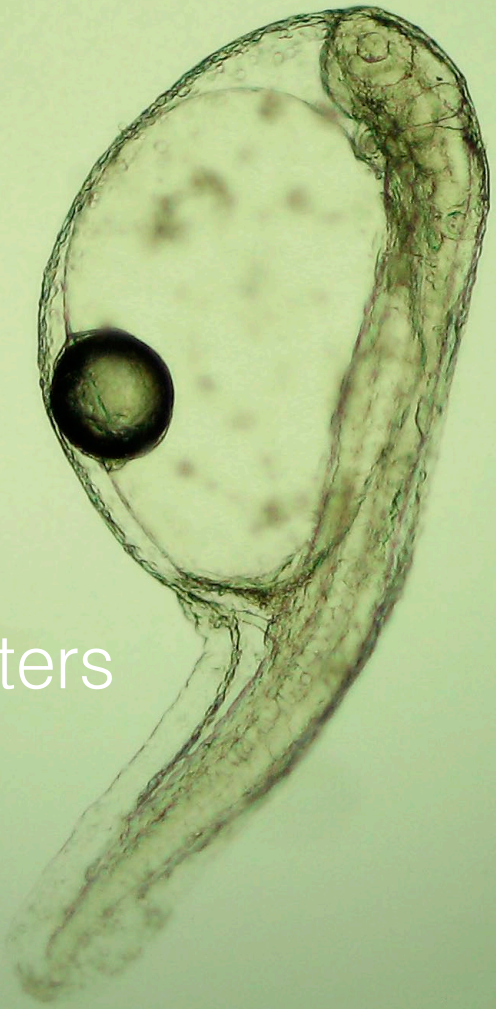
University of Glasgow | College of Science & Engineering

College of
Science and Engineering
Industry Day 2013

PhD Student Research Posters



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For the College's third Industry Day, we thought that it would be a really positive development to involve our research students.

They, after all, are the industry-leaders or academics of the future and the chance to network with employers, discuss their research with potential collaborators and simply to gain more experience at conveying the impact of their research is a valuable one.

PhD students are a vital part of any research-intensive University and we hope this sample of their work will give you a good impression of the level of work of which our students are capable. Some of our students already work with industry and some are working on projects which could have industrial application but do not have partners as yet.

We are, of course, always keen to hear from prospective partners, particularly those who might be able to support us to support students either through a collaborative PhD or sponsoring our innovative activities or helping deliver training for students who are keen to move to industry.

For more information, please contact the Graduate School directly:
scieng-gradschool@glasgow.ac.uk

I hope you find Industry Day 2013 informative, useful and inspiring.

Professor Jon Cooper
Dean of Graduate Studies

The Wolfson Chair of Bioengineering
Head of Division of Biomedical Engineering
College of Science & Engineering International Dean for China and East Asia

Joanna Cholewa
School of Physics and Astronomy

Nanocharacterisation of precipitates in high manganese steels

The aim of my PhD is to investigate and develop our physical understanding of the crystallographic nature of precipitates in high manganese austenitic steels and their orientation correlation with matrix. This process should reveal the best way to control the orientation in nanoscale and its influence on mechanical properties of analysed steels. The precipitation process is forced by micro-alloying the high manganese steels by Nb, Ti and V, and control of hot deformation compression treatment.

The main goals of the research are the:
1. Optimisation of a sample preparation method
2. Characterisation of strain-induced precipitation
3. Characterisation of kinetics during first moments of precipitation
4. Development of advanced methods for the characterisation of precipitates in steels

The biggest advantage of high manganese austenitic steels is they can be a useful prospect for automotive body-shells because of the weight reduction and improvement of safety. In many European research laboratories the gaps in our knowledge of these steels are being investigated. The precipitation process is not well known and there are no sufficient data of description thermodynamics and kinetics of precipitation. As a result, there is no nanoscale characterisation of crystallographic nature of precipitates, their chemical composition, volume fraction, distribution, and orientation relationship with the matrix. My PhD project will provide the basis for modelling and further alloy design for better mechanical properties control.

In general the high manganese austenitic steels are a desirable innovative material for automotive applications. Their characteristic features are weight reduction and enhancement of safety. The project is focused on investigation of crystallography features of precipitates – iron carbides, transition-metal-carbides and carbonitrides in microalloyed high manganese austenitic steels. Those steels can be divided into groups of new generation high strength alloys, where the precipitation process in the development of mechanical properties plays a crucial role. The PhD project aims to give preliminary answers about characteristic of precipitation process in austenitic TWIP steels. This is the first insight into the precipitation process in steels with strain induced plasticity effect of – iron carbides, transition-metal-carbides and carbonitrides. This work might be decisive for the further development of high manganese steels with characteristic of improved mechanical properties.

Alisha Contractor
School of Engineering

CubeSat Constellation for Telecommunication

In 1999, CalPoly (California Polytechnic) and Stanford University collaborated to deliver the space industry with CubeSat. CubeSats are 10cm cube-shaped satellites often called 1 Unit. The marvel of CubeSat lies in its ability to perform the same task as a conventional satellite despite dimension and weight. However, it is unfortunate that as yet CubeSats are mainly considered as the best choice for conducting academic experiments while they are overlooked for commercial satellite missions. An attempt is made in this research to investigate utilising CubeSats for telecommunication missions with an aim to produce convincing evidence to take the concept of small satellites to a commercial level. In an era where maximum budget cuts are faced by the Space industry, it becomes vital to sustain satellite missions by budgeting efficiently. The concept of CubeSat constellation itself is fraught with challenges regardless of the requirements for COTS (Commercially off the Shelf) subsystem for CubeSats to undertake telecommunication missions. This research intends to deliver answers to challenges faced to CubeSat constellations for telecommunications such as power budget; intersatellite link; communication payload specifically for CubeSat; attitude determination and control subsystem; and computing for CubeSats in constellation. If CubeSat constellations are used for communication then it would be likely to be of advantage to the space industry. An attempt to make CubeSats formation feasible for commercial purposes is considered by this research. Upon further scrutinising the results achieved they can be exercised to commence work on airborne command centres; providing fundamental/ COTS parts for various satellite missions such as earth observation, space weather monitoring, solar energy transmission and surveillance.

