM) as a computational framework for simulating complex fluids under such inertialess, multiphysics conditions. The mesoscopic nature of LBM makes it especially well-suited to resolving the interplay between flow, structure, and transport across scales where traditional CFD struggles. Overall, this work demonstrates how LBM can enable predictive, efficient simulations across a wide range of applications, from energy systems to biological and soft matter flows, and supports the optimisation of engineering designs in multiphysics environments.

Inhalation Dynamics and Deposition of Cigarette-Derived Microplastics in a CT-Resolved Human Airway Model

Suvash C. Saha*, Xinlei Huang

University of Technology Sydney (UTS), Sydney, Australia

*Presenting author: Suvash.Saha@uts.edu.au

Background

Microplastics (MPs) have been detected in air and human respiratory specimens, establishing inhalation as a credible exposure pathway. Conventional cigarette smoking introduces an additional, potentially direct route for MP inhalation via particles originating from filters and/or tobacco matrices. However, the transport and deposition of cigarette-borne MPs in anatomically realistic airways under transient smoking puff profiles remain insufficiently quantified, particularly for non-spherical, elongated MPs whose orientation-dependent aerodynamics may alter regional dosimetry.

Methods

We developed a computed-tomography (CT) based respiratory tract model spanning from the nasal/oral inlet to the 13th bronchial generation to preserve anatomically driven flow features (curvature, area change, bifurcation carinae) that govern inertial impaction and secondary flows. Airflow was simulated using a finite-volume solver with the $k - \omega$ shear-stress transport (SST) turbulence closure, coupled to a one-way Eulerian–Lagrangian discrete phase model (DPM) for MP tracking. Three transient puffing profiles (fast, intermediate, slow) were prescribed to represent realistic variability in puff flow rate and duration. MPs with equivalent-volume diameters $d_p \in [1, 100] \mu\text{m}$ were simulated for four polymer categories. To capture non-spherical effects, elongated MPs were represented via a cylinder-equivalent parameterization using experimentally measured circularity and eccentricity to compute a shape factor ϕ , which enters a non-spherical drag correlation through coefficients (b_1, b_2, b_3, b_4) .

Results

Across all puffing conditions, MPs predominantly deposited in the conducting airways by end-inhalation, with a strong dependence on puff intensity. Total deposition decreased monotonically from fast to slow puffing (98.63% \rightarrow 96.78% \rightarrow 94.15%), indicating that gentler inhalation reduces proximal filtering and increases through-transport to distal regions and beyond the modeled outlets. The oral cavity acted as a dominant “inertial filter” under fast puffing, accounting for 95.58% of all released particles (96.91% of deposits). As puffing slowed, oral deposition declined (90.04% then 76.84%), while deposition shifted downstream: deposition in the upper airway excluding the oral cavity increased from 2.35% to 5.65% to 15.74%, and lower-airway deposition increased from 0.70% to 1.09% to 1.57%. Consistently, the escaped fraction increased with slower puffing (1.35% \rightarrow 3.19% \rightarrow 5.84%), implying enhanced distal penetration. These trends follow classical scaling via an effective Stokes number ($Stk \propto d_p^2 U$); higher characteristic flow speed U amplifies inertial impaction at the oropharyngeal bend and laryngeal jet, producing intense proximal hot spots on carinal ridges and outer walls. Lower U reduces overshoot, increases residence time, and promotes gravity-assisted settling and deposition across successive bifurcations, thereby “distalizing” deposition. Risk-relevant analysis using a risk contribution fraction metric, $RCF = (N_{deposit} + N_{out})/N_{in}$, indicated that sub-5 μm MPs dominate

tracheobronchial and deep-lung relevant exposure, with the highest RCF under slow puffing and a sharp decline as diameter increases.

Significance

This work provides a mechanistic, anatomy-faithful quantification of cigarette-derived MP inhalation dosimetry under transient smoking waveforms, incorporating non-spherical particle effects. Results suggest two distinct exposure regimes: (i) rapid puffs concentrate MP loading in the mouth–throat and laryngeal regions (high local impaction and hot-spot formation), whereas (ii) slower puffs promote distal penetration of fine MPs, increasing lower-airway deposition and through-transport toward deeper lung regions where clearance is slower. These findings support exposure assessment efforts and may inform harm-reduction strategies and regulatory frameworks targeting MP release from tobacco products.

Numerical Modelling of Bubbling Rayleigh-Bénard Convection Using OpenFOAM

Fangming Zhai, Michael Heisel, Chengwang Lei

School of Civil Engineering, The University of Sydney

The rapid advancement of artificial intelligence (AI) has made power electronics indispensable, yet their efficiency is inherently constrained by resistive heating. Two-phase immersion cooling is a promising thermal management technique to prevent performance degradation due to overheating. It is a direct cooling system which involves boiling bubbles carrying latent heat from hot surfaces and releasing it through condensation. One of the simplified physical representations of the process is bubbling Rayleigh-Bénard convection (RBC). Accurate computational fluid dynamics (CFD) modelling of bubbling RBC is pivotal for elucidating the physical mechanisms of buoyancy-driven two-phase heat transfer and optimising system cooling efficiency.

In this study, we present an Eulerian-Lagrangian non-dimensional numerical model in OpenFOAM, derived from a classical dimensional bubbling RBC framework. The model accounts for bubble-induced buoyancy effects on convection and latent heat transport. Its dimensionless formulation ensures scalability and generalisation across diverse physical regimes; for example, the fluid momentum and thermal diffusion terms are characterised as functions of the Rayleigh (Ra) and Prandtl (Pr) numbers. We solve the continuous phases via an Eulerian approach and employ a Lagrangian particle tracking method to resolve the velocity, diameter, and trajectories of point-like spherical bubbles. Bubble dynamics are modelled by integrating forces including drag, lift, added mass, pressure gradient, and buoyancy, with the latter parameterised by a function of the Froude number (Fr). Two-way coupling is achieved via an additional source term in the momentum equation, reflecting the feedback of collective bubble force/momentum contributions within a fluid cell. Thermal exchange is resolved via Newton's law of cooling, with the bubble surface temperature maintained at saturation. The thermal exchange rate is parameterised by a surface Nusselt number (Nub) dependent on the bubble Péclet number (Peb) and the Jakob number (Ja). Based on the net heat exchange and the dimensionless latent heat of vaporisation, the bubble volume is updated, thereby enabling the modelling of bubble expansion and condensation. Finally, reciprocal heat exchange is incorporated into the fluid energy equation to ensure conservation. The model serves as a robust foundation for future studies on bubble/light-particle-laden flows and can be extended to incorporate additional mechanisms such as the variation of saturation temperature.

