Welcome to MEPC 1

Dear Participants,

This is the inaugural conference highlighting the research of postgraduates in the Department of Mechanical Engineering. There are over 80 PhD students at various stages of their research, working in and across various groups in the Department. There are also about 20 ME research students. These numbers are growing, and growing rapidly. There is a danger that we grow apart, rather than grow together. Equally, there is a risk that the research community in the Department is dissipated rather than strengthened. These lie partly behind the motivation for this conference: to foster collaboration and communication within the Department, and to strengthen our community spirit.

The conference will also highlight our research. Much of this is undoubtedly world-class and is published in journals and presented at conferences around the world. Here is an opportunity for us to see what others in the Department are doing, to learn from them and perhaps work with them. The backbone of the programme comprises 30 presentations by PhD students at later stages of their research. This is augmented by 20, short "work-in-progress" presentations by very-early-stage researchers, which allow them to describe their work to date and future plans. Those who cannot present this year will be able to do so at future conferences: the plan is for this to be an annual event, and we will encourage the postgraduates themselves to take the lead in organising and administering the event.

There is no doubt that the Department is currently an exciting place to work: we are in a period of growth, with new labs and facilities at Newmarket and a building programme planned for the City campus. There is much high-quality research underway that we should be proud of. Let us use this conference as an opportunity to learn from each other and to showcase our research.

Prof. Brian Mace

Head of Department
Organising Committee
Chen Huang
Eryn Kwon
Elinor Swery
Yuanbin Wang
Mingzhu Zhu

Advisory Committee
A. Prof. Kean Aw
Dr. Richard Lin
Prof. Brian Mace
Dr. Andrew McDaid
A. Prof. Robert Raine
Prof. Xun Xu

Conference Secretariat
Tracey Bourke
Hanlie Van Zyl

Technical Editors
Dr. Peter Lescher
Elinor Swery
## Conference at a Glance

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00</td>
<td>Registration</td>
</tr>
<tr>
<td>10:00</td>
<td>Welcome and Opening – <strong>ALR1</strong></td>
</tr>
<tr>
<td>10:15</td>
<td>Keynote I: A. Prof. Kean Aw</td>
</tr>
<tr>
<td>10:45</td>
<td>Keynote II: A. Prof. Robert Raine</td>
</tr>
<tr>
<td>11:15</td>
<td>Break</td>
</tr>
<tr>
<td>11:30</td>
<td>[2A] – <strong>ALR1</strong></td>
</tr>
<tr>
<td></td>
<td>Natural Fibre Composites</td>
</tr>
<tr>
<td></td>
<td>Bio-Robots</td>
</tr>
<tr>
<td></td>
<td>[2B] – <strong>ALR5</strong></td>
</tr>
<tr>
<td></td>
<td>Robot-Assisted Rehabilitation</td>
</tr>
<tr>
<td></td>
<td>Control and Dynamics</td>
</tr>
<tr>
<td>1:00</td>
<td>Lunch</td>
</tr>
<tr>
<td>2:00</td>
<td>[3A] – <strong>ALR1</strong></td>
</tr>
<tr>
<td></td>
<td>Composite Materials Modelling</td>
</tr>
<tr>
<td></td>
<td>Heat/Wind Energy</td>
</tr>
<tr>
<td></td>
<td>[3B] – <strong>ALR5</strong></td>
</tr>
<tr>
<td></td>
<td>Smart Materials and Structures</td>
</tr>
<tr>
<td></td>
<td>Medical Devices</td>
</tr>
<tr>
<td>3:30</td>
<td>Break</td>
</tr>
<tr>
<td>4:00</td>
<td>[4A] – <strong>ALR1</strong></td>
</tr>
<tr>
<td></td>
<td>Manufacturing</td>
</tr>
<tr>
<td></td>
<td>Junior PhDs</td>
</tr>
<tr>
<td></td>
<td>[4B] – <strong>ALR5</strong></td>
</tr>
<tr>
<td></td>
<td>Composite Materials</td>
</tr>
<tr>
<td></td>
<td>Junior PhDs</td>
</tr>
<tr>
<td>5:35</td>
<td>Break</td>
</tr>
<tr>
<td>6:00</td>
<td>Dinner and Awards</td>
</tr>
</tbody>
</table>
## SESSION 1: Keynote

