

PhD in the Systems, Power & Energy Division

The School of Engineering at the University of Glasgow is a dynamic centre for academic research that brings together fundamentals, technologies and applications. The School offers excellent facilities for research, including a stimulating working environment and an excellent student support and supervision structure. The Systems, Power & Energy Division within the School of Engineering offers the possibility of undertaking PhD projects in a number of areas of research described in more detail below.

Research Areas

Dynamics

The Dynamics Group offer a range of PhD projects in applied dynamics and power ultrasonics. The group develop analytical and computational models to understand and analyse the dynamic responses of complex structures and systems. The group has excellent laboratory facilities and vibration measurement instrumentation that permit validations of models, dynamic behaviour characterisations and insight into dynamics phenomena. The group conducts fundamental and applied research across a wide range of applications including, among others; surgical devices, space technologies, smart structures, automotive structures and drivetrain, joining technologies. Our research is well funded by research councils and industries and we collaborate across multiple disciplines to address major challenges in dynamics research.

Computational Fluid Dynamics

The research work of the Computational Fluid Dynamics (CFD) group ranges from the design, implementation and demonstration of novel computational technologies to the analysis of complex flow problems of mechanical, aeronautical, civil and biomedical engineering. Many of our current projects are interdisciplinary concentrating on a wide range of topics including the investigation of wind, gas and hydraulic turbine flows, combustion, stenosis blood flows and injected drug flows. The algorithm development work includes the development of time- and frequency-domain Navier-Stokes solvers for the analysis of unsteady flows, and novel approaches to high-performance parallel computing for large CFD applications. The group has ongoing collaborative projects with other academic and public institutions, and industries. A significant part of the CFD group research is funded by research councils and industries.

Energy

The Energy Group offers a range of PhD projects in diverse subjects such as the monitoring of Nuclear safeguards, biomass and combustion systems, Stirling engines, thermoelectric materials, smartgrids and smart meters, low energy lighting, power converters and a wide range of the underpinning energy extraction and conversion technologies. There are PhD projects in lasers and optical systems, including: the growth and extraction of biodiesel from algal biomass, optimal design for photobioreactors, laser decontamination, and the development of optical fibre sensors for extreme environments. Projects involving practical implementations and mathematical modelling / simulation, spanning basic to applied research are available. Our research is funded by research councils and industry. Interdisciplinary research proposals or proposals which involve an industrial partner are particularly welcome.

Materials

The Materials Group offers PhDs ranging from fundamental science projects investigating the structure-property relationship of materials through to industrially-focused and applied projects such as virtual manufacturing, adhesive bonding and impact testing. The Materials Lab recently benefited from significant inward investment (Glasgow Research Partnership in Engineering) and contains unique test facilities (ballistic range, biaxial equipment and the largest single testing rig in the UK). We apply various modelling strategies (e.g. multi-scale, multi-physics) using a number of computational modelling codes (both in-house and commercial) to investigate: advanced composites, smart materials, engineering fabrics, porous structures and ultra-thin sheet-metals. As part of a leading multi-disciplinary university we benefit from access to expertise and facilities across the university (Kelvin Nano-Characterisation Centre, WestChem, James Watt Nanofabrication Centre) enabling unique research opportunities in materials-focused mechanical engineering.

Power Engineering

Power Engineering is primarily concerned with the economic and efficient generation, distribution and conversion of electrical power. There have been significant advances in all these areas over the last 100 years but there is little doubt that we are currently experiencing a 'Golden Era' in power engineering research given the challenges to combat climate change through the economic use of renewable energy technologies, flexible transmission systems and energy efficient motors and converters. The Power Engineering Group offers a wide range of PhD research projects in this field, including electric motors and generators, power electronics and drives, renewable energy technologies and power systems.

Science and Music

PhD projects offered by the Science and Music Group are carried out in the framework of the Network for Interdisciplinary Studies in Science, Technology and Music (n-ISM). This is an interdisciplinary, inter-faculty, inter-institutional, international consortium of collaborating researchers. We are inter-disciplinary because we are active in projects which involve different disciplines operating different research methodologies. Projects involving composition, performance and engineering, for example, will demand the deployment of skills associated with each discipline at the highest level, with the potential of advancement in all fields. The research outcomes often give rise to new, richer trans-disciplinary approaches to research.

