Leeds Fluid Dynamics Symposium 2022

Welcome

From swimming ducklings to tsunamis, blood flow and sand dunes, fluid dynamics is ubiquitous in the world around us. Research in this field contributes to solving the most important modern-day challenges, including the drive to net-zero, improving healthcare, and predicting weather and climate. The Leeds Fluid Dynamics Symposium brings together experts across different areas of fluid dynamics to share their research. It is our great pleasure to welcome you to this year's symposium.

We would like to thank Nancy Ingham and Emily Bryan-Kinns for their assistance with logistics, as well as Peter Jimack and the CDT Management Board for their guidance and suggestions.

The Student Organising Committee
Rose Collet
Michael MacRaild
Jacob Perez

Wednesday 22nd June 2022

10:00 Opening Address
Prof. Steven Tobias

10:05 Towards a real-time early tsunami warning system
Dr Usama Kadri, Cardiff University

11:00 Sand dunes and their turbulent relationships
Dr Karol Bacik, University of Bath

11:30 Effects of marine biofouling on wall-bounded turbulence
Dr Angela Busse, University of Glasgow

12:00 Lunch and Poster Session

13:00 Exploring shock-induced cavity collapse and extreme hydrodynamics
Prof. Yiannis Ventikos, UCL

14:00 Haemodynamics in artificial hearts
Dr Katharine Fraser, University of Bath

14:30 Using animal models to understand endothelial cell responses to blood flow
Dr Jovana Serbanovic-Canic, University of Sheffield

15:00 Coffee Break

15:30 Lessons learned from ducklings and spiders
Dr Zhiming Yuan, University of Strathclyde

16:30 Poster Prizes

16:40 Drinks Reception

Abstracts

Towards a real-time early tsunami warning system

Usama Kadri, *Cardiff University*

Tsunamis have a long history of devastation, causing more than 250,000 deaths worldwide during the last two decades. Current warning systems rely on DART-buoys and seismic measurements. DART-buoys measure a tsunami directly once it arrives, which may leave no warning time, whereas seismometers provide a measure on earthquakes but not tsunamis, causing false alarms. Reducing false alarms has been emphasised in recent UNESCO tsunami expert meetings. To this end, we have developed a complementary real-time early tsunami warning system methodology. The methodology is based on analysing acoustic signals under the effects of gravity, known as acoustic-gravity waves (AGWs), that are generated together with the tsunami. The signals travel at the speed of sound in the medium which far exceeds the maximum phase speed of the tsunami. AGWs carry information about the source which is recorded by remote hydrophones (underwater microphones). Analysing these recordings in real-time, requires solving both the inverse and direct problems, which are the main strength behind the proposed warning methodology. In addition, we use machine learning to classify the type of earthquake: horizontal vs vertical. The latter is a necessary condition for the generation of tsunamis.

In this talk, we shall discuss various acoustic-gravity wave theories and applications, both fundamental and applied, with a particular focus on real-time early tsunami warning. The direct and inverse problem models derived from the linear wave equation will be briefly presented. In addition, the nonlinear resonant triad interaction of acoustic-gravity waves will be discussed and its potential for describing non-point-source tsunamis will be highlighted, focusing on the recent global Tonga tsunami.

Sand dunes and their turbulent relationships

Karol Bacik, *University of Bath*

Sand dunes are spectacular geological structures which arise spontaneously due to the dynamical interplay between granular matter and the turbulent flow of the overlying fluid. They rarely occur in isolation, but often form larger collectives known as dune fields, whose structure is believed to be controlled by (either remote or direct) interactions between neighbouring dunes. In my talk, I will describe a suite of idealised subaqueous experiment aimed at uncovering how sand dunes interact with their surroundings. First, I will discuss the fluid dynamical underpinnings of the dune-dune interactions. Second, I will describe what happens when the course of a migrating dune is interrupted by a topographical obstacle and how it relates to the flow structure near the obstacle.

Effects of marine biofouling on wall-bounded turbulence

Angela Busse, *University of Glasgow*

Marine biofouling is a problem that has impacted seafaring since ancient times. The accumulation of marine organisms on a ship leads to a significant increase of the hull's skin-friction drag, and thus an increase in fuel consumption and greenhouse gas emissions. This presentation will focus on the impact of fouling by barnacles, a form of calcareous macrofouling which has strong impact on the shipping industry. Direct numerical simulations are used to investigate the fluid-dynamic properties of realistic barnacle surfaces which were created using an algorithm that emulates the settlement behaviour of barnacles. In addition to mean flow and turbulence statistics the blanketing-layer concept is applied to understand how the outer flow perceives barnacle roughness of increasing solidity.

Exploring shock-induced cavity collapse and extreme hydrodynamics

Yiannis Ventikos, *University College London*

In this talk, we shall discuss phenomena connected to the interaction of gas-filled cavities, "bubbles", with shockwaves. Such interactions can lead to extreme conditions, regarding pressures, densities and temperatures achieved during the collapse processes. Whereas in many technical applications we are interested in eliminating such phenomena –cavitation damage in propellers and hydraulic equipment for example –there are other applications where these can be harnessed to pursue otherwise inaccessible conditions. An example of the latter is lithotripsy and histotripsy. Another example, that we shall discuss in some detail, is fusion. We shall present computational methods suitable to explore such problems and experimental work that validates the experiments

Haemodynamics in artificial hearts

Katharine Fraser, *University of Bath*

Worldwide 40 million people suffer from heart failure, which is the inability of the heart to supply enough blood to the body. Treatments include medical therapies and pacemakers, but heart failure is a degenerative disease and eventually the treatments fail to control the symptoms. These patients need a new heart: but donor hearts are limited, and the number of patients listed for transplant continues to grow. Mechanical Circulatory Support Devices (MCSDs or artificial hearts) can support or replace the native heart, either until a suitable donor is found, or permanently, or in some cases until the heart recovers.