Multiphase Lattice Boltzmann Modelling of Gas Diffusion Electrodes: Applications towards CO₂ Electrolysis

Travis R. Mitchell

School of Mechanical and Mining Engineering, The University of Queensland, St.
Lucia QLD 4072, Australia
Associate Investigator, ARC Centre of Excellence for Green Electrochemical
Transformation of Carbon Dioxide
*Email: t.mitchell@uq.edu.au

Carbon dioxide (CO₂) electrolysis is a promising approach to convert a waste product that contributes to anthropogenic climate change into valuable carbon-based feedstocks. Industrial-scale implementation was initially hindered by the low solubility and diffusivity of CO₂ in aqueous electrolytes, limiting the mass transport of reactants to catalyst sites. To overcome these challenges, porous gas diffusion electrodes (GDEs) were used to facilitate direct gaseous transport to a layer of catalyst particles, significantly increasing achievable production rates. Despite their advantages, GDEs used in CO₂ electrolysis are prone to flooding, where electrolyte invasion blocks gas diffusion pathways, compromising system stability. Flooding represents a critical barrier to industrial adoption, requiring thorough characterisation of pore-scale dynamics to develop more effective GDE designs.

GDEs are employed in various applications outside of CO₂ electrolysis as they facilitate efficient mass transport in electrochemical devices such as fuel cells, electrolyzers, and metal-air batteries. The electrode itself consists of a porous catalyst layer supported by a conductive carbon-based gas diffusion layer with a hierarchical structure. The macroporous carbon fibre substrate facilitates bulk gas transport, while the micro-porous layer offers resistance to liquid penetration and supports the catalyst layer. However, cracks in the microporous layer can create pathways for liquid infiltration, thereby diminishing its capacity to prevent flooding. Liquid accumulation within the pore space remains a significant challenge, obstructing gas transport and limiting performance. Computational modelling has emerged as a valuable tool for understanding, predicting, and optimising transport within these structures. However, simulating an entire electrode at pore-scale resolution is impractical even at the lab-scale. Consequently, determining a representative elementary volume (REV) is necessary for robust characterisation of transport in GDEs. The REV is the minimum domain size required for models (or experiments) to capture bulk transport properties of a material. In thin, porous materials like gas diffusion layers, the through-plane dimension is often insufficient for a meaningful representative volume, necessitating the definition of a representative elementary area instead. The conventional approach for determining this area relies on ensuring that average morphological properties become independent of domain size. However, this single-phase perspective does not account for the formation of complex multiphase flow patterns, which are critical to understanding flooding behaviour.

To address this challenge, the lattice Boltzmann method (LBM) was applied to evaluate the REV for both single- and multi-phase (relative) permeability in the carbon fibre substrates of commercially available gas diffusion layers. High-resolution X-ray computed tomography was used to reconstruct the samples and isolate the carbon

fibre substrate, with single-phase permeability first determined as a baseline. This presentation will detail the open-source lattice Boltzmann framework, TCLB, as well as the multiphase modelling approach employed to study electrolyte–CO₂ interaction in porous electrodes. The workflow for robust characterisation of electrode transport properties will be presented with current findings and limitations discussed.

Improving inkjet aerosol extraction

C. Dykstra¹ S.G. Mallinson^{1,2} G.D. Horrocks² J. Lawrence²

¹ University of New South Wales

² Memjet

During inkjet droplet ejection, the ejected slug of ink typically breaks into a main droplet and several smaller trailing droplets. The larger of these trailing droplets are often referred to as satellites, whilst smaller trailing droplets are called mist. The value of the Stokes number, Stk , for the main droplets is greater than unity, and these droplets are barely affected by the crossflow which can be induced by paper or head motion. The satellites and mist, collectively called aerosols, have $Stk \ll 1$, and are carried along by the flow which can cause several issues. Aerosols landing on the media, away from their intended location, can cause unwanted optical density variations. The interior of the printer can become fouled when aerosols land on interior surfaces; they can also cause undesirable backside marking of the media. If the aerosols leave the printer, this poses a serious health and safety risk if they are ingested by operators, users or customers. Thus, it is essential to capture the aerosols before they cause issues.

Here we present a numerical study of collection of aerosols by a simple angled duct connected to a larger plenum, with suction applied at the top of the plenum. Simulations are performed using a Navier-Stokes solver, coupled to a particle-in-cell (PIC) method, which also stores the landing location of injected droplets. First, we consider the region between the print and suction zones to be sealed to prevent escape of aerosols. Many printing systems are not easily sealed in between these zones, and the second part of the study examines how the lack of seal between print and suction zones impacts the effectiveness of the suction system. Specifically, we examine the effect of varying different aspects of the design on the total mass flux landing on the paper, walls and the suction port, as well as through the outlet port. One key feature is the addition of an air-jet or air-knife [1] to divert stray aerosols into the suction path. The following shows a comparison of the velocity magnitude on the centre-plane together with the location of the satellite droplets, for the case with the region between the print and suction zone open. The top left shows the uncontrolled case, without suction or air-jet; the bottom left shows what happens when suction is activated: a very low fraction of stray aerosols is captured in this case. The top and bottom right show the effect of adding an air-jet: for jet suction velocity larger than about 2 m/s, nearly all the stray aerosols are captured.

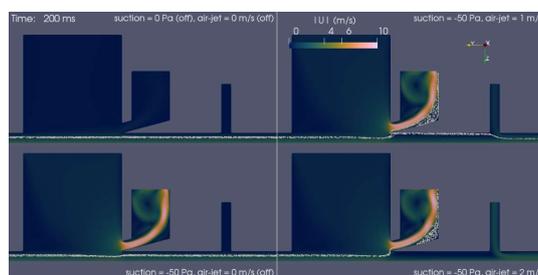


Figure 1. Comparison of aerosol capture for different scenarios.