Training and experience

Students will receive comprehensive training in research in the engineering disciplines associated with their project and the research group's activities, typically across a range of advanced analytical, numerical and experimental techniques. Additionally, most PhD projects are multi-disciplinary and offer training across a number of disciplines such as life sciences, mathematics and design. In addition, students will receive a coordinated programme of essential research skills and generic transferable skills that will benefit them in their studies and future careers.

Person Specification

Candidates must have a good first degree (or equivalent) in an appropriate discipline. Good communication skills in English, both oral and written, are also essential, as is a strong background in the advanced undergraduate level subjects relevant to the PhD project. The

successful applicant is expected to conduct independent research leading to original contributions to the PhD project, culminating in a PhD thesis.

Possible projects

Possible research projects to be undertaken in the Systems, Power & Energy Division of the School of Engineering are given below. If you are interested in any of these projects, you should email the prospective supervisor associated to the chosen project for discussing your intentions (see contact email next to the project title).

Alternatively, you are welcome to identify a different project topic within any of the previously described research areas by emailing your project proposal to the Head of Division, Prof. Margaret Lucas (margaret.lucas@glasgow.ac.uk), who will direct you towards a prospective supervisor with expertise in that area.

1. *Optimising growth and oil extraction from genetically modified algae*
Contact: Dr Ian Watson (ian.watson@glasgow.ac.uk)

Many species of microalgae are highly nutritious and have high lipid content, resulting in significant opportunities for efficient food and oil production. Optimising oil yields from algae depends on a large number of factors that interplay and modify the oil, carbohydrate or protein quality and its ultimate use, however this can be engineered for positive benefit. Work at the University of Glasgow has focused on photobioreactor designs to optimise growth conditions of *Nannochloropsis oculata*, dewatering systems for algae separation and oil extraction processes. These systems will be scaled-up to increase algal biomass production for detailed analysis of the algae products for a range of applications, including food and biodiesel production. As part of the optimisation strategy, rapid lipid detection systems will be developed and genetic analysis and genetic engineering conducted to maximise lipid production. The flux through the pathway involved in lipid biosynthesis will be improved by using commercial gene synthesis to generate enhanced derivatives of the existing genes. These codon optimized genes will be tested for their ability to enhance lipid biosynthesis through established assays that have been shown to measure changes of less than 0.1% in lipid concentration. Parameter mapping techniques of the physical variables associated with algal growth will lead to process optimization for the genetically modified algae. The effect of chemical and physical treatment on the oil extraction efficiency will be investigated and include for example, ultrasonic, microwave and laser treatment. The route to commercial exploitation remains complex due to relatively complex and expensive process requirements. Thus, it is important to appreciate the scientific, engineering and business implications of the processes. To this end, detailed models coupling these disciplines will be developed to allow holistic process optimisation and a strategy to successful commercialisation.

2. *Simulation-based design of ultrasonic surgical needles for bone penetration and targeted drug delivery*
Contact: Prof Margaret Lucas (margaret.lucas@glasgow.ac.uk)

A well-funded research activity currently exists to deliver novel miniature ultrasonic bone cutting devices for minimal access orthopaedic surgical applications. This new project aims to deliver even more challenging configurations, in the form of ultrasonically excited needles, with capability to penetrate bone for targeted drug delivery. The devices will meet the needs of a variety of potential clinical applications where direct drug delivery either into the bone is required or needle penetration through the bone is required to access difficult surgical sites. Current research in the power ultrasonics group is already delivering a new generation of small surgical devices based on novel flexensional transducers. Another line of research has been in combining longitudinal and torsional vibration responses to improve penetration into hard materials. This project will investigate how to create ultrasonic needle device configurations based on flexensional transducers to excite optimised combined longitudinal-torsional (L-T) needle tip vibration responses. To maximise the effectiveness of these devices, a major challenge now exists to identify what ultrasonic parameters and device features are required in order to penetrate bone with low ultrasonic power. Since this relies on a substantial parametric study, it is best achieved through developing simulations via multi-scale