Over 3000 artificial hearts are now implanted annually around the world and 2-year survival is 73%, showing a benefit to patients in extended life. However, complication rates are high with bleeding, infection and stroke all common. If the safety profile of artificial hearts were improved many more patients could benefit from the technology.

My group study the fluid dynamics of blood flow in artificial hearts. A better understanding of the fluid dynamics, and the interactions between the flow and the blood, will allow us to design safer artificial hearts. We use a combination of computational and experimental methods and collaborate closely with leading academic groups and industry around the world. In this talk I will present a few of our recent projects, ranging from studies of the fundamental interactions between the complicated rheology of blood and the flow field, to the use of fluid-structure interaction methods for studying novel pulsatile artificial hearts, and optimization methods for turbomachinery applied to the world's smallest mag-lev blood pump.

Using animal models to understand endothelial cell responses to blood flow

Jovana Serbanovic-Canic, *University of Sheffield*

Cardiovascular diseases are a major cause of death globally. The majority of these deaths are due to coronary heart disease and stroke, and the main cause of these is atherosclerosis. Atherosclerosis is a focal disease characterised by build-up of fatty plaques in the inner walls of arteries. It is initiated at branches and bends of arteries exposed to disturbed flow that generates low wall shear stress (WSS). This mechanical environment promotes development of atherosclerotic lesions by inducing dysfunction of endothelial cells (ECs) lining blood vessels. On the other hand, regions exposed to high WSS are protected from lesion development. However, the molecular mechanisms underlying the effects of WSS on EC physiology and atherosclerosis are not completely understood.

To generate a panel of putative WSS-sensitive regulators of EC function, we first used magnetic resonance imaging and computational fluid dynamics (CFD) modelling to characterise flow and WSS in the porcine aorta. Based on our CFD model, we isolated ECs from high and low WSS regions of the porcine aorta and performed transcriptome profiling. We identified ¿850 shear-responsive genes, with roles in programmed cell death (apoptosis), inflammation, proliferation, embryonic development and others.

Here I will present a range of in vivo and in vitro approaches we use to study the function of WSS-responsive molecules in regulating EC function. I will demonstrate how integrating different mammalian and non-mammalian models can help us define roles of these molecules in vascular health and disease. This will improve our understanding of mechanisms that control spatial distribution of atherosclerotic plaques and may provide therapeutic targets for prevention or treatment of cardiovascular diseases.

Lessons learned from ducklings and spiders

Zhiming Yuan, *University of Strathclyde*

It has been a long-held hypothesis that many flying and swimming animals can preserve energy and improve individual locomotion performance by travelling in highly organized groups. Most of the studies are focused on the animals moving in a single medium, either air or water. In these works, the vortices in wakes were considered as the main reason for energy savings by group locomotion. Ducklings are commonly observed to swim in formation on the free water surface, which is the interface between the air and water. This is very similar to the surface moving ships, but different from the animals moving in the single medium. The questions arise: 1) why are they swimming in formation? 2) what is the best swimming formation? 3) how much energy can be preserved by each individual in formation swimming? 4) what lessons can a naval architect learn from ducklings? In this talk, I will present my answers for these questions as a naval architect. Two new and interesting phenomena in fluid will be introduced: *wave-riding* and *wave-passing*.

The other lesson that the ocean engineers can learn from animals is how to design a safe and cost-effective ocean hub to accommodate offshore renewable devices under ocean waves. Spiders provide us a perfect flexible web that can withstand extreme wave loads with minimum damage, and at the lowest material and manufacturing cost. In this talk, I will present my initial idea of a novel OceanWeb concept inspired by spider web, and to show how this flexible web could help ocean engineers to design the future flexible and lightweight offshore structures with excellent hydrodynamic performance.

Poster Session

Julie Frank
Modelling Melting of Phase Change Materials for Latent Heat Thermal Management Systems for Military Aircrafts
University of Leeds

Alexander Edwards
A mathematical model for assessing transient airborne infection risks in a hospital
University of Leeds

Yatin Darbar
Internal and External Dynamics of Coalescing Non-Isothermal Droplets
University of Leeds

Joe Bennett
Fluid Mechanics of Polymer Melt Filtration
University of Leeds

Emily Butler
An investigation of the Fluid Structure Interaction in articular cartilage across disparate scales
University of Leeds

George McGilvray
How Electromagnetic Effects Affect the Stability of Plasmas in Tokamaks
University of Leeds

Hamza Liaquet
Robotic Inspection of Pre-filled Medical Syringes
University of Leeds

Isabel Latimer
Numerical study of sediment beds with a coupled Lattice Boltzmann - discrete element method
University of Leeds

Jacob Perez
Feature Based Analysis of the North Atlantic Eddy Driven Jet
University of Leeds

Giulia Fedrizzi
Investigating the Links Between Melt Flow Processes and Geometrical Patterns in Partially Molten Rocks
University of Leeds