Caroline Fahy
School of Engineering

A hygro-mechanical lattice approach for porous materials

Reinforced concrete is one of the most commonly used structural materials in the world. It is used for buildings and many different types of civil engineering structures, such as bridges, tunnels and airports. The majority of these structures are required to remain in service for at least 50 years while others are expected to last well over 100 years. In many cases, the structures suffer from premature deterioration, which leads to a shortened lifespan. Corrosion of reinforcement bars is one of the commonly encountered degradation processes and is caused by the constrained volume expansion of corroded reinforcement bars. The cost associated with inspecting, maintaining and repairing corroded structures runs into billions of pounds in the UK alone. Corrosion can also lead to structural failure with severe financial, environmental and safety consequences. The costs arising from structural failure are extremely high and therefore, in practice, repair work tends to be implemented even when it is not entirely necessary. The focus of this project is to develop a computational model capable of accurately describing the degradation of a reinforced concrete structure due to the corrosion of the rebars. A coupled transport and mechanical approach will be used to describe the expansion of the reinforcement bar due to the formation of corrosion products, their penetration into the surrounding pores and microcracks and the resulting fracture of the surrounding concrete.

This poster outlines the initial work to couple transport and mechanical models proposed in [1, 2]. A hygro-mechanical lattice approach to modelling displacements in saturated porous materials such as cementitious or geological materials is proposed. A dual Delaunay and Voronoi tessellation of the specimen domain is carried out to create the mechanical and transport elements. The performance of the proposed coupled approach is studied by comparison of the numerical results with the analytical solution for an elastic thick-walled permeable cylinder. The effect of Poisson's ratio on the accuracy of model also studied.

[1] C. Fahy, D. Gallipoli and P. Grassl, Lattice Model for *Mass Transport in Unsaturated Porous Materials,* in: Proceedings of The 20th UK Conference on Computational Mechanics (ACME-UK), Manchester, United Kingdom, 2012.

[2] C. Fahy, D. Gallipoli and P. Grassl, *On the Mesh Dependence of Lattice Models for Analysing Concrete Fracture,* in: Proceedings of The 19th UK Conference on Computational Mechanics (ACME-UK), Edinburgh, United Kingdom, 2011.

Alison Gibbings
School of Engineering

Laser Ablation for the Deflection and Exploration of Asteroids

Asteroids, the leftover debris from planetary formation, represent both an opportunity and a risk. Their pristine environment captures the early impact evolution of the solar system, whereas their impact risk could result in the mass extinction of life. This is considered to have happened once before, approximately 65 million years ago, with the mass extinction of the dinosaurs. It will happen again. It is only a matter of time. However, novel techniques are now being developed to mitigate and assess the impending asteroid-to-Earth impact risk. Specifically, asteroid deflection through laser ablation is considered to be a promising mitigation technique. This is achieved by irradiating the surface of an asteroid with a laser light source. The resulting heat enables the surface rock to ablate, transforming the material directly from a solid to a gas. The ablated material then expands to form an ejecta plume. Over an extended period of time, this provides a continuous and controlled force that can be used to actively deviate small to medium size asteroids.

To fully examine the laser ablation approach a series of self contained experiments have been performed. The aim was to examine the formation and evolution of the ejecta plume, and the associated rates of ejecta contamination. This is in a continued effort to determine whether or not laser ablation is an effective and achievable method of deflecting asteroids. A 90 watt laser was used to initiate the ablation response. All experiments were conducted within a vacuum chamber. Two different asteroid analogue target materials were tested – a dense solid sample and a highly porous sample. This was used to represent the diversity within the asteroid population. Results to date have assessed the thermal influences – the surface spot temperature and the volumetric heating of the sample – and the mass flow rate, velocity and divergence of the developing ejecta plume. The deposition and associated contamination of any optical surface within the local vicinity of the ejecta plume has also been examined.

Compared to the numerical model, considerably less contamination has been observed. This will, critically, affect the lifetime of the mission and the achievable rates of asteroid deflection. The experiment has therefore provided both validation and calibration of the current theoretical model and existing theory. Furthermore, and of most significance, is that the experiment has demonstrated the diversity of using laser ablation for a range of space based missions. The experiments have revealed that laser ablation is effective in the successful extracting and analysis of the target material's subsurface composition. Laser ablation, therefore, does not only offer itself as an effective method of asteroid deflection, but also as a contact-less method for the potential exploitation, exploration and analysis of asteroids, and other rocky bodies. Work has been performed in collaboration with the Advanced Concept Laboratory, University of Strathclyde, the Institute of Photonics, University of Strathclyde, the Planetary Society and the Mechanical Engineering department, University of Glasgow.

Lauren Gilpin
School of Chemistry

Developing the understanding of a selective hydrogenation catalyst for an agri-chemical production chain

Primary amines are one of the most important intermediates in the chemical industry. Many products require the use of a primary amine in their production including (but not limited to) pharmaceuticals, agrichemicals and plastics. Although it is possible for such compounds to be synthesised by a number of different routes it is the heterogeneously catalysed hydrogenation of nitriles that is most commonly used to prepare an amine in certain agrichemical production chains.

Typically skeletal metal catalysts are used, however, in fine chemical applications the selectivity to the desired amine is often compromised by reduction of other functional groups. To avoid this, palladium supported catalysts are often used to reduce the nitrile group when other functional groups are present.

