School of Mechanical and Chemical Engineering
SEMMESTER 1 2014 – FINAL YEAR PROJECT LIST

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Final Year Research Projects for the School of Mechanical & Chemical Engineering Semester 1&2, 2014

The Fluid Science Division will offer up to 15 new places across 7 projects in the first semester 2014 to undergraduate FYP students. Students should follow the process for applying for these projects established by the School of Mechanical & Chemical Engineering

FSD-1: Natural Gas and LNG property prediction
Supervisors: W/Prof. Eric May, Dr Brendan Graham
Suitability: Chemical Engineering, Mechanical Engineering, Mechanical Engineering (Oil and Gas Major)

Unplanned shutdowns of LNG plants caused by hydrocarbon solids blocking cryogenic heat exchangers are a major, ongoing problem for the industry. Current methods of avoiding them are costly and energy intensive. In addition, LNG production systems are over-engineered because the predictions of process simulators are unreliable. Furthermore, the natural gas industry needs new thermo-physical property data at high-pressures and low temperatures to develop more efficient processes capable of handling more problematic gas reserves. These projects aim to develop new predictive models to avoid shutdowns and improve plant efficiency, and/or improve the reliability of process simulator predictions by anchoring their underlying thermodynamic models to data characteristic of realistic LNG fluids and conditions. Students working on these projects will help develop or improve models that predict crucial properties such as vapour-liquid and solid-liquid equilibrium, density, heat capacity, viscosity, surface tension or thermal conductivity for binary and multi-component hydrocarbon mixtures. This will be done by combining state-of-the-art measurements of these properties with new property package models in process or multi-phase flow simulation software.

FSD-2: Advanced Natural Gas Separation Technology
Supervisors: Dr Brendan Graham, W/Prof Eric May
Suitability: Chemical Engineering, Mechanical Engineering, Mechanical Engineering (Oil and Gas Major)

Carbon dioxide capture, whether from natural gas streams or from flue gases, is an important and increasing area of research with significant implications for our economy and environment. N₂ capture from natural gas is increasingly important in the development of LNG projects where this component is energetically parasitic. These projects will look at the use of novel materials for improved capture efficiency that are either solid adsorbents, including carbons, zeolites and calixarenes, or liquid solvents, such as transition metal complexes. Students working on these projects will help develop and characterise the separation performance of new materials synthesized in our laboratory over a wide range of temperature, pressure and mixture compositions, and/or use the results of such experiments to develop numerical models of advanced industrial separation processes.

FSD-3 – Flow assurance and natural gas hydrates
Supervisors: W/Prof. Eric May, W/Prof Mike Johns
Suitability: Chemical Engineering, Mechanical Engineering (Oil and Gas Major)

Natural gas hydrates are ice-like solids that form and can often suddenly stop the flow during oil and gas production. The cost of their prevention during design and production is high and the removal of hydrate plugs is expensive and dangerous. Today hydrates are still a major flow assurance concern especially as production moves to deeper water, and many of Australia’s major new gas field developments are considering innovative approaches to this long-standing problem. However, naturally-occurring gas hydrates also represent a tremendous energy reserve and offer significant potential for CO₂ sequestration. In early 2013, first production was reported from a naturally occurring hydrate reserve located offshore the coast of Japan. These projects aim to provide the knowledge needed for a risk-based approach to hydrate management by establishing quantitative model to assess plugging potential, optimize inhibitor doses, and develop methods to detect hydrate formation and location using novel technologies. The outcomes will help reduce chemical use by the industry, provide better methods to locate plugs and provide safer methods for their remediation, ultimately allowing for the reliable and economic development of marginal oil and gas fields. Students working on these projects will measure and/or model hydrate formation, agglomeration and dissociation processes.