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Presenters</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:15 – 10:45</td>
<td>Polymer-based Memories and Transducers</td>
<td>Kean Aw (#1) -p8</td>
</tr>
<tr>
<td>10:45 – 11:15</td>
<td>Hands-on research of diesel-like fuels</td>
<td>Robert Raine (#2) -p9</td>
</tr>
</tbody>
</table>

## SESSION 2A: Natural Fibre Composites & Bio-Robots

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Presenters</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:30 – 11:45</td>
<td>Flammability characteristics of wool fibre polypropylene composites using halogen-free fire retardants</td>
<td>Nam Nyeun Kim, Debes Bhattacharyya and Richard Lin (#3) -p10</td>
</tr>
<tr>
<td>11:45 – 12:00</td>
<td>Natural fibre composites – fibre and interphase properties</td>
<td>Shyam Panamoottil and Raj Das (#4) -p11</td>
</tr>
<tr>
<td>12:00 – 12:15</td>
<td>Fire retardant characteristics of polypropylene/kenaf short natural fibre composites</td>
<td>Aruna Subasinghe and Debes Bhattacharyya (#5) -p12</td>
</tr>
<tr>
<td>12:15 – 12:30</td>
<td>CPG-based control of a soft-bodied swallowing robot</td>
<td>Mingzhu Zhu and Peter Xu (#6) -p13</td>
</tr>
<tr>
<td>12:30 – 12:45</td>
<td>Soft-bodied peristaltic actuator and pressure sensation system for biomimetic modelling of esophageal swallowing</td>
<td>Steven Dirven, Peter Xu and Leo Cheng (#7) -p14</td>
</tr>
<tr>
<td>12:45 – 12:30</td>
<td>Inverse dynamics of a redundantly actuated masticatory robot</td>
<td>Chen Cheng and Peter Xu (#8) -p15</td>
</tr>
</tbody>
</table>

## SESSION 2B: Robot-Assisted Rehabilitation & Control and Dynamics

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Presenters</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:30 – 11:45</td>
<td>A subject-specific biomechanical model to study ankle dynamics in robot-assisted therapy</td>
<td>Mingming Zhang, Shane Xie and Claire Davies (#9) -p16</td>
</tr>
<tr>
<td>11:45 – 12:00</td>
<td>EMG-based human-robot interface for elbow joint and forearm rehabilitation</td>
<td>Ran Tao and Shane Xie (#10) -p17</td>
</tr>
<tr>
<td>12:00 – 12:15</td>
<td>An effective biological command based controller for improving the effectiveness of human-inspired robotic rehabilitation after neurological disorders</td>
<td>Ye Ma, Shane Xie and Yanxin Zhang (#11) -p18</td>
</tr>
<tr>
<td>12:15 – 12:30</td>
<td>Movement planning in goal-directed reaching by people with cerebral palsy</td>
<td>Alexander R. Payne and Claire T. Davies (#26) -p19</td>
</tr>
<tr>
<td>12:30 – 12:45</td>
<td>Model predictive control on a two-wheeled robot for traction constraints</td>
<td>Ronald Ping Man Chan, Karl Stol and Roger Halkyard (#24) -p20</td>
</tr>
<tr>
<td>12:45 – 12:30</td>
<td>Time-domain flexural wave intensity estimation in plates</td>
<td>Nicholas Ng, Roger Halkyard and Karl Stol (#25) -p21</td>
</tr>
</tbody>
</table>
SESSION 3A: Modelling of Composite Materials & Heat and Flow Energy

14:00 – 14:15 Predicting permeability from scanned images: A tool to optimise the manufacturing process of composite materials
Elinor Swery, Piaras Kelly, Tom Allen and Krishnan Jayaraman (#15) -p22

14:15 – 14:30 Water impact simulation of a composite helicopter subfloor
Thomas Billac and Mark Battley (#16) -p23

14:30 – 14:45 Micromechanical modelling of closed-cell foams
Youming Chen, Raj Das and Mark Battley (#17) -p24

14:45 – 15:00 Individual pitch and trailing edge flap control on upscaled wind turbines
Jeremy Chen, Karl Stol and Brian Mace (#18) -p25

15:00 – 15:15 The effect of preheating on micro combustion
Zerrin Turkeli-Ramadan, Rajnish Sharma and Robert Raine (#19) -p26