models of ultrasonic bone penetration, specifically concentrating on the interaction of the needle and bone material at the microscale in order to gain knowledge of how damage is initiated at the interaction site. Bone tissue is a highly anisotropic material that possesses stochastic variability in its elastic, plastic, viscous and hardness properties due to its high porosity and osteonal structure. The computational study will therefore focus on simulating the interaction between the vibrating needle and both cortical and cancellous bone, taking into consideration the anisotropic, heterogeneous, hierarchical nature of bone, and accounting for spatial randomness of bone properties and bone microstructure. The aim is to achieve a significant advance on existing ultrasonic bone cutting models. The design requirements for an optimal flexensional transducer and attached L-T needle will rely on the outcomes of the computational models. The simulations will provide better insights into the mechanisms of bone penetration and the interactions of the ultrasonically excited needle and cortical bone at multiple scales. This will focus the design requirements on achieving the right penetration mechanisms to deliver an accurate and efficient cut through bone as predicted by the models. The models will also enable a parametric study to be conducted, incorporating variation of frequency, ultrasonic amplitude, load, and needle cutting edge geometries, in order to identify design requirements which result in an acceptable cutting force for hand-held ultrasonic needle devices.

3. *MySolar: Concept and Development of a Novel PV-TE Hybrid Solar System for Sustainable Power Supply in Developing Nations*

Contact: Dr Manosh Paul (manosh.paul@glasgow.ac.uk)

Energy demand throughout the world is increasing systematically with increases in world population and rapid industrial growth in Asia (e.g. India and China). Fossil fuel reserves are finite and their international distribution asymmetric. Beyond these principally economic considerations, CO₂ emissions from fossil fuels have risen almost exponentially since 1870. Despite this many of the poorest regions of the world still have no affordable means of generating electricity or heat. Although Scotland is becoming a leading player in renewable energy technologies such as hydro and wind, the major global market for green power generation lies with solar-based systems. The European Photovoltaic Industry Association (EPIA) and Greenpeace, showed in a recent survey that with appropriate development ca. 12% of electricity demand (~1,845 GW) could be met by solar in EU countries by 2020 and in many Sunbelt countries including China, the Middle East and India by 2030. Despite considerable efforts most commercially available PV modules cannot exceed an efficiency level of 20%. Ironically, PV performance is lowest at the highest temperatures when solar irradiation reaches its peak. Cooling is thus essential and a PV panel can be passively (cheaply) cooled by the convection of air to enhance its operating efficiency, but this wastes a large portion of the available solar energy (to the environment). An ideal would be to harness this waste heat while improving the performance of the PV and to achieve this as a low cost solution. We, therefore, aim to develop a new hybrid PV-TE system, by integrating a TE converter with a PV module and investigate the energy conversion efficiency at elevated temperatures. A whole network model will be designed for the hybrid system by the application of computational fluid dynamics (CFD). For the first time we will test and model the effects of mounting and convection, in combination with the utilisation of various PV and TE materials to achieve a general optimisation method for the system to yield its best possible efficiency. Many parts of the world operate with no electricity at all. MySolar aims ultimately to bring sustainable electricity to remote areas and generate economic benefits for society in its entirety. The research will intrinsically link with nanofabrication and nanocharacterisation and material for TE PV cells which will, in future, lead to a significantly advanced solar energy technology.

4. *Ultrasonic power and data transmission through space structures*

Contact: Dr Patrick Harkness (patrick.harkness@glasgow.ac.uk)

Ultrasonic vibration provides a mechanism by which power and data can be transmitted across or through structures which are not suitable for electrical connection, for example across sealed pressure hulls or along deployed structures. Tape springs are often proposed for space deployable structures and the elimination of electrical current in such structures may have particularly attractive applications in fields such as magnetometry or antenna support, where it can induce a contaminating magnetic field. This project seeks to determine the optimum waveform for power transmission across a wide range of structures, including tape spring based deployable architectures, to determine the applicability of a range of transducer types and piezoelectric materials. In particular the use of novel transduction equipment, multi- mode excitation and modal interactions will be investigated to

determine if it is possible to transmit power-carrying waves in one direction whilst signal-carrying waves propagate in the other, thereby moving towards the closure of a non-electrical two-node loop with a power generator/spacecraft bus at one node and a sensor suite at the other. Ultimately, the signal-carrying wave would be generated by a device at the sensor node using power harvested from the power-carrying wave. This project will entail mathematical modelling of electromechanical structures, experimental work, and liaison with specialists in the field of electronics and nanoscale engineering. The work is expected to be technically difficult but a University-wide support structure is now in place to facilitate space systems engineering and the successful applicant may expect to work in an environment in which practical spaceflight opportunities for the knowledge and technology they develop will be sought, identified, and exploited to the furthest possible extent.