FSD-4 – Crude oil emulsions
Supervisors: W/Prof. Mike Johns, Dr Brendan Graham
Suitability: Chemical Engineering, Mechanical Engineering, Mechanical Engineering (Oil and Gas Major)
Unwanted Emulsions of (crude) oil and water are frequently encountered during oil production across the world including in Western Australia (which is now Australia’s main liquid fuel provider). Such emulsions add significantly to operating (e.g. pumping) and capital (e.g. processing vessel size) costs, accentuate corrosion and generally adversely affect product quality. Essential to process routes/treatments to break such emulsions (i.e. separate the water and oil phases) are the use of cheap, robust methods and real-time measurement of the emulsion droplet size distribution. In this context, projects are available that focus on optimising our unique Nuclear Magnetic Resonance (NMR) instrumentation for on-line emulsion droplet sizing; Modelling and experimental observation of oil-water gravity separation units with the inclusion of a water recycle for emulsion inversion (crude oil-in-water emulsions are much easier to break than water-in-crude oil emulsions); efficient extraction of naturally occurring resins from crude oil that have been proven to significantly reduce emulsion strength, use of CO$_2$ for emulsion droplet disruption and encouraged coalescence and technical reviews of emerging emulsion breaking technologies.

FSD-5: Remote Process Water Analysis

Supervisors: W/Prof. Mike Johns, Dr Brendan Graham

Suitability: Chemical Engineering, Mechanical Engineering, Mechanical Engineering (Oil and Gas Major)

There are three projects in this research category:

(i) The moisture content of iron ore deposits is a critical parameter for their subsequent extraction and processing. There is extensive industrial interest in the mining industry in the use of Nuclear Magnetic Resonance (NMR) logging tools for the in situ determination of this moisture content in exploration wells (of which in excess of 40,000 are drilled in Western Australia annually) before mining has commenced. Alternative logging techniques have proven to be inadequate for this purpose. However significant laboratory based measurements are required to properly interpret this NMR logging data – this essential calibration is currently being performed at UWA and the project would assist with development and implementation of these measurements. The approach adopted is equally applicable to glauconite-containing greensands as are frequently encountered during gas and oil NMR logging in Western Australia.

(ii) Desalination of seawater to provide potable water is a rapidly expanding activity in Western Australia (providing 50% of your potable water) and across the world. Increasingly this is done using reverse osmosis membranes in the form of spiral-wound modules (ROMs). These are however susceptible to bio-fouling by a range of organisms which can cause serious performance degradation and complete failure of the ROMs within one year. We have developed cheap, mobile Nuclear Magnetic Resonance (NMR) instruments employing the Earth’s magnetic field to provide an early warning (i.e. more sensitive than trans-membrane pressure drop) of such biofouling development in ROMS, such that corrective actions can be initiated. We are currently expanding the capability of this instrument such that faster velocities can be realized.

(iii) Gas production results in the requirement to discharge simultaneously produced water back to sea. We are currently developing technology to monitor the oil contamination of this discharge water such that it is compliant with environmental legislation. We are also exploring options for this water separation and discharge to be effected sub-sea.

FSD-6: Carbon Sequestration

Supervisors: W/Prof. Mike Johns, W/Prof. Eric May

Suitability: Chemical Engineering, Mechanical Engineering, Mechanical Engineering (Oil and Gas Major)

Western Australia will soon be the world leader in the geo-sequestration of carbon dioxide. Both the Gorgon project and the recently announced South West CCS Hub will store several million tonnes per annum of CO$_2$ in saline aquifers. Two of the most important but least understood mechanisms by which CO$_2$ remains trapped in these aquifers are known as residual trapping and solution trapping. Residual trapping relies on capillary forces to immobilize CO$_2$ “droplets” within the porous rock containing the aquifer.

Research will be conducted to enable better prediction of the extent of these two trapping mechanisms; this will exploit simple NMR characterization of rock cores extracted from suitable reservoirs. Western Australia has several major offshore gas assets containing significant quantities of carbon dioxide. Scenarios for dealing with this CO$_2$ must be developed before these gas fields can be developed. One scenario involves the re-injection of carbon dioxide produced from one reservoir into the extremities of a different natural reservoir for the purpose of both CO$_2$ disposal and enhanced gas recovery. However, such a strategy is only viable if the probability of breakthrough by the re-injected CO$_2$ to the producing wells is small and the contaminated gas mixing zone remains small over the life of the asset. Simulating reliably this novel reservoir production scenario requires an improvement in our fundamental understanding of the hydrodynamic behaviour of supercritical CO$_2$ in heterogeneous gas and water-saturated rock. Students working on this
project will have the opportunity to conduct and model CO\textsubscript{2} core-flooding experiments at the laboratory scale. The data and models will be used to determine the dispersion of CO\textsubscript{2} as a function of pressure, temperature, rock heterogeneity and saturation.