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Evolution of Droplet Size in Aerosol Jet Printing Processing

Yang Zhang^{1,2} Qijun Zheng^{1,2,*} Shibo Kuang³ Xinni Tian^{2,4,5,*} Minsu Liu^{3,4} Zhouyou Wang³ Aibing Yu^{2,3} Feng Gu⁶

¹ Department of Mechanical and Aerospace Engineering, Monash University, Clayton, VIC 3800, Australia

² Monash-Southeast University Joint Research Institute, Suzhou, 215123, China

³ Department of Chemical Engineering, Monash University, Clayton, VIC 3800, Australia

⁴ Department of Materials Science and Engineering, Monash University, Clayton, VIC 3800, Australia

⁵ Monash Centre for Additive Manufacturing (MCAM), Monash University, Notting Hill, VIC 3168, Australia

⁶ Nanchang Key Laboratory for Advanced Manufacturing of Electronic Information Materials and Devices, Nanchang, 330013, China

Aerosol jet printing (AJP) technology enables high-resolution deposition of functional materials and is highly promising for additive manufacturing. The size evolution and control of droplets in the AJP process are vital for the printing quality, which is however seldom studied. In this work, Laser Particle Size Analysis and CFD simulation were conducted to measure the droplet sizes at the inlet and outlet of AJP, respectively, showing that the median droplet diameter varies significantly by up to 45.4% under the test conditions using a 300 μm nozzle. The CFD modelling demonstrates that, in water-based systems, the evolution of droplet size is fundamentally governed by the combined effects of coalescence and evaporation. Elevated humidity can suppress evaporation and promote coalescence, whereas higher temperature accelerates evaporation, narrows the droplet-size distribution, and enhances jet collimation. Inlet droplets smaller than 3 μm are easily entrained by the carrier gas and fail to deposit effectively, while larger droplets with higher Stokes numbers partially decouple from the gas stream, maintaining stable jet focusing. Stable and continuous line formation typically requires the mass-weighted mean droplet diameter to reach approximately 6 μm . At the process level, the gas flow rate crucially regulates the droplets size by mechanism of gas turbulence and droplet collisions, changing the median droplet diameter by up to 76.4% under different flow-rate conditions. These findings unveil the coupled roles of coalescence and evaporation in water-based systems and offer general principles for ink formulation and process optimization in next-generation additive manufacturing.

Performance of cyclic injections in soft granular media: Trapping efficiency and hysteretic behaviour

Haiyi Zhong¹, Zhongzheng Wang², Yixiang Gan^{1*}

¹ School of Civil Engineering, The University of Sydney, NSW 2006, Australia

² School of Mechanical, Medical and Process Engineering, Faculty of Engineering, Queensland University of Technology, QLD 4001, Australia

Carbon dioxide (CO₂) and hydrogen (H₂) storage in geological formations are two key approaches to reducing carbon emissions, with capillary trapping being the most efficient mechanism for ensuring storage security. Understanding the behaviours of immiscible fluid-fluid displacement in porous media is crucial for optimizing trapping efficiency. Previous studies have primarily focused on trapping behaviours in fixed rigid particles during single injections, which may fail to accurately predict trapping efficiency. This limitation arises because storage media can be relatively deformable under pressures reaching MPa, and cyclic injections, rather than single injection, are commonly encountered in the field. This study experimentally investigates the effects of particle deformability (*i.e.*, rigid and soft particles) on trapping behaviours during cyclic injections under quasi-2D conditions using a Hele-Shaw cell. Our results reveal significant differences in trapping behaviours between soft and rigid porous media. In soft porous media, gas bubbles evolve from cavities to ganglia, leading to a noticeable increase in residual saturation during cyclic injections. In contrast, rigid porous media exhibit initial pore invasion, with residual saturation remaining nearly unchanged throughout the cycles. Ultimately, soft porous media demonstrate higher storage capacity compared to rigid porous media. These findings provide valuable guidance for the development of more efficient geological gas storage strategies.

Modelling complex multiphase flow and reaction systems: Recent progress

Shibo Kuang

Process Technology Laboratory, Department of Chemical and Biological Engineering, Monash University, VIC, 3800, Australia

Multiphase flow and reaction systems play a critical role in many industrial and natural processes. They are characterised by strong coupling among fluid flow, heat and mass transfer, phase change, chemical reactions, and related phenomena across a wide range of spatial and temporal scales. Owing to this inherent complexity, experimental investigation alone is often insufficient to adequately resolve the underlying mechanisms to effectively guide industrial applications. Numerical modelling has therefore become an increasingly important and complementary tool, enabling detailed interrogation of process behaviour, improved understanding of dominant transport and reaction phenomena, and informed development of optimisation and control strategies. This presentation reviews recent progress from our research group in mechanistic modelling complex multiphase flow and reaction systems, with selected representative examples including ironmaking blast furnaces, reactors fuelled by large biomass particles, emerging low-carbon reactors, non-Newtonian suspension flows, and tribocharging of non-spherical particles. In addition, recent efforts to integrate data-driven and artificial intelligence–based approaches with physics-based models are discussed, highlighting emerging opportunities for rapid visualization of complex internal system states and for enabling online monitoring and control of complex multiphase systems.

X-ray radiography-based 4D particle tracking of heavy spheres suspended in a turbulent jet

Olga Stamati, Benjy Marks, Edward Andò, Stéphane Roux, Nathanaël Machicoane

School of Civil Engineering, The University of Sydney, NSW 2006, Australia

X-ray imaging is a non-invasive method that can be used to observe tracer particles in an ambient fluid. In this work, the radioSphere technique was used to track multiple heavy spheres in an upward turbulent jet, to capture a time-resolved 3D trajectory of each individual sphere. The 3D + time kinematics yield the evolution of the statistics of the position and velocity of the spheres as a function of the number of spheres and for two jet Reynolds numbers studied. Drastic changes in behaviour occur when many spheres are present, leaving a clear signature on the temporal dynamics.