The present work examines the application of supported Pd catalysts for the selective hydrogenation of aromatic nitriles.

Experimental methodologies and reaction mechanisms are developed, which are then compared to comparable investigations at the industrial centre.

Domokos Gyore
Scottish Universities Environmental Research Centre

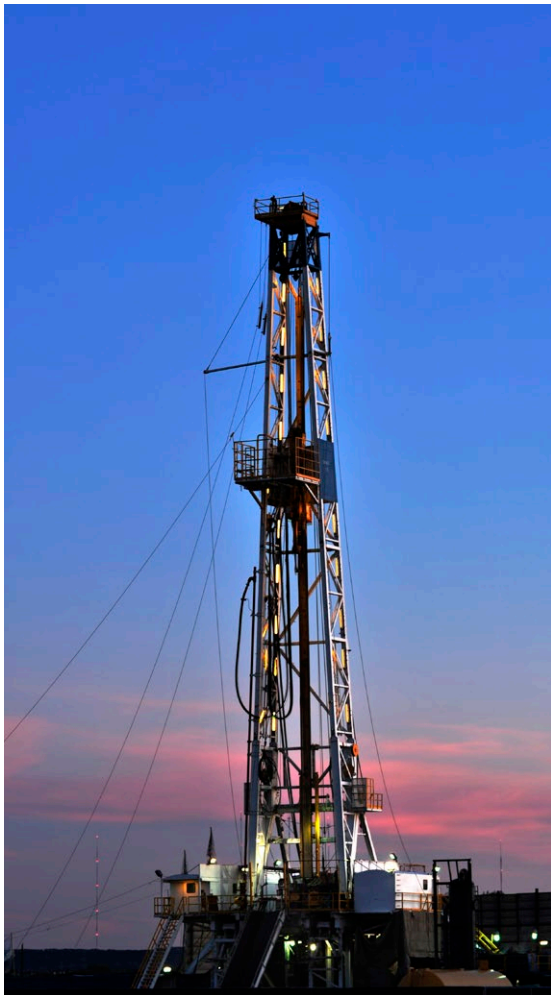
Tracking the fate of injected CO_2 in a CCS reservoir analogue

Underground sequestration has the potential to reduce anthropogenic CO_2 emission. The fate of injected CO_2 and the mechanism of the storage remain significant unknowns that hamper the large-scale application of underground carbon capture storage.

I am investigating the feasibility of tracing the movement of injected CO_2 in the subsurface using a comprehensive suite of natural chemical and isotope tracers. I am developing a system that permits analysis of stable (C, H, O) and noble gas (He, Ne, Ar) isotopes, and major components (e.g. CO_2, CH_4, C_2H_6, N), of crustal gases. We have selected the Cranfield (MS, USA) enhanced oil recovery (EOR) site as the main test field for the study. The injected CO_2 has a diagnostic isotopic composition and the injection and sample wells cover a large area allowing a thorough assessment of gas mobility in the reservoir and overlying layers. Gas samples have been taken from three different stages during the injection project in order to provide rates of gas migration.

The main goal of the project is to develop a model of subsurface gas mobility around sites of gas injection. It is hoped that the analysis of the inert gases, in particular the isotopic composition of He, will provide an early warning of the arrival of the injected CO_2. This will have use in CO_2 storage, for instance as a tracer of leakage from reservoirs, and in enhanced oil recovery operations, allowing, for instance, the number and distribution of wells to be optimized, and injected rate to be controlled.

In addition to the applicability to other areas of the CCS sector, the skills I am developing, combined with the new analytical facility, have potential for other aspects of energy-related research. The ability to identify the source of methane (CH_4) has numerous applications. For instance, it has proved a key tool in legal cases contesting the release of methane into shallow groundwaters during extraction of unconventional gas (shale gas and coal-bed methane). The chemical and isotopic composition of gases released during underground coal gasification has potential to constrain peak temperatures and gas extraction efficiency.



Augustine Kwanashie
School of Computing Science

Efficient algorithms for matching under preferences

The research considers the problem of allocating resources arises in a wide range of real-world applications. Centralised matching schemes exist in many countries around the world assigning medical doctors to hospitals, kidney donors to recipients, students to colleges, students to projects and research papers to reviewers. These applications and many others can be modelled as *matching problems* where sets of agents seek to be assigned to one another. Some or all agents may be required to express preferences over other agents they wish to be assigned (or matched) to. Where this is allowed, scenarios arise where such assignments (we call matchings) can be subverted by dissatisfied agent pairs who find each other more acceptable than their assigned partners. We call such matchings unstable as there is a tendency for such agents to abandon the matching and become paired to one another. We seek to develop efficient algorithms for finding stable matchings in the many variants of matching problems motivated by various real-world applications.

My research is aimed at identifying and modelling certain variants of matching problems that are of practical importance, analysing the complexity of these problems and designing efficient algorithms for solving them. I am also involved in implementing these algorithms and evaluating their performance against real-world and generated datasets.

Research into matching problems in general has been very active over the last 50 years. This is mainly motivated by the various real-world applications to these problems that have been identified. The adoption of efficient algorithms developed over the years has helped in preventing the instability that is likely to occur if a “free-for-all” scheme is employed. By continuing to investigate these problems and develop more efficient algorithms to solve them, we increase the scale of solvable problem instances and promote the adoption of these matching schemes in new application areas.

I am particularly interested in variants of matching problems in which agents may be indifferent in their preferences over other agents and problems in which agents may not have a complete knowledge of the preferences of other agents in the schemes. These properties are found in some of the real-world applications and they greatly affect the nature of the matching problems and our ability to develop efficient algorithms to solve them. For example in both variants, it is possible to obtain stable matchings of different sizes and the problem of finding a stable matching of maximum size if computationally hard. I am involved in developing techniques to offset this hardness.