15:15 – 15:30 Performance of a hybrid residential water heater
Grant Bourke, Robert R. Raine and Pradeep Bansal (#20) -p27

SESSION 3B: Smart Materials and Structures & Medical Devices

14:00 – 14:15 3D printed conducting polymer micro-structures as low velocity fluid flow sensor
Harish Devraj, Kean Aw, Jadranka Tracvs-Sejdic and Rajnish Sharma (#21) -p28

14:15 – 14:30 Impact-based frequency up-conversion for low frequency energy harvesting
Bryn Edwards, Kean Aw and Aiguo Hu P. (#22) -p29

14:30 – 14:45 PCB Inductive sensor for IPMCs displacement sensing
Jiaqi Wang, Andrew McDaid and Kean Aw (#23) -p30

14:45 – 15:00 The smart Peano fluidic muscle: A low-profile flexible orthosis actuator that feels pain
Allan Veale and Shane Xie (#12) -p31

15:00 – 15:15 Iterative feedback tuning of position control on a redundantly actuated ankle rehabilitation platform
Charles Zhe Lu and Shane Xie (#13) -p32

15:15 – 15:30 A new dynamic modelling algorithm for pneumatic muscle actuators and it application in control simulation of a lower limb rehabilitation robot
Jinghui Cao and Shane Xie (#14) -p33
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>16:00 – 16:15</td>
<td>A Smart CNC System</td>
</tr>
<tr>
<td></td>
<td><em>Zhiqian Sang and Xun Xu (29) - p34</em></td>
</tr>
<tr>
<td>16:15 – 16:30</td>
<td>Relationship matrix based automatic assembly sequence generation from CAD</td>
</tr>
<tr>
<td></td>
<td><em>Mick Ou and Xun Xu (30) - p35</em></td>
</tr>
<tr>
<td>16:30 – 16:45</td>
<td>Open cloud manufacturing environment for future manufacturing business</td>
</tr>
<tr>
<td></td>
<td><em>Yuqian Lu and Xun Xu (51) - p36</em></td>
</tr>
<tr>
<td>16:45 – 16:50</td>
<td>Damage modelling in multi-scale polymeric functionally graded materials</td>
</tr>
<tr>
<td></td>
<td><em>Maedeh Amirpour and Raj Das (31) - p37</em></td>
</tr>
<tr>
<td>16:50 – 16:55</td>
<td>Brain computer interface using steady state visual evoked potential (SSVEP)</td>
</tr>
<tr>
<td></td>
<td><em>Kiran Atal and Shane Xie (32) - p38</em></td>
</tr>
<tr>
<td>16:55 – 17:00</td>
<td>A new approach to sound and vibration shielding using non-linear mechanical</td>
</tr>
<tr>
<td></td>
<td><em>Arnab Banerjee, Raj Das and George Dodd (33) - p39</em></td>
</tr>
<tr>
<td>17:00 – 17:05</td>
<td>Mechanistic study of dislocation nucleation from grain boundaries using</td>
</tr>
<tr>
<td></td>
<td><em>Nathaniel Burbery and Raj Das (34) - p40</em></td>
</tr>
<tr>
<td>17:05 – 17:10</td>
<td>Localization of an Autonomous Mecanum wheel forklift</td>
</tr>
<tr>
<td></td>
<td><em>Theng Kiat Chua and Peter Xu (35) - p41</em></td>
</tr>
<tr>
<td>17:10 – 17:15</td>
<td>A performance characterisation of a vertical axis wind turbine with</td>
</tr>
<tr>
<td></td>
<td><em>Simon Corkery and Richard Flay (36) - p42</em></td>
</tr>
<tr>
<td>17:15 – 17:20</td>
<td>Soft-bodied peristaltic XY machine table</td>
</tr>
<tr>
<td></td>
<td><em>Zhicong Deng and Peter Xu (37) - p43</em></td>
</tr>
<tr>
<td></td>
<td><em>Valerio Giovannoni, Rajnish Sharma and Robert Raine (38) - p44</em></td>
</tr>
<tr>
<td>17:25 – 17:30</td>
<td>Designing an adaptive controller for the ankle rehabilitation robot using</td>
</tr>
<tr>
<td></td>
<td><em>Soroosh Haj Hosseimnejad and Shane Xie (39) - p45</em></td>
</tr>
<tr>
<td>17:30 – 17:35</td>
<td>Lateral and directional control of the aircraft using synthetic jets</td>
</tr>
<tr>
<td></td>
<td><em>Pititat Itsariyapinyo and Rajnish Sharma (40) - p46</em></td>
</tr>
</tbody>
</table>
SESSION 4B: Composite Materials & Junior PhDs  room ALR5