Transition between buoyancy- and Coulomb-dominated regimes in Rayleigh-Bénard convection with an additional side-heated wall and charge injection

Jiachen Zhao, Zhongzheng Wang, Yuantong Gu, Emilie Sauret

School of Mechanical, Medical and Process Engineering, Faculty of Engineering,
Queensland University of Technology, Brisbane, 4001, QLD, Australia

A unified lattice Boltzmann method (LBM) is employed to investigate Rayleigh–Bénard convection (RBC) subjected to sidewall heating and unipolar charge injection from the bottom wall. The study focuses on how the complex and nonlinear coupling between the buoyancy and Coulomb effects modify the heat transfer, flow structure, and the transition between buoyancy- and Coulomb-dominated regimes. The results show that a side-heated wall, in the absence of charge injection, enhances the heat transfer rate and changes the scaling law between the Nusselt number Nu and Rayleigh number Ra from $Nu = 0.22Ra^{0.29}$ (classical RBC) to $Nu = 0.56Ra^{0.22}$ due to an additional buoyancy effect from the sidewall. When the electric charge is injected from the bottom wall, it is shown that the thermal boundary layer thickness decreases, leading to a further enhancement of heat transfer. Furthermore, systematic simulations over a broad range of Ra and electric Rayleigh numbers T reveal that, at given T , Nu remains constant when Ra is low, indicating a Coulomb-dominated regime. Beyond a critical value of Ra , a power-law relationship between Nu and Ra emerges, signifying a transition to the buoyancy-dominated regime. This transition can be well predicted by a dimensionless parameter, which is developed considering buoyancy to Coulomb forces. In addition, by analysing the flow structure using the Fourier mode decomposition, a phase diagram describing the dominant flow modes is proposed. The results demonstrate that the proposed dimensionless parameter not only delineates the transition between the two heat transfer regimes but also accurately captures the flow mode shift. Our findings offer new insights into the complex interaction between buoyancy and Coulomb effects and their influence on heat transfer and flow structure, with potential implications for the design of heat exchangers aimed at actively and efficiently controlling heat transfer.

Modeling of Particle Agglomeration in Flash Ironmaking Based on Natural Gas Combustion in a Mini-Pilot Reactor

Jiayi Wang, ^{1,2,3*} Qiang Zheng, ^{1,2} Tim Evans, ² Sunny Song, ² Xiaoping Guan, ³ Ning Yang ³ and Shibo Kuang ^{1,2}

¹ Process Technology Laboratory, Department of Chemical and Biological Engineering, Monash University, Clayton, VIC, 3800, Australia

² ARC Research Hub for Smart Process Design and Control, Department of Chemical and Biological Engineering, Monash University, Clayton, Victoria, 3800, Australia

³ State Key Laboratory of Mesoscience and Engineering, Institute of Process Engineering, Chinese Academy of Sciences, Beijing 100190, PR China

*Corresponding author: Jiayi.wang3@monash.edu (J. Wang)

Flash ironmaking represents a highly promising pathway for low-carbon steel production, owing to its rapid reaction kinetics, direct utilization of iron ore fines, and compatibility with hydrogen-based reductants. These advantages make it an attractive alternative to conventional ironmaking routes, particularly in the context of future carbon-neutral steelmaking. However, as the technology progresses toward industrial implementation, new challenges emerge under high-temperature and high-concentration operating conditions. Among these, particle agglomeration is one of the most critical issues, as it can impair heat transfer, inhibit gas-solid reactions, and ultimately threaten reactor stability. To address these challenges, this study develops a comprehensive computational framework for simulating flash ironmaking under realistic operating conditions. A key contribution is the incorporation of a force-balance-based agglomeration model into an Euler-Euler two-fluid framework, enabling the simultaneous prediction of particle clustering, reduction behavior, and combustion processes. This model facilitates a systematic investigation of the effects of operating parameters, such as oxygen-to-fuel ratios, on both reduction efficiency and agglomeration intensity. The results reveal that while enhanced combustion accelerates particle heating, excessive oxygen input leads to pronounced temperature non-uniformity and severe particle clustering. Therefore, optimal process performance requires a careful balance between thermal input and structural stability. Overall, this work provides a practical modeling tool and valuable insights for the design and operation of next-generation flash ironmaking systems.

Wall-modelled immersed boundary-lattice Boltzmann method and its applications

Fangbao Tian

School of Civil Engineering, The University of Sydney, NSW 2006, Australia

This presentation introduces a recent solver using the wall-modelled large eddy simulation in the immersed boundary-lattice Boltzmann method (IB-LBM). A few key elements are involved in this solver, including the multi-block lattice Boltzmann method, immersed boundary method (IBM), large eddy simulation (LES) and wall model. Regarding the LBM, both multiple-relaxation-time (MRT) and recursive regularized (RR) are implemented. The LES model includes both static and dynamic methods. An equilibrium wall model with both diffusive- and sharp-interface immersed boundary methods (IBMs) is incorporated into the IB-LBM to handle the turbulent boundary layer in high Reynolds number turbulent flows. When the wall model is applied near a rigid wall, an iterative strategy is required to handle the mismatching due to the consecutive implementations of wall models and multi-block information exchange. The performance of the solver is validated and verified by a few benchmarks, i.e., turbulent flow in a channel, flow around a hull of submarine, flow around an Ahmed car model, flow around a circular cylinder and beyond. It is found that a diffusive-interface IBM with wall model is capable to achieve excellent results for the simulation of external flows around bluff objects but fails in the simulation of internal flows of underestimating the wall shear stress due to its extra dissipation. The sharp-interface IBM with the wall model predicts the internal flow very well but fails in some simulations of external flow around bluff bodies due to the failure in the separation flow modelling. Several applications of the solver will be introduced to demonstrate its versatility.