My presentation will involve an introduction to matching problems and some important variants. I will identify some of the applications of matching problems especially those of interest to my research group. I will give some detail into my research results and potential areas of progress.

Abdul Lawal
School of Engineering

A performance evaluation of an equatorial inclined constellation of low cost SAR satellites

The high cost of space missions, restricts the access to space for typical countries like USA, Russia and other ‘space giants’. Recent trends indicate an increase in the number of spacefaring industries, owing to the reduced sizes of spacecraft. The launch cost is an area where the cost of space mission, can be reduced considering the correlation between the mass of spacecraft and its launch cost. Invariably, to provide developing nations a better opportunity of affording high resolution active sensing satellites for conducting urban development missions, a low-cost SAR platform is a potential solution. This paper evaluates the stability of a constellation of spacecraft in pendulum configuration consisting of two orbital planes and four spacecraft in each plane.

The low earth orbit constellation is tasked with gathering data on oil resources within the equatorial region using interferometry.

The performance of the system will be evaluated based on pre-defined mission requirements such as high resolution imagery, near-real time imagery, collision avoidance and baseline stability.

Xiang Liu
School of Mathematics and Statistics

Wrinkling-resistant analysis of thin annular plate in tension

This presentation is about wrinkling and how to prevent wrinkling. Wrinkling is a short-wave-length deformation pattern, which is a common occurrence in our daily life such as the wrinkling of clothes, foil, film, leaves, flowers, skin, retina, etc. Some of the wrinkling patterns contribute to the beauty of the world, while in some cases we would like to avoid them. In the latter cases, we can regard wrinkling as a type of mechanical failure. This work is on the wrinkling-resistant analysis of a composite annular plate subject to tensile loads.

It is interesting that in a stretched annular plate with uniform material, a circumferential wrinkling pattern can be triggered near the inner rim by the radial stretching along its boundaries, which have been investigated thoroughly. In this research, we extend the former tensile wrinkling problem into a bi-annular system consisting of two (mechanically different) concentric annular plates perfectly bounded along a circular interface. Indeed, this can be regarded as a composite structure. Then we discuss the wrinkling-resistant capacity by using both numerical and asymptotic analysis, which leads to the following results.

1. We found that a bi-annular plate with stiffer inner annulus is prone to wrinkle under a smaller stretching displacement on the inner rim, since a stiffer inner layer will intensify the stresses concentrating. On the other hand, a slender-inner-layer plate can endure larger tractive displacement on the same boundary.

2. The Poisson ratio of either sub-annulus exerts a global effect on the wrinkling resisting capability of the bi-annular structure. Largely speaking, the smaller of the Poisson ratio, the lower wrinkling resistance will be. However, it is the Poisson ratio of the wrinkled region that plays a dominant effect on the critical stretching loading.

3. The wrinkling mode appears as a finer structure (larger number of wrinkles) when the wrinkles are localised near the interface.

4. When the inner rim is far from the interface, the wrinkles tend to locate within the inner annulus next to the inner rim; otherwise the wrinkling mode is mainly localised in the outer annulus. The wrinkles might be also localised in both annuli near the interface but this mode is rarely seen.

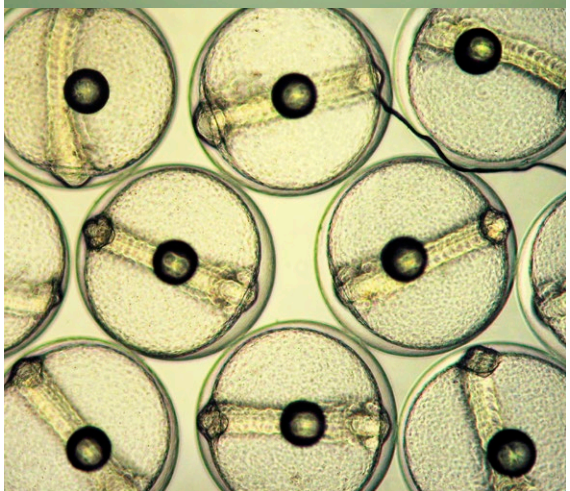
The results are of guiding significance in designing with respect to wrinkling: we can control the presence of wrinkling by choosing the Young’s modulus, Poisson ratio and the geometrical aspect ratios of the two annuli. Also, the above conclusions shed light on the wrinkling-resistant design of a structure with discontinuities.

Niall MacDonald
School of Engineering

3D printed micro arrays for automated trapping of zebrafish embryos

Zebrafish *(Danio rerio)* has recently emerged as a powerful experimental model in drug discovery and environmental toxicology. Drug discovery screens performed on zebrafish embryos mirror with a high level of accuracy. The tests usually performed on mammalian animal models, and fish embryo toxicity assay (FET) is one of the most promising alternative approaches to acute ecotoxicity testing with adult fish. However, automated in-situ analysis of zebrafish embryos is still deeply in its infancy. This is mostly due to the inherent limitations of the conventional techniques and the fact that metazoan organisms are not easily susceptible to laboratory automation. In this work, we present evidence that chips can combined with time-lapse imaging to provide real-time developmental analysis.

Our platform, fabricated using 3D printing technology, enables rapid trapping of the embryos in low shear stress zones, uniform drug microperfusion and high-resolution imaging without the need of manual embryo handling at various developmental stages. The work provides a rationale for rapid automated manipulation and analysis of developing zebrafish embryos at a large scale.



Lewis MacKenzie
School of Physics and Astronomy

Measuring Peripheral Vasculature Oxygenation

Diseases affecting the peripheral vasculature such as diabetes are a major health concern, with over 194 million people worldwide affected by diabetes alone. Such afflictions are very serious; potentially resulting in amputations and a very large treatment bill for governments.

