EPSRC
Engineering and Physical Sciences Research Council

UNIVERSITY OF LEEDS

Fluid Dynamics Symposium: Fluid Dynamics Modelling for Real World Applications

Programme

Wednesday 20th June 2018
09:30-15:45

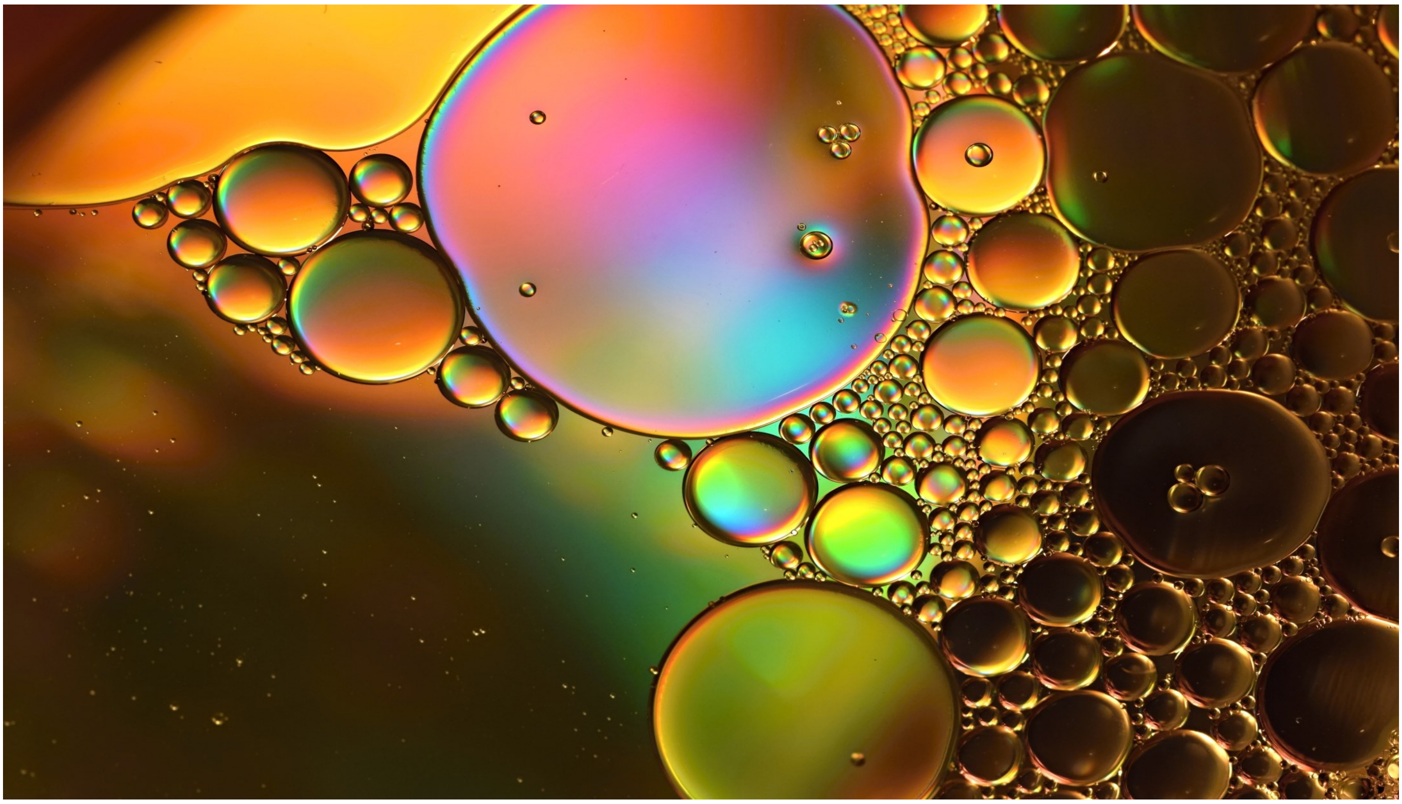
Welcome

Welcome to the Symposium:

Fluid Dynamics Modelling for Real World Applications

Recent years have seen exciting advances in modelling techniques in diverse areas of Fluid Dynamics, with benefits to society including applications in industry, geosciences, hazard prediction and weather forecasting. Advances include theoretical and mathematical innovations, as well as the efficient exploitation of new computational resources such as massively-parallel machines.