A 3D-PTV Algorithm for Characterizing Complex Vortical Flows Using Stereoscopic Shadowgraphy

Xiaohan Mei, Qian Wang*

School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai
200240, China

* Corresponding author: qianwang@sjtu.edu.cn

Three-dimensional particle tracking velocimetry (3D-PTV) has emerged as a forefront experimental tool for capturing complex flow structures. In the current study, an improved algorithm is proposed based on a two-view stereoscopic shadowgraph system. The algorithm, referred to as the neighboring particle correction–multi-scale displacement adaptive (NPC-MDA) particle tracking method, incorporates local particle information to refine trajectory predictions and employs a skip-frame tracking strategy to improve stereo matching for low-velocity particles, thereby significantly enhancing the robustness of the overall tracking process. Validation using synthetic data demonstrates a notable reduction in ghost particle and vector detection rates. The proposed approach was applied to the 3D measurement of the flow field induced by a low-aspect-ratio hydrofoil oscillating in still water. It successfully reconstructs 3D particle trajectories. The trajectories are interpolated onto a Cartesian grid to obtain the Eulerian velocity and vorticity fields, revealing the formation, evolution, and convection of coherent vortex structures during the hydrofoil's oscillation.

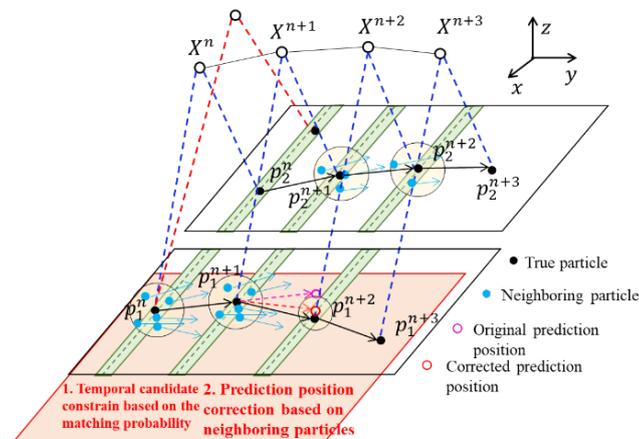


Figure 1 Schematic of the 3D particle tracking algorithm

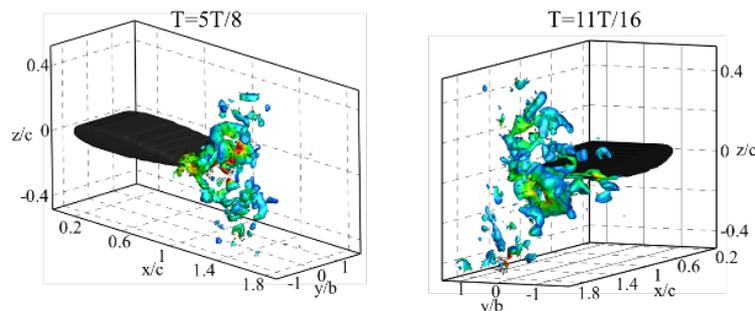


Figure 2 Three-dimensional vortex structures extracted using Q criterion

Anisotropy analysis of clay microstructure under shear using SAXS

Viet Khuyen Bui^{1,2}, Kenichi Soga², Itai Einav¹, François Guillard¹

¹ School of Civil Engineering, the University of Sydney, Sydney, NSW 2006, Australia

² Department of Civil and Environmental Engineering, University of California, Berkeley, USA

Small-Angle X-ray Scattering (SAXS) is a powerful non-destructive technique that provides information on the size and shape of particles in suspension and colloids, as well as the ordering and structure of their internal arrangement [1]. This makes it particularly relevant for clay materials, whose mechanical response is highly dependent on the micro-structure. SAXS has been used to study the consistency characteristics of Na-montmorillonite, which demonstrates its effectiveness in capturing micro structural details [2]. Moreover, when combined with a rheometer, SAXS can track particle orientation under shear conditions [3]. Here, we develop a novel method for analysing SAXS images which extracts the degree of orientation and preferred angles from SAXS images. This objective characterisation of the internal material fabric is applied to clay slurries sheared in a Couette cell under various shear rates and similar relative liquidity for three different clay minerals: kaolinite, halloysite and Na-montmorillonite. Kaolinite exhibits significantly higher anisotropy compared to halloysite and Na-montmorillonite and reaches its maximum anisotropy under a lower shear rate. The results of particle orientation including anisotropy ratio and angle of rotation provide experimental evidence of how fabric arranges itself during shearing. These results can inform and validate clay models, such as the thixotropy-viscoelastic models [4]. Beyond clay science, the methodology developed in this study opens new possibilities in broader materials science and nanotechnology for studying the size, shape and orientation of other particles and internal fabrics.

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A Gravity Modified Criterion for Particle Activity and Fabric Stability in Gap Graded Soils

Xiaoyi Wang, Mahdi Miri Disfani

Department of Infrastructure Engineering, The University of Melbourne, Parkville,
VIC 3010, Australia, xiaoyi.wang12@student.unimelb.edu.au

Internal erosion poses a significant threat to hydraulic structures such as earth dams and levees, with suffusion—the loss of fine particles from the soil skeleton—being particularly challenging to predict. The susceptibility of gap-graded soils to suffusion is fundamentally governed by the spatial distribution of fine particles and their mechanical participation in stress transmission. In natural deposits, gravitational sedimentation during formation produces vertically heterogeneous microstructures with fine particles preferentially concentrated in lower regions, a characteristic that significantly influences soil stability but is rarely captured in numerical simulations. Conventional Discrete Element Method (DEM) sample generation techniques typically produce idealized, homogeneous assemblies through simultaneous compression or radius expansion protocols, failing to replicate the gravity-induced segregation inherent in real geomaterials. This study develops a DEM sample preparation methodology that generates gap-graded granular assemblies with realistic, gravity-dependent fine particle distributions by temporarily immobilizing coarse particles to establish a stable skeleton while allowing fine particles to settle freely under incremental gravitational loading, followed by controlled release and isotropic consolidation. Parallel simulations are conducted under identical conditions with and without gravitational acceleration, enabling direct isolation of gravity effects on microstructural characteristics. The mechanical role of fine particles is quantified using coordination number metrics and stress reduction factors, with fine particles classified as active, semi-active, or inactive based on their contribution to the load-bearing skeleton, and a weighted formulation accounting for contact force magnitude is introduced to capture gravity-induced force chain heterogeneity. Results demonstrate that gravity effects are most pronounced under conditions of low confining pressure and low fine content, where gravity-enabled samples exhibit significant vertical segregation with elevated fine particle concentrations, higher coordination numbers, and increased proportions of mechanically active fines in lower regions, while gravity-free samples maintain uniform distributions throughout. However, under high confining pressure or high fine content conditions, the influence of gravity becomes limited and can be reasonably neglected, as the densely packed structure constrains particle rearrangement regardless of gravitational loading.