5. *Innovative Manufacturing of 3-D Advanced Composite Components*
Contact: Dr Philip Harrison (philip.harrison@glasgow.ac.uk)

One of the main thrusts of the UK's strategy for economic growth and recovery is to promote innovative manufacturing. Advanced composites have an unsurpassed potential to reduce weight in automotive and aerospace applications, an important route to reducing CO₂ emissions, as well as in renewable energy applications, for example in enabling the manufacture of ever larger wind turbines. As the final mechanical properties of advanced composite parts are implicitly linked to their manufacture, computational design tools that begin with the manufacture method and progress through to the final design stage are essential. The project will focus on modelling one of the most promising fully-automated low cost manufacture techniques, namely, sheet thermoforming. Using multi-scale constitutive models already developed by researchers in the Advanced Materials Group at the University of Glasgow, the thermoforming process will be simulated using the finite element method. For the PhD student, the crux of the project will be to develop an interface allowing forming predictions to be used in subsequent mechanical simulations, based on predictions of fibre re-orientations that occur during the forming process. Stochastic modelling of mechanical properties due to inherent fibre directional variability of 'off-the-roll' engineering fabrics will be undertaken as a subsequent step, employing unique in-house codes already available within the group. Numerical work will be supported by an experimental program which will benefit from access to the extensive machine-shop facilities available in the School of Engineering. Novel components will be press-formed and used to evaluate forming predictions. Once the stiffness of these parts can be predicted, the codes will be enhanced to include strength and damage modelling capabilities. The underlying goal of this research will be to push the technology forward, creating prototype components of unique complexity, but with practical value. The work will aim to demonstrate the potential of the finite element approach over more widespread and simpler kinematic methods, typically used by industry today. In so doing the PhD student will gain relevant experience in topics such as advanced composites, continuum mechanics and computational modelling and the project will support the UK in its drive to excel in the area of high-value innovative manufacturing. Output of the project will be exploited by Scotland and more widely in the UK, feeding into an extensive network of industrial and academic partners; the work will be of interest to several multi-national companies in the aerospace and renewable energy sectors situated in the Glasgow area, and enhance related research programs at the new UK Innovative Manufacturing Centres.

6. *Characterisation of transverse strength of fibre-matrix interface within bonded polymeric composite joints*
Contact: Dr Safa Hashim (safa.hashim@glasgow.ac.uk)

Adhesive bonding is potentially the most effective joining method for lightweight, energy efficient composite constructions such as aircrafts, turbine blades, ships and automotive structures. Currently, most of these structures are bolted, necessitating thicker laminates to reduce stress concentration around the holes. The bonded laminates on the other hand do not need to be that thick. However, these could ultimately fail under the transverse stresses generated from the peel/transverse forces within the adhesive bondline which pulls the top composite surface causing delamination. The main limitations for bonding in this case is low interlaminar transverse tensile strength which is ultimately controlled by the interface between individual filaments with the matrix resin as well as the architecture of the top fabric ply. The lack of relevant experimental technique to study this (transverse strength) at micro-scale level makes this research an extremely challenging and interesting topic. The project aims to characterise the interface strength under transverse loading and determine failure mechanism and criteria. Both meso-scale and micro-scale modelling

will be used and the micro-scale modelling involves numerical and experimental techniques. While the numerical methods are readily available to study this, the mechanical testing is a major challenge, specifically in relation to applying lateral loading on 20um glass fibre/filament to determine the interface strength. To this end, an up-scale experimental models, typically 100:1 to 50:1 are proposed to represent this and characterise failure and behaviour using an appropriate dimensional analysis methodology. The study will take into consideration fabric architecture, type of resin and fillers, fibre size and interface conditions including defects will ultimately influence the transverse strength and hence joint failure. The dimensional analysis will take into consideration the geometrical and mechanical properties of materials, glass in this case. In addition, the study will also require intensive imaging and microscopy work to quantify the level and distribution of micro-scale defects/flows within the actual fibre resin interfaces, to account for in the numerical and experimental models.