This symposium brings together leading researchers in different fields within Fluid Dynamics, to share latest results and ideas related to the modelling of real-world phenomena.



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Programme

Time	Activity	Presenter
09.30-10.00	Registration Tea/Coffee	N/A
10.00-10.05	Introduction	Prof Peter Jimack, University of Leeds
10.05-10.55	Talk: Turbulence in Electrically conducting fluids: from nuclear reactors to planetary cores and the experiments to model them	Prof Alban Potherat, University of Coventry
11.00-11.50	Talk: Turbulent dispersed flows in industry and environment	Prof Cristian Marchioli, University of Udine Italy
11.55-12.45	Talk: Boundary layers in quasilinear approximation	Prof Bruno Eckhardt, Philipps-Universität Malburg
12.45-13.30	Lunch	N/A
13.30-14.20	Talk: Understanding of boundary-layer processes and improving their representation in models using Large-Eddy simulations	Dr Fleur Couvreux, National Centre for Meteorological Research
14.25-15.15	Talk: Modelling and simulation of soft tissue mechanics and fluid-structure interaction	Prof Xiaoyu Luo, University of Glasgow
15.15-15.45	Tea/Coffee	N/A
15.45	Close	N/A

Speakers' Biographies and Abstracts

Prof Alban Potherat,
University of Coventry

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Alban Potherat is Professor of Fluid Mechanics at Coventry University. He obtained his PhD from Grenoble Institute of Technology (France) in 2000 for his derivation of novel equations for quasi-two dimensional flows based on an asymptotic approach. He then moved to Cambridge (UK), where he derived exact upper bounds for the number of degrees of freedom of MagnetoHydroDynamic (MHD) turbulence. He was appointed Junior Professor at the Technical University of Ilmenau (Germany) in 2004 and started a small group mainly supported by the Deutsche ForschungsGemeinshaft. The group worked on experimental and theoretical aspects of MHD flows at low magnetic Reynolds number, in particular, separated flows and the transition between two and three-dimensional MHD turbulence. In 2007, he took up a Readership at Coventry University, and became Professor in 2013. With support from the Royal Society and the Leverhulme Trust, he developed new approaches to the direct numerical simulation of MHD flows and worked on the magnetoconvection within the Earth's liquid core. In particular, he built a unique experimental model using a transparent electrolyte. In 2015, he was awarded a Wolfson Research Merit Award from the Royal Society in recognition of this work. Today, he continues to explore the properties of MHD turbulence, Alfven waves, Rotating flows and Rotating MHD convection, mainly by means of two experimental platforms hosted at the Grenoble High Magnetic Field Laboratory through a long term collaboration with the French CNRS. He also became interested in particulate flows and receives important support from industry to work on processes involving liquid metals.

Talk Title: Turbulence in Electrically conducting fluids: from nuclear reactors to planetary cores and the experiments to model them

Abstract:
Electrically conducting fluids and magnetic fields cross paths in a vast range of seemingly unrelated natural and man-made processes: from stellar disks and planetary interiors, to industrial processes in metallurgy and even in the design of the future nuclear fusion reactors. In each case, the electric currents induced by the motion of the fluid in the field drive electromagnetic forces that can radically alter all classical processes associated to fluid dynamics: boundary layers, convection, turbulence, but also heat and mass transfer. For example, the amount of heat extracted from the Earth solid core by the convection in its liquid core is tightly linked to the dynamics of the planetary magnetic field. In the cooling blankets of nuclear fusion reactors, the high dissipation incurred by the confinement field of the main reactor alters turbulence is so profoundly, that extracting heat from the reactor becomes a major technological challenge. In accretion disks, the very mechanism igniting the turbulence that is necessary for the creation of planets is through to be driven by an instability of electromagnetic origin. Understanding any of these phenomena requires a profound insight into the coupling between the dynamics of the magnetic field and fluid dynamics. From the experimental point of view, the challenge is made tougher by the opacity of most electrically conducting fluids, which are therefore significantly harder to probe than water or other transparent fluids.