The aim of this research is to develop a *minimally invasive* technique to image the peripheral microvasculature with an emphasis on measuring blood oxygenation levels (which is a key indicator of disease). Developing and applying such a technique in a clinical setting would be of great benefit to medical professionals. Progress is currently at the initial image technique evaluation and testing stage.

In-vivo measurements of the peripheral vasculature network and blood oxygenation are very difficult to obtain because respectively resolutions on the order of tens of microns, and spectral sensitivity to oxygenated and deoxygenated haemoglobin is required.
For these reasons, established medical imaging techniques such as *MRI* and *Ultrasound* are not viable, and no current imaging technique promises to provide an 'off the shelf' solution to this problem, thus a combination of complimentary imaging techniques is likely to be necessary.

Optical wavelengths (400-700nm) provide good contrast between oxygenated and deoxygenated haemoglobin as well as the high resolutions required for micro vascular imaging. However, optical light is strongly scattered and absorbed by skin tissue and thus purely optical techniques (such as *Optical Coherence Tomography (OCT)*) are limited to imaging depths of $<$2mm in skin. Achieving an imaging depth greater than 2mm is desirable as it allows a more complete picture of the peripheral microvasculature. Other optical techniques such as speckle imaging may also be utilised. Another key advantage of optical techniques is that they can be packaged into minimally invasive probes.

Photoacoustic Tomography (PAT) combines optical and ultrasonic techniques, allowing for high resolution imaging, with good haemoglobin contrast up to depths of $\sim$5mm. PAT and OCT have been combined into a single system by other groups to yield complimentary information; PAT gives clear images of the microvasculature, and OCT gives good depth-resolved imaging of the skin structure up to 2mm as well as flow measurements.

The effectiveness of these techniques may be enhanced by optical clearing of the skin via application of substances such as glycerol; this allows light to penetrate further into tissue by matching the refractive indexes of skin tissue components - reducing scattering.

This research is at the initial evaluation and viability phase, but it appears likely that some combination of OCT, PAT, speckle and Doppler imaging, and optical clearing techniques will be used. Further testing and evaluation of imaging techniques is required; especially PAT systems which are not available commercially and have to be designed and built by researchers. Once these technologies have been proven viable, a prototype imaging system will be developed and applied in clinical trials.

Richard Middlemiss
School of Physics and Astronomy

An Ultra Sensitive MEMs for Gravity Imaging

We propose to design, fabricate and field test an ultra-high sensitivity MEMS (Micro Electro Mechanical System) gravimeter for gravity imaging applications. The target acceleration of better than $10^{-7}ms^{-2}/Hz$ (10ng/Hz) is at least as accurate as current instruments.

The gravimeter comprises a proof mass, which is attached to a flexure, and a sensor to measure the relative displacement of the mass from its nominal position. Operating the device in feedback mode allows the gravitational force to be determined from the spring constant of the flexure. A proof mass of 0.2g together with a soft flexure will provide a resonant frequency of 7Hz and provide ultra-high sensitivity at low frequencies.

Such a device will have wide ranging applications in air and land-based oil and gas exploration, environmental monitoring for nuclear waste management, detecting subterranean tunnels or landmines, mapping the gravitational fields of other planets and in fundamental physics.

Clement Morisse

Correlations between reaction profiles and catalyst structure for nitrobenzene hydrogenation over alumina-supported Pd catalysts

The hydrogenation of nitrobenzene to form aniline is a large-scale industrial process performed using a variety of heterogeneous catalysts [1]. One variant of the process involves the application of alumina-supported Pd catalysts. Although several Pd/Al_2O_3 formulations exhibit high aniline selectivity (ca. 98%), different grades of these catalysts favour different impurities. For example, fig 1 below shows impurities detected as a function of temperature for a 0.3% Pd/Al_2O_3 catalyst.

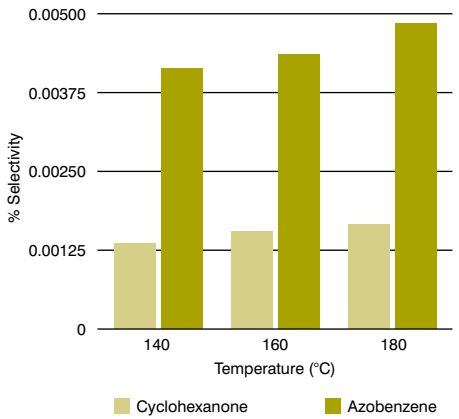


Figure 1: Impurities produced with 0.3% Pd/Al_2O_3 catalyst used in gas phase nitrobenzene hydrogenation.

In order to investigate whether the origins of impurity formation are connected to catalyst structure, a series of Pd catalysts active for this reaction have been characterised by a variety of techniques; such as chemisorption measurements, X-Ray Diffraction, Transmission Electron Microscopy, Temperature-Programmed Desorption and InfraRed spectroscopy.

This presentation will link reaction profiles with catalyst characteristics for this economically relevant reaction.

Reference

[1] E.R. Riegel, J.A. Kent, Handbook of Industrial Chemistry and Biotechnology, 2007, Springer

Hemanth Pasumarthi and Martin Coleman
School of Geographical and Earth Sciences

Developing sensor technology for measuring dissolved organic carbon in the natural environment

Increasing interest in the effects of global change on the metabolism and cycling of carbon (C) in the ecosystem has promoted research on the organic carbon cycle. Carbon cycling is intimately linked with climate change impacts such has global warming and we have observed increasing exports of Dissolved Organic carbon (DOC) from terrestrial reservoirs into river sytems, where DOC concentrations [DOC] vary widely spatial and temporal, reflecting its diverse sources. Understanding this variability and its controls is important in predicting the response of aquatic ecosystem, as well as local and regional and Global disturbances.