**FSD-7: Software Interface for Gas Processing Software**

*Supervisors:* W/Prof. Mike Johns, W/Prof. Eric May

*Suitability:* Software Engineering

A number of simulation codes have been developed within the Fluid Science Division to simulate a range of thermo-physical properties relevant to transport and processing in the oil and gas industry. This project will aim to both optimise the numeric requirements of these codes and provide a user-friendly interface for use by workplace engineers. As such this represents an opportunity to apply software skills directly to a prominent WA industrial sector.

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**PROFESSOR TIM SERCOMBE**

**Topic 1 - Oxygen variation during Selective Laser Melting**

A thesis that was completed in semester 2, 2013 discovered some interesting variations in oxygen content during SLM of titanium. During the build, the oxygen content of the atmosphere would initially decrease and then increase again. The aim of this research topic is to determine if this phenomena is unique to titanium, or if it occurs in other materials as well. It will also look to determine a reason for the increase and a method to prevent it.

**Topic 2 - Properties of Al Matrix Composites made via Selective Laser Melting**

Current (and a recently completed) theses have explored the possibilities of producing Al matrix composites using SLM. We now wish to extend this work and have a detailed look at the properties, including the effect of heat treatment on the mechanical and wear properties.

**Topic 3 - Design and construction of powder handling unit for Selective Laser Melting.**

One of the big safety issues with Selective Laser Melting is the handling of large quantities of potentially explosive powder. This project will design and build a powder handling system that will reduce the inherent risks and provide other benefits to the users of the equipment.

**Topic 4 - Design of a powder heating unit**

The aim of this project is to continue the design a new powder heating system for our SLM equipment that is capable of heating powder to ~600deg C. Due to limitations in the equipment, the heating will need to be done from above. The project will involve design and specification of the heaters, measurement and control system and mounting method. During implementation testing and verification will be performed and then initial testing.

**Topic 5 - Properties of carbon fibre sandwich panels with cores produced from SLM**

In this project we will use Selective Laser Melting to produce various scaffold structures which will then be used as cored for carbon fibre composite panels. The properties and failure modes of these panels will be benchmarked against conventional core materials.

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**ASSISTANT PROFESSOR IGOR SHUFRIN**

**Modelling of drill string dynamics in borehole rotary drilling**

1. **Drill bit whirling vibrations in borehole rotary drilling**

   Rotary drilling is the most common method used in mining and petroleum. The rotary drilling systems consist of a very long and slender drill string and a drill bit at its low end. In this project, we will investigate lateral vibrations of rotated drill strings. We will concentrate on the drill bit whirling vibrations leading to a departure of drill bits from the borehole axis and a detrimental effect of rolling of drill bits around the borehole bottom. The project
will involve mathematical modelling of the drill string vibrations, programming using MATLAB and numerical analysis of the whirling phenomenon.

2. Free lateral vibrations of sectional drill strings subjected to axial forces 

Rotary drilling is the most common method used in mining and petroleum. The rotary drilling systems consist of a long drill string assembled from thin-walled drill pipes and a drill bit at its low end. In this project, we will concentrate on the continuous modelling of free lateral vibrations in drill strings made of different sections. We will consider influence of axial forces and various boundary conditions. The project will involve mathematical modelling, programming using MATLAB and parametric analyses of free vibrations of drill strings.


Rotary drilling is the most common method used in mining and petroleum. The rotary drilling systems consist of a slender string of thin-walled drill pipes, a drill bit and a heavy thick-walled drill collar fitted above the drill bit to produce pressure on the bit. This pressure termed as the weight-on-bit results in compressive stresses applied along a part of the drill string. In this project, we will investigate the drill string stability loss caused by the weight-on-bit pressure. We will consider an elastic buckling and post-buckling behaviour of drill strings. The project will involve analytical modelling of drill strings, programming using MATLAB and numerical study of elastic stability of drill strings.