In this lecture, we will review some of the most fascinating examples of MHD flows and showcase some of the very specific techniques, in particular experimental ones, that their study necessitates. We will illustrate some of the radical changes that a magnetic field can incur with two examples: we will first show how turbulence in high magnetic fields becomes so anisotropic that instead that of promoting small dissipative scales, it tends to favour large scales with entirely different properties in terms of dissipation and transfer. We will also show how using extreme magnetic fields helped us reproduce a scaled down model of the Earth core, where magnetoconvection can be visualised.

Prof Cristian Marchioli,
University of Udine Italy

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Prof Cristian Marchioli is an Associate Professor of Fluid Mechanics at the University of Udine, Italy. His research interests include modelling and simulation of turbulent dispersed flows; Eulerian-Lagrangian simulation methods; turbulence structure and modulation; and environmental fluid mechanics.

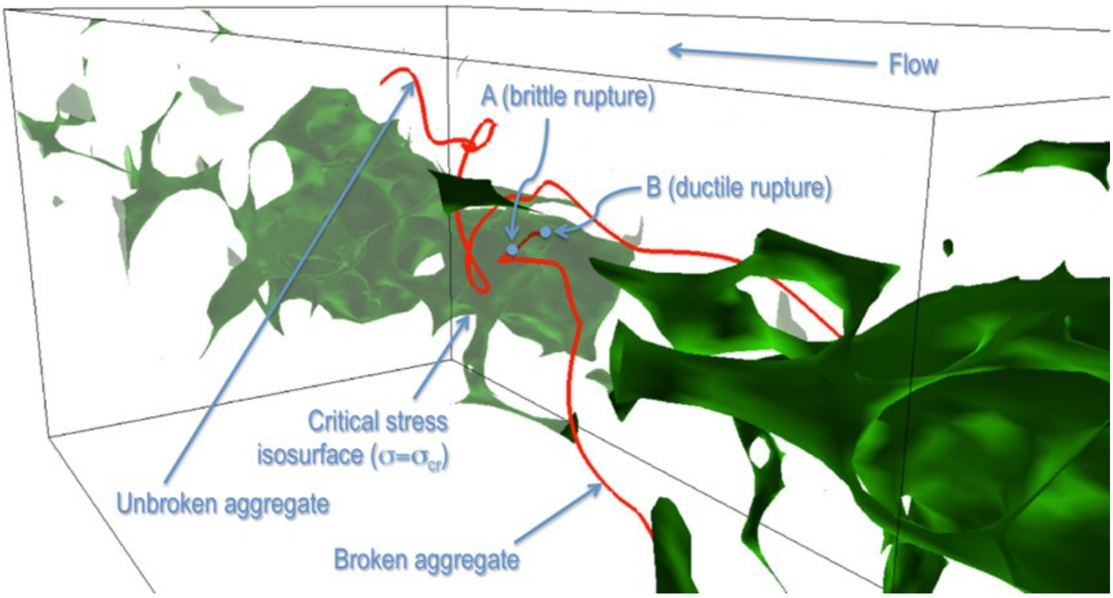
Talk Title: Turbulent dispersed flows in industry and environment

Abstract:
Turbulent fluids and small particles or droplets or bubbles are common to a number of key processes in energy production, product industry and environmental phenomena. In modelling these processes, the dispersed phase is usually assumed uniformly distributed. Indeed, it is not. Dispersed phases can be focused by turbulence structures and can have a time-space distribution which barely resembles prediction of simplified averaged modelling.

Preferential distribution controls the rate at which sedimentation and re-entrainment occur, reaction rates in burners or reactors and can also determine raindrop formation and, through plankton, bubble and droplet dynamics, the rate of oxygen-carbon dioxide exchange at the ocean-atmosphere interface. In this talk, we will review a number of physical phenomena in which particle segregation in turbulence is a crucial effect describing the physics by means of Direct Numerical Simulation of turbulence. We will elucidate concepts and modeling ideas derived from a systematic numerical study of the turbulent flow field coupled with Lagrangian tracking of particles under different modeling assumptions. We will underline the presence of the strong shear which flavors wall turbulence with a unique multiscale aspect and adds intricacy to the role of inertia, gravity and buoyancy in influencing particle motion [1]. We will describe the role of free surface turbulence in dispersing and clustering the light particles such as plancton [2, 3] and the role of the distribution of dissipation in non-homogeneous turbulence to control breakage rates of brittle and ductile aggregates [4].