Evaporation in humid air: A tale of two sprays

Mogeng Li

School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney, Darlington, NSW 2008, Australia

Humidity in the ambient environment surrounding liquid droplets strongly influences their growth or shrinkage. However, when coupled with local temperature and vapour variations, the precise fate of a liquid droplet in a spray can be more complex.

In the first part of the talk, I will present a collaborative work on direct numerical simulations of a turbulent respiratory puff. We show that in cold, humid environments aqueous droplets can initially grow due to local vapor supersaturation within the puff, before eventually shrinking, departing from the classical picture of monotonic evaporation. A simple quasistationary jet model accurately predicts the onset of supersaturation.

In the second part, I will showcase experiments on turbulent sprays of highly volatile non-aqueous droplets (HFE-7000), which demonstrate the opposite trend: increasing ambient humidity accelerates evaporation. Here, water vapor condensation on the droplet releases latent heat, enhancing heat transfer and driving evaporation of the volatile liquid.

Insights from X-ray radiography and rheography for multiphase flows

François Guillard et al.

School of Civil Engineering, The University of Sydney, Sydney 2006 NSW, Australia

Many soft materials and complex fluids, such as granular media, geomaterials, foams, and suspensions, are optically opaque as they are composed of mixed phases that tend to scatter light. This makes them challenging to image experimentally, often limiting their observation to their boundaries or free surfaces. However, the material's state can be significantly influenced by wall effects, underscoring the need for non-invasive internal measurement methods. While many such methods have been developed over the years, such as X-ray and neutron tomography or refractive index matching, they all have significant limitations in terms of their temporal resolution and the types of materials they can accommodate.

In this talk, we will demonstrate the use of X-ray radiography to provide insight into materials with density fluctuations. Radiography can provide dynamic measurements in flowing materials, providing information on the density, particle size, shape, and orientation, as well as velocity through the use of a reconstruction algorithm coined rheography. We will showcase the use of X-ray radiography to develop our understanding of various systems of interest to industries ranging from material conveying to mining, and featuring dry granular flows, granular suspensions, and foams

A Novel HGD-CFD Framework for Efficient Simulation of Fluid-Particle Systems

Jiahuan Li, Alistair Gillespie, Matthew Cleary, Itai Einav, Benjy Marks

School of Civil Engineering, The University of Sydney, Sydney 2006 NSW, Australia

Computational modelling of granular flows is vital for optimising and controlling fluid-particle systems. Moreover, understanding how particle size distributions evolve over time provides key insights for enhancing process performance. However, existing discrete particle methods are limited by the number of particles that can be simulated. To address this gap, we introduce a novel numerical method that couples the stochastic Heterarchical Granular Dynamics (HGD) model with Computational Fluid Dynamics (CFD). The HGD component tracks the particles and their interactions, while the CFD component models the fluid flow. Coupling the two components allows to capture particle-fluid interactions. This coupled approach overcomes the computational limitations of traditional discrete particle methods while accurately tracking the population of particle sizes in space and time. Validation against benchmark cases demonstrates the method's effectiveness in capturing the dynamic behaviour of granular flows in fluids, offering a promising tool for advancing process design and optimisation.

Reconstruction of the pressure field in dense granular flow using physics-informed neural network

Yue Hu^{1,3} Yinghui Wu^{1,2} Aibing Yu^{1,2} Qijun Zheng^{1,3,*}

¹ Southeast University–Monash University Joint Research Institute, Suzhou, 215123, China

² ARC Research Hub for Smart Process Design and Control, Department of Chemical and Biological Engineering, Monash University, Clayton, Victoria 3800, Australia

³ Department of Mechanical and Aerospace Engineering, Monash University, Melbourne, VIC 3800, Australia

* Corresponding author: Qijun.Zheng@monash.edu

Granular flows are extensively witnessed in natural environments such as dunes in deserts and avalanches, and industrial applications such as transporting cement and grains. Measuring the inherent pressure fields is usually challenging in such flows. In this work, we utilise the physics-informed neural networks that solves the inverse problem of reconstructing the pressure field of granular materials using the data of velocity fields. The proposed Physics-Informed Neural Network for Modelling Granular Flow (GF-PINN) incorporates the Navier-Stokes equation and the $\mu(I)$ rheology of dense granular materials, and deploys a regularisation parameter λ to circumvent the divergence of the model. The results show that the GF-PINN enables the reconstruction of the pressure fields based solely on the velocity fields, with the L2 norm error of the reconstructed pressure field less than 10% under various configurations. Furthermore, GF-PINN can infer key material parameters of the $\mu(I)$ rheology directly from the field flow with an error range of less than 6%. In addition, the GF-PINN maintains good accuracy of pressure prediction until the noise intensity of velocity fields increases up to 0.5.

A Hybrid Solid–Sink Approach for Canopy Flow Modelling with the Lattice Boltzmann Method

I. M. Bugarin^{1*}, S. Armfield¹, M. Kirkpatrick¹ and N. Williamson¹

¹ School of Aerospace, Mechanical and Mechatronic Engineering, The University of Sydney, NSW, Australia

*Email: isadora.bugarin@sydney.edu.au

The present work proposes to validate the efficiency and fidelity of a simplified coupled solid-sink model solution for accurately capturing the effects of canopy on LES lattice Boltzmann simulations. Existing studies on flow simulation through vegetation typically represent tree canopies either as distributed momentum sink regions or as fully resolved solid geometries. While sink-based approaches sacrifice geometric detail, fully solid representations demand substantially higher mesh resolution and computational cost. The proposed model combines a drag-based sink term—parameterised by leaf area density (LAD) and leaf drag coefficients—for the canopy foliage with a simplified solid representation of tree trunks, thereby balancing geometric fidelity with computational efficiency. Two scenarios were considered to validate the turbulence statistics downstream of the canopy against wind tunnel experiments: a single tree and an array of twelve equally spaced trees. All simulations were carried out using waLBerla, a high-performance computational framework for Lattice Boltzmann Method (LBM) simulations, capable of handling complex geometries and large-scale turbulent flows.