4. Free axial vibrations of drill strings with bilinear boundary conditions. 

Rotary drilling is the most common method used in mining and petroleum. The rotary drilling systems consist of a long drill string and a drill bit at its low end. Axial vibrations of this drilling system are featured by bilinear stiffness: the upward motion of the drill bit is resisted merely by the drill string, while going downwards it performs against the rock and drill string. In this project, we will concentrate on characterisation of axial vibration resonance modes. We will analytically model axial drill string behaviour including the bilinear nature of the problem and study the free vibrations modes of this system. The project will consist of the analytical modelling, numerical implementation using MATLAB and parametric analyses.

WINTHROP PROFESSOR JAMES TREVELYAN

Project JT1: 3-D Printing (starting semester 1, 2014) 

3-D printing technology has advanced to the point that fully functional, high strength parts can be made using relatively inexpensive equipment. The aim of this project is to purchase and evaluate a modestly priced 3-D printing machine for student use. The likely candidate is a machine from www.indimension3.com.

A group of students will be required to set up the machine and find appropriate combinations of software to enable students to manufacture parts for operating mechanical models and projects such as the Weir-Warman student design competition. Videos of recent entries are at:

http://m.youtube.com/watch?v=z613O5wx8
http://m.youtube.com/watch?v=xm7FbULnNy8

Students taking this project will be expected to help coach second-year students entering the Weir-Warman design and build competition in 2014.

Project JT2: Low Energy Consumption Air Conditioning

Close Comfort, a start-up company, is commercialising low power air-conditioners that focus the air conditioning affect just where it is needed rather than calling an entire space. This technology seems to be highly attractive in low income countries where the cost of electricity is relatively high compared with people’s incomes. These units operate on a battery backup uninterruptible power supply during frequent power interruptions that occur in many countries. The power consumption is typically 250W, up to 10 times less than a conventional air-conditioner.

A group of students were conduct performance measurements on different prototypes using a variety of instrumentation including hotwire anemometers and an infrared imaging camera. The aim is to develop low-cost techniques for performance measurement in order to assess quality control of manufacture.
In addition, another group of students will be required to participate in the product redesign for large-scale manufacture. The company is collaborating with a Chinese manufacturer. It is possible that prototype components will be constructed using 3-D printing technology (see project 1).

PROFESSOR ADAM WITTEK

**Topic 1 - Towards modelling of soft tissue damage/failure for computational impact biomechanics and surgery simulation**

Tissue damage modelling is an unsolved and very challenging problem of computational biomechanics. It requires dealing with extremely large deformations and the emergence and propagation of discontinuities (cracks) within an analysed continuum. Ability to model damage to soft tissues is of immense importance for impact and injury biomechanics as well as for surgical applications. Potential applications include virtual evaluation of car crash safety through modelling of traumatic injury to car occupants and pedestrians as well as simulators for surgical training and surgery planning. This project will start with the literature review of constitutive models of soft tissues, algorithms of computational mechanics for modelling of damage/failure of soft continua, and damage/failure criteria for soft continua and selected soft tissues. Based on the literature review, the project will focus on the following lines of investigation:

1) Performance of the procedures available in selected commercial finite element codes in modelling of soft tissue damage/failure under transient load associated with injury and automotive trauma;
2) Performance of the procedures available in selected commercial finite element codes in modelling of soft tissue damage/failure in surgical dissection;
3) New algorithms of computational mechanics (using finite element and/or meshless discretisation) for modelling of soft tissue damage/failure under transient load associated with injury and automotive trauma;
4) New algorithms of computational mechanics (using finite element and/or meshless discretisation) for simulation of surgical dissection of soft tissue.