7. *Development of a nonlinear frequency-domain Navier-Stokes solver for the aeroacoustic analysis of prop-fan aircraft engines*

Contact: Dr Sergio Campobasso (sergio.campobasso@glasgow.ac.uk)

The use of nonlinear frequency-domain Navier-Stokes (NS) computational fluid dynamics (CFD) solvers for the analysis of unsteady periodic flows substantially reduces the required computational time with respect to time-domain (TD) NS solvers without spoiling the solution accuracy. The Harmonic Balance (HB) method is one such technique, and the COSA parallel HB NS FORTRAN solver being developed at the School of Engineering of Glasgow University has already been successfully applied to the prediction of wind turbine unsteady periodic flows, leading to a reduction of one order of magnitude of the computational time for the unsteady flow analysis with respect to the TD method. This PhD project concerns the development of an HB NS FORTRAN solver for the analysis of multi-stage turbomachinery flows. The computational technology to be developed will be used to analyse the aeroacoustic emissions of prop-fan aircraft engines, a non-conventional engine layout aimed at reducing fuel consumption while maintaining the performance level of modern high-bypass-ratio turbofan engines. Flight tests conducted in the US in the past 10 years have highlighted that prop-fan engines reduce fuel consumption by 30 percent with respect to turbofan engines with the same thrust rating, but they are often more noisy. Acoustic emissions are indeed the main remaining issue preventing the large-scale deployment of prop-fan engines. This PhD project will contribute to solving this issue by developing a novel HB NS CFD solver for multi-stage turbomachinery and using it for the aeroacoustic analysis of the counter-rotating fans of prop-fan engines. The PhD student will run these simulations using large parallel computers and each simulation is expected to require about 4 thousand cores. The use of the HB NS technology will allow each of these analyses to be performed in just a few hours. The student will also analyse the results of these analyses, with the objective of establishing the relationships between different layout and design of the counter-rotating fans and the characteristics of the emitted noise. The project will be carried out in collaboration with the Whittle Laboratory at Cambridge University. The PhD candidate for this post will hold a First Class degree in one of the following fields: mechanical engineering, mathematical modelling, scientific computing or a related area. The successful applicant will have good analytical and modelling skills, and sound knowledge of computational fluid dynamics and fluid mechanics. Basic knowledge of the following applications would be an advantage: FORTRAN and/or C/C++, open-source or commercial CFD solvers and grid generation software. Enthusiasm and determination in exploring original ideas as well as good team spirit are essential qualities of the successful candidate. Very good spoken and written English is essential.

James Watt Scholarships

The School of Engineering offers a number of scholarships that will cover tuition fees and an annual stipend of £13,590. These competitive scholarships will be available to highly qualified applicants of any nationality who hold very good honours undergraduate or taught postgraduate degrees, or equivalent, in a relevant subject.

Because of the significantly higher cost of overseas tuition fees compared to home/EU ones, only a very limited number of scholarships (typically one or two) are allocated to overseas candidates (i.e. candidates from outside the European Union). This means that competition among overseas candidates is particularly intense, with only outstanding applicants standing a reasonable chance of success.

Application procedure

If you are interested in any of the previously listed projects, you should first contact the relevant supervisor to discuss your intentions. You are also welcome to propose a different project from those listed, provided that the project has been agreed with a supervisor from the School of Engineering.

After having discussed with the prospective supervisor and received his/her support, you can apply for a scholarship by following the two-stage procedure outlined below:

1. First, apply for admission as a postgraduate research student to the Graduate School of the College of Science and Engineering¹ by using the online system at the following link:

www.gla.ac.uk/colleges/scienceengineering/graduateschool/prospectivestudents/howtoapply/

Remember to include in Section 2 of the application form the title of the project together with the name of the prospective supervisor and to state in Section 9 that the prospective supervisor has agreed to support your candidature for a James Watt scholarship.

2. Secondly, apply for a James Watt scholarship by completing the form downloadable at the following link:

<http://www.gla.ac.uk/schools/engineering/phdopportunities/appform>

This form must be submitted by email to the address eng-jws@glasgow.ac.uk not later than **Mon 2 April 2012**.

Application outcome

The prospective supervisor is responsible for liaising with his/her Head of Division to support your application for a James Watt scholarship. The decision about which candidate is awarded a scholarship will be taken by the School Management Board, in consultation with Heads of Division, **by the end May** and communicated back to prospective supervisors.

If you have not heard about the outcome of your application before the end of May, please liaise with your prospective supervisor to receive confirmation about whether you have been awarded a scholarship or not.

¹ Note that an offer of admission by the Graduate School does not guarantee the award of a James Watt scholarship.