[DOC] in fluvial systems can be subject to changes occurring on the order of hours rather than days (heavy precipitation events) and seems to covary with other hydrochemical variable such as the volume of water in a system, seasonal changes and pH. This is useful as it suggests we may be able to create a model from easily logged hydrochemistry parameters that describes the temporal and spatial variability in [DOC]. This would be of value to industry (and water treatment plantations in particular) because DOC is usually considered undesirable in drinking water due to the colouration it causes. Being able to convert these parameters easily into a [DOC] value could indicate whether DOC treatment is likely to be required for a particular sample.

However, in order to create such a model we need high resolution time series. Here we present time series data from two different catchments: the first is a large urban river system – the River Kelvin in Glasgow with a catchment area of 335 km2. The second is a rural stream in a 7.5km2 catchment draining part of Europe's largest wind farm Whitelee, which has been subject to disturbance. At the River Kelvin site samples are collected on a semi-daily basis and returned to the laboratory where the sample is filtered and [DOC] is measured using high temperature catalytic oxidation. At Whitelee [DOC] is measured using a field deployed DOC sensor from S::CAN (a Spectro::lyser) which although overestimating the concentration, this can be corrected to produce high resolution profiles.

Comparison of these two profiles will show that semi-daily manual sampling is insufficient to capture detailed information about changes in [DOC], but the size of the Spectro::lyser limits field deployment so new sensor technology is needed. Our research work hopes to identify the most reliable method of [DOC] measurement and to implement the design in field environments and would be keen to discuss this further with interested parties.

Andy Singleton
School of Geographical and Earth Sciences

Measuring landslide movements from space using satellite radar (SAR) imagery

Whilst being spatially concentrated, landslides are a global and hazardous phenomenon. This study focuses on slow-moving landslides (in the order of tens of cm's per year) within the Three Gorges region, China. These landslides are large, with whole villages built upon them and buildings/infrastructure which are suffering from the ground movement. Over the last decade, construction of the Three Gorges dam has created a 600 km long reservoir with a bi-annually fluctuating water-level which has also been shown to reactivate ancient landslides. Obviously it is important to monitor large regions to detect actively moving slopes and then measure the rates of movement over time. It is then feasible to relate the patterns of observed movement with external factors such as rainfall or fluctuating reservoir water levels to understand the landslide mechanisms and potential future scenarios.

The challenge of this research is to develop a suitable and accurate method of detecting and measuring landslide movements remotely, i.e. without the need for ground instrumentation. The use of satellite radar sensors (Synthetic Aperture Radar – SAR - sensors) has been developed over the last 30 years to accurately monitor ground deformations with cm to mm precision over very large areas and has been applied to a variety of geophysical processes such as volcanoes, earthquakes, glaciers, subsidence etc. This approach has also been significantly applied to various landslide hazards. However, there are several factors which limit the validity of using SAR imagery and InSAR techniques for monitoring changes in the elevation of the Earth's surface, such as dense vegetation coverage and/or atmospheric water vapour effects in the satellite imagery.

Whilst trying to extract reliable measurements of numerous landslides throughout the densely vegetated Three Gorges region, it is also possible to compare the advantages/limitations of processing data from a variety of different SAR sensors.

Overall, the aims of this research are:

1. To assess the capability of various SAR data products for monitoring landslides in the difficult study area of the Three Gorges region.
2. Where possible, develop a reliable InSAR processing chain to identify and measure active landslides.
3. Model slope stability in stable and active areas to assess the geophysical mechanisms responsible for slope instability (including understanding any relationships between movements and triggering factors).
4. Provide a quantitative hazard assessment for the region.

Focusing on the use of remotely acquired satellite data, we can effectively monitor and understand landslide hazards without the requirement for fieldwork and ground instrumentation. This obviously has some important cost savings and also means we can study numerous, large areas with relative ease from our desks in Glasgow. Increasing our knowledge of these regional hazards and the associated triggering mechanisms should help reduce the vulnerability of buildings and communities affected by these landslides with the use of appropriate remedial measures.

Anna Vass and Daisy Rood
School of Geographical and Earth Sciences

Fracturing, healing and fluid rock interactions in reservoir rocks

In this study we are looking at physical and chemical interactions that can change the permeability and structure of rocks. One part of the study deals with fluid overpressure in rocks leading to hydrofractures that act as conduit for fluids and increase the permeability of a rock suite. These hydrofractures can close (heal) when material is precipitating in the fracture creating veins. We are trying to understand the fluid-rock interaction that creates the veins, we investigate fluid flow through rocks that fracture and heal and we try to define conditions, which produce characteristic fracture patterns. The study, thus, addresses many questions, such as what controls the fluid flow and the healing, what effect does the healing have on the rocks, can different fracture patterns be linked to certain mechanisms?

The second part of the study deals with the local mass transfer of material within rocks. Dissolution of material due to overburden stresses may take place at discrete interfaces. The material is then transported through the rock and precipitates in fractures and heals them. This process leads to a restructuring of the rock itself. Dissolution seams have complicated structures and collect insoluble material. They may act as fluid barriers or fluid may flow along the dissolution seams. The different questions that we address are: How do dissolution seams change the structure of the rock, can we predict the shape and permeability structure of the dissolution seams depending on rock parameters and boundary conditions?

Several methods are being used to investigate the subject in detail. Different microscope techniques, high resolution laser scanning, isotope – and fluid inclusion analysis are carried out in order to unravel the geological history and understand the rock-fluid interaction. With the help of computer modelling it is possible to visualise different geological scenarios and their effect on the rock system. The challenges of the computer modelling, however, are the uncertainties of the rock properties during the deformation, and to define the boundary conditions under which the system reacts.

The importance of the project primarily lies in its applicability to the industry. Information on the palaeopermeability of the rocks is a crucial key in the exploration and prospect for raw materials and energy sources.