**Topic 2 - Mining truck tyre modelling**

Vehicle mobility, stability and manoeuverability are to large extent determined by tyre behaviour/performance. For large mining trucks, tyre failure poses significant safety hazard. Through application in tyre design and maintenance, tyre modelling using the algorithms of non-linear computational mechanics may lead to improvements in tyre performance and mitigation of failure risk. This study will start with the literature review of mining truck tyre behaviour/responses, tyre interactions with terrain, tyre mechanical properties and constitutive models, models and algorithms for simulation of truck tyre (including failure) and its interactions with terrain. Based on the literature review, the project will focus on the following lines of investigation:

1) Modelling of interactions between a tyre and terrain using a selected commercial finite element code (or codes);
2) Modelling of mining truck tyre for vibration and transient analysis using a selected commercial finite element code (or codes);
3) Modelling of mining truck tyre failure using a selected commercial finite element code (or codes);
4) New efficient algorithms of computational mechanics for tyre modelling.

**Topic 3 - Understanding of pressure vessel mechanics and design requirements for teaching in master of professional engineering mechanical design course**

Pressure vessels are commonly used in daily life and industry to store and process gases and liquids at pressure appreciably different from the ambient pressure. Examples include soft drink cans, air receivers, water boilers, desulfurisation adsorption columns for natural gas processing plant etc. Consequently, pressure vessel design is an important component of mechanical engineering design curriculum. It is anticipated and expected that results, reports etc. of this project will be used in teaching of Mechanical Engineering BE and MPE courses at the UWA. This study will start with the literature review of Australian and international standards for pressure vessel design, review of the literature on pressure vessel design, review of methods of pressure vessel manufacturing, and review of the analytical and numerical methods for predicting the stress/strain state in a vessel wall. Following the literature review, the project will focus on analysis of a soft drink can as an example for a pressure vessel along three lines of investigation:
1) Analytical methods/models for predicting the stress distribution in a vessel/can walls and pressure that results in vessel failure/rupture;
2) Numerical methods (e.g. finite element analysis FEA) and models for predicting the stress distribution in a vessel/can walls and pressure that results in vessel failure/rupture;
3) Experimental measurement and analysis of the stress/strain distribution within a vessel/can wall.

**Topic 4 - Spinal cord modelling for understanding and preventing of injury**
In Australia alone there are around 400 new cases of spinal cord injury every year. The domestic cost of spinal cord injury is approximately $1 billion. A small reduction in the number and severity of spinal cord injuries through improving of safety countermeasures could reduce this cost. Computer models that predict/simulate the mechanical responses of the spinal cord can play a crucial role in design of such countermeasures. This project will start with a review of the medical/biological and biomechanical literature on mechanisms and criteria of the spinal cord injury, review of the literature on constitutive properties of the spinal cord tissue/tissues and biomechanical studies for modelling of the spinal cord responses and injury. Based on the literature review, the project will focus on the following lines of investigation:
1) Modelling of the constitutive responses and damage/failure of the spinal cord tissue using a selected commercial finite element code (or codes);
2) Integration of information on biological/physiological and mechanical aspects of the spinal cord injury to create a single comprehensive injury criterion and implementation of this criterion in a selected commercial (or in-house) finite element code;
3) New efficient algorithms of computational mechanics for modelling of the spinal cord (including injury).

**PROFESSOR HONG YANG**

**Topic 1 - Design of Laboratory Testing Procedures to Evaluate Commercial Corrosion Inhibitors**
A significant range of corrosion inhibitors are commercially available for a range of industrial applications. This project aims to develop methods for accelerated corrosion testing in laboratory settings to evaluate the corrosion inhibition performances of these inhibitors for specific applications.

**Topic 2 - Investigation of Ion-Exchange Capacity of Industrial Biochars**
This project aims to extend our knowledge on the key chemical property of ion-exchange capacity of biochars. The renewed interest in biochars in recent years is largely driven by the need for effective carbon sequestration to combat the global climate change, in conjunction with a range of recognized beneficial effects of biochars as soil conditioners in agriculture, as absorbents for waste water treatments and for heavy metal removal in mine tailings. Among many other properties of biochars, the cation exchange capacity (CEC) is perhaps the most important property underlining the beneficial utilization of biochars. Students will conduct a critical review on reported CEC data, establish the mechanism(s) governing the CEC, conduct laboratory measurements to further extend the work we are undertaking in this area at the Centre for Energy.