Through a number of physical examples of practical interest such as boundary layers, free-surface and stratified flows, we will show that a sound rendering of turbulence mechanisms is required to produce a physical understanding of particle trapping, segregation and ultimately macroscopic flows such as surfacing, settling and re-entrainment.

Rendering of brittle and ductile rupture of colloidal aggregates in turbulent flow. The trajectory of two different aggregates is shown, superimposed onto the isosurface of the critical stress $\sigma = \sigma_{cr}$ required to produce brittle (instantaneous) rupture or activate ductile rupture (resulting from continuous deformation of the aggregate). The broken aggregate trespasses the σ_{cr} isosurface at point A (potential brittle rupture) and undergoes ductile rupture at point B (where the ductile breakage condition is met). The unbroken aggregate avoids all regions where $\sigma>\sigma_{cr}$ and does not break within the time window considered in this figure. Critical stress isosurface is taken at the time of ductile rupture. Aggregate trajectories are tracked several time steps backward from this time.



[1] Marchioli, C., and Soldati, A., 2002 "Mechanisms for Particle Transfer and Segregation in Turbulent Boundary Layer", J. Fluid Mech., 468, 283-315.
[2] Lovecchio, S., Marchioli, C., and Soldati, A. 2013 "Time persistence of floating particle clusters in free-surface turbulence," Phys. Rev. E, 88 033003.
[3] Lovecchio, S., Zonta, F. and Soldati, A., 2015 "Upscale energy transfer and flow topology in free surface turbulence," Phys. Rev. E, 91 033010.
[4] Marchioli, C. and Soldati, A., 2015 "Turbulent breakage of ductile aggregates", Phys. Rev. E, 91 053003.

Prof Bruno Eckhardt,
Philipps-Universität Malburg

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Prof Bruno Eckhardt is a theoretical physicist at Philipps-University of Marburg with an interest in fluid mechanics and nonlinear dynamics. He graduated from U Bremen and held positions at the Research Centre Jülich and Philipps-University of Marburg before being appointed Associate Professor at U Oldenburg and then Professor at U Marburg. Eckhardt's research covers all aspects of fluid mechanics and nonlinear dynamics, with a particular focus on the underlying fundamental concepts. The application of concepts from dynamical systems theory to the transition to turbulence in pipe flow and other shear flows lead to the identification of exact coherent structures in subcritical bifurcations, the demonstration of the transience of turbulence and the development of a chaotic repellor based transition paradigm. For higher Reynolds numbers, an analogy between three canonical flows, Taylor-Couette, Rayleigh- Bénard, and pipe flow, proofed useful in exploring similarities and differences between the flows. A synchronization model for the wobbling of the Millennium bridge provided the stimulus to study synchronization in bacterial flagella. This work eventually led to the identification of a new mode of bacterial locomotion, where the flagellum is wrapped around the cell body.

Current work focuses on the transfer of ideas that have proven useful in the context of transitional flows to higher Reynolds numbers. We have demonstrated how exact coherent structures at ever smaller scales appear as the Reynolds number increases, and we have used the quasilinear approximation to patch solutions at different length scales together. These ideas are the first steps towards the development of self-similar boundary layer structures that will be the topic of the talk.

Talk Title: Boundary layers in quasilinear approximation

Abstract:

The quasilinear approximation to the Navier-Stokes equation maintains a sufficient set of nonlinear couplings to give rise to complex dynamics and to reproduce several aspects of turbulent flows, as shown in several applications to geophysical flows. In 2-d, the equations become particularly simple and allow for a complete analysis of the stationary states and mean profiles. Specifically, the formation of ever steeper boundary layers can be connected to sequences of bifurcations in which additional contributions to the turbulent stresses come in. The structure of the equations is reminiscent of marginal stability theory, but goes beyond it in that it connects the mean profile with the structure of the neutrally stable modes of the mean profile, so that the stability of the profile and the shape of the profile can be determined self-consistently.