This study is carried out within the framework of DGMK (German Society for Petroleum and Coal Science and Technology) research project 718 “Mineral Vein Dynamics Modelling”, which is funded by the companies ExxonMobil Production Deutschland GmbH, GDF SUEZ E&P Deutschland GmbH, RWE Dea AG and Wintershall Holding GmbH, within the basic research program of the WEG Wirtschaftsverband Erdöl- und Erdgasgewinnung e.V.

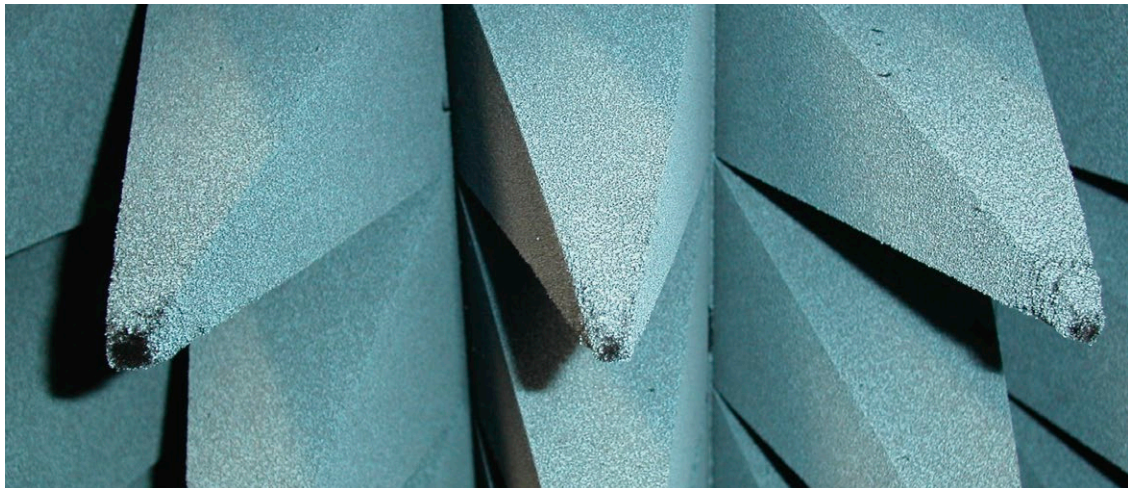
Clement Vourch
School of Engineering

Deployable antenna

The subject of my research is the design, simulation and characterisation of deployable antennas. The main constraints for good deployable antennas are to occupy a small volume when folded and to have the same performance as conventional antennas once deployed. Such antennas have several future potential applications. One of these is with Cubesats which are small satellites, typically cube-shaped with side lengths of 10cm. Even though the payload is limited, they are much cheaper to launch into space than standard-size satellites. In order to have the same functionality as a bigger satellite, the communication part, especially the antenna, must be efficient and reliable and preferably be able to extend outside of the Cubesat’s body.

In order to solve this problem, the antenna I am currently investigating is the reflectarray.
A reflectarray consists of a primary source that illuminates an array of phase-shifting cells.
By controlling individually the phase shift of the unit cells, one can easily control the direction of the main beam. Thus a reflectarray can be seen as a reflector antenna having the main advantage of being flat, unlike a dish antenna that has to be parabolic shaped. This simple geometry makes it an excellent candidate for being adapted to a deployable structure.

In order to study the behaviour of these antennas, we are exploiting state-of-the-art facilities at the University of Glasgow. For characterisation, we have an automated spherical near-field scanner by NSI in an anechoic chamber that is 4.5m by 4.5m by 4m, operating in the frequency range 500 MHz to 18GHz, although higher frequencies are possible with additional cabling. For the theoretical side, we are using simulation software, split into two stages. The first is the optimization of the shape of the reflectarray unit cells using electromagnetic solver tools. This gives us accurate predictions of the phase of the reflection, as a function of geometrical parameters.
The entire reflectarray is however too big in comparison to the wavelength to provide fast results using software deployed on a single workstation. To solve this problem, the second task is to use world-leading academic solver tools (finite-different time-domain, FDTD) that are intended for large parallel computations on high performance computers, such as the 1.3 TB RAM, 288 core cluster we host.



Lada Vybulkova
School of Engineering

Impact of tidal turbines on the seabed

One of the most important aspects of the environmental impact of a tidal turbine is the effect on sediment transport in the immediate vicinity of the device. The interaction between the wake that is produced downstream of tidal turbines and the sediment on the seabed is of particular concern given the potential damage to the habitat of marine plants and animals. The three-dimensional nature of the flow through the rotor of a tidal turbine proves to be crucial for the assessment of the impact of the device on sediment transport.

Changes in sediment erosion due to the turbine have been investigated by high resolution three-dimensional computational simulations of the hydrodynamics of the rotor wake. A model of the interaction of the wake and a velocity profile has been developed. A quantity evaluating the role of free stream vorticity in the development of the wake has been identified. Several velocity profiles have been investigated to study the influence of incoming tide on the turbine wake.

The mechanism whereby material is eroded from the seabed is represented by a threshold value of the bed shear stress that has to be reached to initiate motion of sediment.

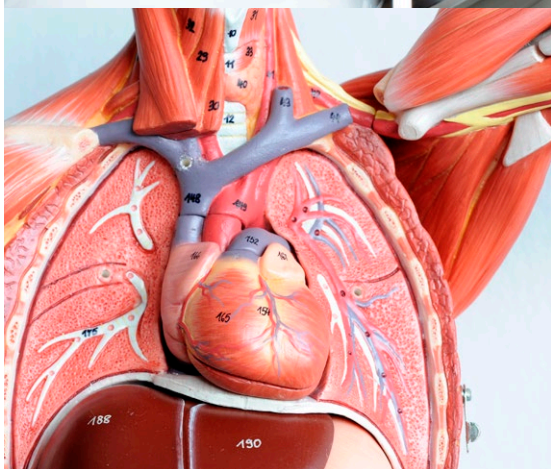
Excess bed shear stress, caused by the presence of a turbine in tidal flow, has been identified as an indicator of the scale of the impact on the seabed. Two areas of the seabed behind the rotor have been identified according to the structure of the wake vorticity field and consequently in the excess bed shear stress.