Validation of waLBerla for Atmospheric Transport and Dispersion in Urban Environments: JU2003 Oklahoma City

Brendan Waters^{1,*}, Helen Schottenhamm², Michael Kirkpatrick¹, Ben Thornber^{1,3}

¹ School of Aerospace, Mechanical and Mechatronic Engineering, University of Sydney, Sydney, 2006, NSW, Australia

² IFP Energies nouvelles, 1 et 4 avenue de Bois-Préau, Rueil-Malmaison, 92852, France

³ School of Mechanical and Aerospace Engineering, Queen's University, Belfast, BT9 5AH, Northern Ireland

* Corresponding author: brendan.waters@sydney.edu.au

In this work, we present a coupled wall-modelled large eddy simulation (WMLES) solver, implemented within the open-source multi-physics framework waLBerla, for the prediction of atmospheric transport and dispersion (AT&D) phenomena in urban environments. The hydrodynamics of turbulent flows are modelled using a D3Q27 cumulant lattice Boltzmann method (LBM), while passive scalar transport is modelled via the MUSCL-Hancock Method (MHM) finite volume scheme. Validation is performed against the Joint URBAN 2003 (JU2003) experimental database for downtown Oklahoma City, considering the botanical garden release into a southerly approach flow.

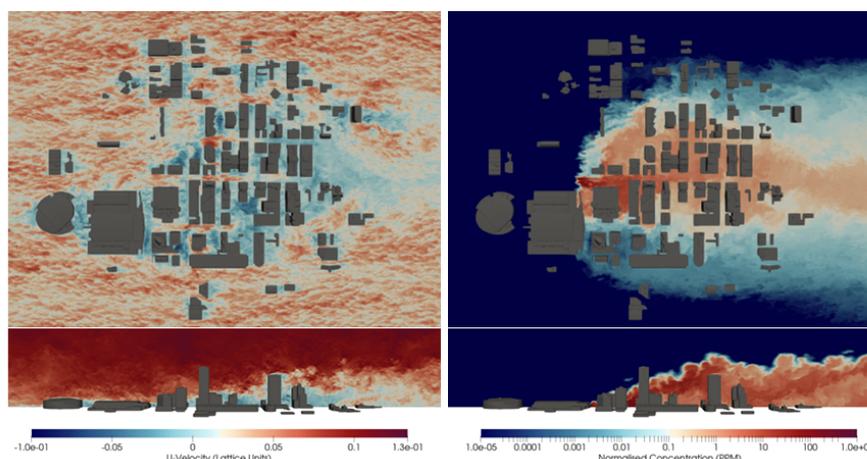


Figure 1: Q-criterion iso-volume (top), instantaneous velocity and concentration on xz -plane at $y_{SI} = 1\text{m}$, and xy -plane at $z_{SI} = 100\text{m}$ (bottom).

Numerical predictions show good agreement with experimental data, meeting or exceeding industry-standard performance criteria, despite minor geometric misalignment. Velocity statistics achieve $\text{FAC}_{1.3}$ accuracy at $\Delta x = 2\text{m}$ resolution, while concentration statistics achieve better than FAC_2 agreement. The computational performance of the implementation is assessed on both CPU and GPU-based HPC architectures, demonstrating near-linear strong scaling and weak-scaling efficiencies above $\eta > 90\%$ on up to 64 nodes. At the maximum tested capacity, over 250×10^9 updates /second is realised

Modeling powder agglomeration and biomass intraparticle temperature gradient in the industrial cement calciner

Qiang Zheng¹ Wei Wang² Shibo Kuang^{1,*}

¹ ARC Research Hub for Smart Process Design and Control, Monash University, VIC, Australia

² University of Chinese Academy of Sciences, Beijing, China

* Email: qiang.zheng@monash.edu, shibo.kuang@monash.edu

Using coarse biomass as fuel in cement calciners is key for reducing carbon emissions in the cement industry [1]. However, raw meal agglomeration and temperature gradients within large biomass particles limit calcination and combustion efficiency, causing downstream blockages and quality issues [2]. Current industrial-scale models neglect inter-particle adhesive forces and intra-particle temperature gradients, failing to accurately capture essential phenomena [3,4]. This work develops an integrated model addressing these limitations. First, this work develops an agglomerate-based method accounting for effects on flow, heat transfer, and reactions, validated in pilot and industrial coal-fueled calciners (**Figure 1(a)**). Subsequently, a sub-particle scale model is developed to capture real-time effects of intra-particle temperature gradients on heat transfer, reactions, and material properties, validated with single biomass and lab-scale reactor experiments (**Figure 1(b)**). These models are then incorporated into an industrial-scale multifluid framework and validated in biomass-fueled cement calciners (**Figure 1(c)**). Finally, an optimization method is proposed to achieve efficient raw meal calcination and biomass combustion. This work aims to address practical cement calciner operational challenges and advance carbon emission reduction in the cement industry.