Dr Fleur Couvreux,
National Centre for Meteorological Research

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Dr Fleur Couvreux graduated as a meteorological engineer in 2002. In September 2005, she received her PhD degree in Atmospheric Physics at Toulouse University on the ‘water vapour variability in the continental convective boundary layer’. Since then, she has a position in the research centre of the French weather bureau, Meteo-France. Her research interests are on convective boundary layers in particular the understanding of the processes involved as well as the best way to represent them in Numerical Weather Prediction Models and Climate Models. To do so she uses Large-Eddy simulations in complement to observations to determine the key processes but also to determine parameterization-oriented diagnosis to help in the development of parameterizations (i.e. simplified way to represent the impact of processes that can not be resolved by the grid of model into the resolved variables). She has ~45 peer-reviewed papers.

Talk Title: Understanding of boundary-layer processes and improving their representation in models using Large-Eddy simulations

Abstract:

In this presentation, I will present some use of Large-Eddy simulations that correspond to numerical simulations of shallow clouds or clear boundary layer where most of the processes are resolved. After, a first description of such simulation and their main advantages and drawbacks, I will detail how they can be used both for the understanding of boundary-layer processes and for the improvement of their representation in models.

I will in particular detail a simulation of initiation of deep convection observed during the AMMA field campaign that occurs over West Africa. With such a simulation, we show the different processes leading to initiation of deep convection in this very dry environment not favourable to convection. I will also show how these simulations can be used to derive parametrization-oriented diagnostics that have been used to improve boundary-layer parametrization.

Prof Xiaoyu Luo,
University of Glasgow

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Prof Xiaoyu Luo is a Professor in the School of Mathematics and Statistics at the University of Glasgow. She received her BSc in Solid Mechanics, MSc in Applied Mechanics, and PhD in Biomechanics from the Xi'an Jiaotong University, China. She worked as a post-doc Research Fellow with Professor TJ Pedley, FRS, on modelling fluid flow in collapsible tubes at Leeds University during 1992-1997, and as a lecturer at the Queen Mary and Westfield College in 1997-2000, and a lecturer/SL at the University of Sheffield in 2000-2005. She joined the University of Glasgow in 2005 and became Professor in 2008. Her current research interests include modelling and numerical simulations of fluid-structure interactions and soft tissue mechanics, with particular interests in cardiovascular applications. She has published over 90 peer-reviewed journal papers and serves on the editorial board for Journal of Royal Society Open Science, International Journal for Numerical Methods in Biomedical Engineering, International Journal of Computer Mathematics – Section B, and International Journal of Applied Mechanics. She has supervised 27 PhD students and 16 post-doc RAs. Luo is the Executive Director of EPSRC SofTMech Centre (www.SofTMech.org), a Fellow of Royal Society of Edinburgh and a Fellow of IMechE.

Talk Title: Modelling and simulation of soft tissue mechanics and fluid-structure interaction

Abstract:
In this talk I will give two examples of solving fluid-structure interaction (FSI) problems involving large deformation soft tissue mechanics. In the first example, we look at the collapsible behaviour of a vessel conveying viscous flows subject to external pressure, a scenario that could occur in many physiological applications. The vessel is modelled as a three-dimensional cylindrical tube of nonlinear hyperelastic material. To solve the fully coupled FSI, we adopt a novel approach based on the Arbitrary Lagrangian–Eulerian (ALE) method and the frontal solver. The method of rotating spines is used to enable an automatic mesh adaptation. We study the behaviour of the tube under a mode-3 buckling and reveal its complex flow patterns under various external pressures. To understand these flow patterns, we show how energy dissipation is associated with the boundary layers created at the narrowest collapsed section of the tube, and how the transverse flow forms a virtual sink to feed a strong axial jet.

In the second example, we build a dynamic mitral valve (MV) model with FSI that includes physiologically detailed descriptions of the leaflets and the chordae tendineae. Three different chordae models — complex, “pseudo-fibre”, and simplified chordae — are compared to determine how different chordae representations affect the dynamics of the MV. The leaflets and chordae are modelled as fibre-reinforced hyperelastic materials, and FSI is modelled using an immersed boundary-finite element (IB/FE) method. The MV model is used to simulate MV dynamics under physiological pressure conditions. Interesting flow patterns and vortex formulation are identified.

Notes