Immediately behind the rotor, the vorticity sheets roll up into vortex filaments, forming a helical structure. The structure is inclined by the depth varying inflow. Further from the rotor the helical form starts to disintegrate. The spatial distribution of excess bed shear stress exhibits concentration of high values no further than two rotor diameters behind the rotor. Further from the rotor, occasional spikes of high value of the excess bed shear stress occur.

Lei Wang
School of Mathematics and Statistics

A computational framework of patient-specific tools on analysing aortic dissection

Several studies have shown that the aortic size used now is inadequate to predict the trend of aortic dissection (AD), and it is the aortic wall stress that could be a better indicator in the view of biomechanics and crucial information for updating diagnosis and treatment strategies of AD. We proposed a computational framework for analysing the stress distribution, especially the peak stress at the tear tip, in the context of finite element analysis. A series of boundary value problems, inflation of a thick-wall cylinder anisotropic nonlinear hyperelastic tube (simplified problem for predicting the initiation of AD) and balance of a same tube with prescribed tear (simplified problem for predicting the trend of AD) have been solved in FEAP and good agreement has been validated with analytical results. Integrated with an appropriate mesh generator (TetGen) of medical image aortic wall, a patient-specific software for aiding management of AD is prospective.



Robbie Warringham
School of Chemistry

Potential large-scale use of CO_2 to produce chemical feedstock – Application of Inelastic Neutron Scattering and Isotopic studies for Ni/ Al_2O_3 dry reforming of methane

Syngas ($CO + H_2$) is a vital feedstock for chemical manufacturing industries,[1] with steam reforming of methane being a well established route (Equation 1).[2] An alternative to this energy intensive process is to use carbon dioxide as the oxidant, in the so called 'dry' reforming process (Equation 2).[3] Dry reforming has strong environmental credentials and yields a product mixture suited to up-stream processes such as Fischer-Tropsch synthesis of relatively high molecular weight hydrocarbons.[4]

$$CH_4 + H_2O \rightarrow CO + 3H_2 \quad (1)$$
$$CH_4 + CO_2 \rightarrow 2CO + 2H_2 \quad (2)$$

Supported nickel catalysts are often utilised for both steam and dry reforming reactions.[5] However, dry reforming over nickel is plagued with rapid deactivation characterised by excessive carbon retention.[6] Understanding the processes that lead to diminished activity with increasing time-on-stream is therefore desirable. This study aims to investigate methane dry reforming using an alumina-supported nickel catalyst that produces filamentous carbon similar to that observed on an industrial scale. Isotopic substitution studies were performed to explore the role of the carbon dioxide during carbon lay down process and inelastic neutron scattering was utilised to quantify retained hydrogen within the carbonaceous matrix.

Dimitrios Xenos
School of Engineering

Evaluation of nonlocal approaches for modeling fracture in notched concrete specimens

Fracture is one of the main problems in structural engineering and there are still many open questions on this subject. Analysing mechanical failure is one of the most significant and urgent challenges in engineering. Unfortunately, most of the existing methods for modeling fracture rely extensively on expensive and complex testing methods, the results of which are often used to develop phenomenological macroscopic models. Furthermore, very large and very small structures (e.g. concrete dams or carbon nanotubes) are difficult to test.

Consequently, it is very complicated or impossible to design such structures accurately to exhibit the required strength. Most of the existing approaches for modelling fracture and material failure cannot be used for prediction outside the range of the experimental results since they are based on curve fitting and not on the mechanics of the underlying processes. A potential solution is the development of methods based on the mechanics of lower scales and the underlying fracture processes.

During fracture in quasi-brittle materials, growth and coalescence of micro-cracks lead to formation of visible fracture process zones that transfer stresses by crack bridging and aggregate interlock. Commonly, the response of these fracture process zones is modelled by nonlinear fracture mechanics approaches using stress-strain laws with softening. In one of these approaches, nonlocal constitutive models are applied, which describe the fracture process zone as regular strain profiles independently of the size of the finite elements. This is achieved by evaluating the stress at a point by a weighted average of state variables in the vicinity of this point. However, there is no consensus how they should be calibrated and how the influence of boundaries should be described in these models. In the present work it is investigated how existing nonlocal models describe the influence of boundaries. Different nonlocal damage approaches proposed in the literature are evaluated for analysing 2D beams with various types of notches. The chosen nonlocal models differ in their averaging procedures, which depend on the spatial position within the specimen and the stress state. Firstly, the nonlocal models are calibrated by fitting stress-strain curves of one dimensional uniaxial tension analyses to mesoscale analyses reported in Grassl and Jirásek (2010). Then, the models are used to simulate 2D three point bending tests with a sharp notch, with a 45o V-type notch and a smooth boundary without a notch. The performance of the nonlocal models is evaluated by comparison of load-displacement curves and dissipated energy profiles along the ligament of the beams with meso-scale analysis results reported in Grassl and Jirásek (2008).

The results of this research will allow us to identify nonlocal models for fracture in concrete, which can describe accurately fracture close to boundaries.

References

P. Grassl and M. Jirásek. Meso-mechanically motivated nonlocal models for the modelling ofthe fracture process zone in quasi-brittle materials. In WCCM8, 8th World Congress on Computational Mechanics, Venice, Italy, 2008.
P. Grassl and M. Jirásek. Meso-scale approach to modelling the fracture process zone of concrete subjected to uniaxial tension. International Journal of Solids and Structures, 47:957–968, 2010.