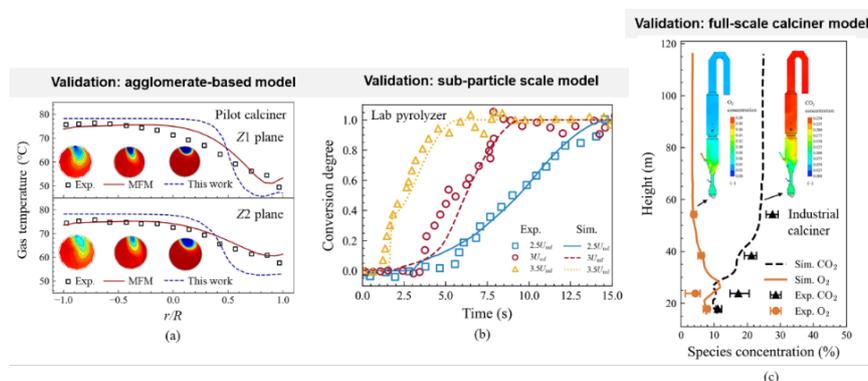


Figure 1. Model validation for (a) agglomerate-based model, (b) sub-particle scale model and (c) full-scale calciner model

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Higher order moments of scalar within a plume in a turbulent boundary layer

Kapil Chauhan

School of Civil Engineering, The University of Sydney, Sydney 2006 NSW, Australia

This talk will discuss the statistical nature of instantaneous scalar concentration in an elevated point-source plume (neutral or buoyant) dispersing within a turbulent boundary layer. Using high-frequency long-duration experimental measurements, the gamma distribution is extensively validated as the appropriate probability density function of concentration, particularly at large scalar magnitudes. The two-parameter gamma distribution is shown to capture the PDF at all locations across the plume. The classical similarity of the mean and root-mean-square (RMS) concentration, often expressed through a Gaussian form, is recovered through an equivalent similarity of the scale and shape parameters of the gamma distribution. In addition, the gamma distribution accurately reproduces the previously observed skewness–kurtosis relationship and the 99th percentile of the instantaneous concentration signal. Extended similarity is demonstrated for the third- and higher-order central moments and standardised central moments from the experimental data, with the gamma distribution framework also analytically extended to these statistics. The results emphasise the importance of achieving statistical convergence for the intermittent concentration signal, which is directly influenced by finite sampling times in a measurement. The results establish the gamma distribution as a consistent and unified model for all scalar concentration statistics in elevated point source plumes within a turbulent boundary layer, with physical arguments supporting the observations.

Numerical investigation on the role of topography in the transport of mineral dust in the atmosphere

Michael Heisel¹, Jasper F. Kok², Marcelo Chamecki²

¹ School of Civil Engineering, University of Sydney, Sydney Australia

² Department of Atmospheric and Oceanic Sciences, University of California Los Angeles, Los Angeles USA

Coarse and giant mineral dust (>5 micrometer diameter) is known to transport through the upper atmosphere across oceans and continents. These dust concentrations warm the planet through absorption of solar radiation and move mineral nutrients between ecosystems. Despite their importance, current global dust models significantly underestimate the presence of coarse and giant dust in the upper atmosphere, in part due to the poor understanding of the physical mechanisms responsible for the vertical transport of particles from the Earth surface to the upper atmosphere. This presentation explores the enhancement of dust transport due to hill topography whose size corresponds to the subgrid-scale of global models.

Large-eddy simulations and Lagrangian particle tracking are used to model the transport of dust particles in the atmospheric boundary layer. The simulations utilise the immersed boundary method to represent flat terrain, a 50-meter-tall hill, and a 100-meter hill. In post-processing, particles are introduced to instantaneous flow volumes from the simulations and the particle trajectories are evolved using a Lagrangian framework. Compared to the flat terrain, the hill topography substantially increases the number of particles reaching high altitudes (i.e. at least 200 meters above the surface). The topography is responsible for three key transport mechanisms: a strong upward mean wind on the windward side of the hill, ejection of particles downwind of the hill crest, and enhanced dispersion in the turbulent wake of the hill. The mechanisms combine to form an efficient pathway for coarse dust at the surface to reach high altitudes which is not parameterized in the subgrid-scale dynamics of global models.

List of Participants (1/2)

Name	Affiliation
Shivakumar Athani	The University of Sydney
Xiaoqian Bi	The University of Sydney
Isadora Montenegro Bugarin	The University of Sydney
Ha Bui	Monash University
Viet Khuyen Bui	The University of Sydney
Kapil Chauhan	The University of Sydney
Dongsheng Chen	The University of Sydney
Mingrui Dong	The University of Sydney
Vedad Dzanic	Queensland University of Technology
Yixiang Gan	The University of Sydney
Dong Geng	The University of Sydney
Yingjie Gu	The University of Sydney
Francois Guillard	The University of Sydney
Zineb Ouled Ben Hammad	The University of Sydney
Michael Heisel	The University of Sydney
Yue Hu	Southeast University-Monash University Joint Research Institute
Ryan Huang	Queensland University of Technology
Lu Jing	Tsinghua Shenzhen International Graduate School
Gholamreza Kefayati	University of Tasmania
Alireza Khoshnood	Queensland University of Technology
Timm Krüger	University of New South Wales
Shibo Kuang	Monash University
Liang Lei	Westlake University
Zhibin Lei	The University of Sydney
Chengwang Lei	The University of Sydney
Christopher Leonardi	University of Queensland
Morgan Li	The University of Sydney
Jiahuan Li	The University of Sydney
Qingchen Liu	The University of Sydney
Sam Mallinson	Memjet
Benjy Marks	The University of Sydney
George McBain	Nanosonics Limited
Travis R. Mitchell	University of Queensland
MB Nikila	The University of Sydney
Niklas Ribic	Karlsruhe Institute of Technology
Thomas Romeijn	Mineral Technologies
Suvash Saha	University of Technology Sydney
Emilie Sauret	Queensland University of Technology
Adnan Sufian	University of New South Wales

List of Participants (2/2)

Name	Affiliation
Fangbao Tian	University of New South Wales
Sergio Andres Galindo Torres	Westlake University
Zhongzheng Wang	Queensland University of Technology
Qian Wang	Shanghai Jiao Tong University
Jiayi Wang	Monash University
Xiaoyi Wang	The University of Melbourne
Brendan Waters	The University of Sydney
Yinghui Wu	Monash University
Howard Young	University of New South Wales
Fangming Zhai	The University of Sydney
Yang Zhang	Monash University
Jiachen Zhao	Queensland University of Technology
Jiayin Zhao	The University of Sydney
Qiang Zheng	Monash University
Haiyi Zhong	The University of Sydney