16:00 – 16:15 Effect of curvature on structural loading of prismatic bodies subjected to water slamming
   John Weber, Mark Battley and Raj Das (#27) -p47

16:15 – 16:30 Manufacturing process of kenaf/polypropylene honeycomb cores
   Nabihah Sallih, Peter Lescher and Debes Bhattacharyya (#28) -p48

16:30 – 16:45 Development of manufacturing process based life cycle assessment framework for fibre reinforced plastics
   Tiange Jack Lu, Richard Lin and Krishnan Jayaraman (#52) -p49

16:45 – 16:50 Failure and residual strength prediction of carbon-epoxy composite materials
   Kariappa Maletira Karumbaiah, Raj Das and Stephen Campbell (#41) -p50

16:50 – 16:55 Development of physical and numerical model to study cranial backspatter
   Eryn Kwon and Raj Das (#42) -p51

16:55 – 17:00 Miniature temperature-compensated fiber optic force sensor for minimally invasive surgeries
   Zonglai Mo and Peter Xu (#43) -p52

17:00 – 17:05 Static and dynamic characterisation of novel composite materials
   Md. Zillur Rahman, Brian Mace, Krishnan Jayaraman and Debes Bhattacharyya (#44) -p53

17:05 – 17:10 Wearable control device with haptic feedback for unmanned underwater vehicle
   Syed Mohamad Shazali and Shane Xie (#45) -p54

17:10 – 17:15 Effective control of end-effector robots for upper limb rehabilitation
   Bo Sheng and Shane Xie (#46) -p55

17:15 – 17:20 Heavy-duty omni-directional mecanum-wheeled robot mechatronics design for energy-optimal autonomous navigation
   Li Xie and Peter Xu (#47) -p56

17:20 – 17:25 Oscillatory flow through sharp edged orifices
   Kartik Yajnanarayan and Rajnish Sharma (#48) -p57

17:25 – 17:30 Wave and Finite Element Modeling of Noise Transmission Through Panels
   Tony Yang and Brian Mace (#49) -p58

17:30 – 17:35 Customer-centric product design for mass personalization in OKP companies
   Pai Zheng and Shane Xie (#50) -p59
Polymer has been widely used in our daily life. However, since the last decades polymers have been increasingly being used in electronic devices. Here, two different applications of polymers will be presented; i.e. electronic memory devices and transducers. Polymethylsilsesquioxane, which is a type of dielectric is used together with gold nanoparticles as optically transparent or mechanically flexible memory devices. Various configurations to achieve these memory devices will be discussed. Finally, ionic polymer metallic composite, which is a type of functional polymer, will be presented. Applications of IPMCs as sensors and actuators will be discussed.

Associate Professor Kean C. Aw is with the Department of Mechanical Engineering, University of Auckland, New Zealand since 2004. Prior to his academic position, he worked at Intel, Altera and Navman for a total of 11 years. His main interests are in micro-systems and deployment of smart/functional materials and structures such as conducting polymers, metallic oxides, etc as sensors and actuators in various applications such as bio-sensors, medical/rehabilitation robots, micro-pumps, micro-manipulators, MEMS, energy harvester, etc. He has over 130 refereed publications.

Thursday, 10:15 – 10:45, room ALR1
SESSION [1]  **Hands-on research of diesel-like fuels**  
*Roger Raine*

In 2012 I spent 7 months Sabbatical Leave at the University of Castilla-La Mancha in Central Southern Spain. This talk will give some idea of the nature of the experience of that Leave, including technical and social aspects.

A commercial high pressure oven (Cetane ID510TM) was used to measure ignition delay of diesel and diesel-like fuels. The design purpose of the ID510 is to measure a Derived Cetane Number for diesel fuels, avoiding the very expensive Standard method of measuring Cetane Number which uses a standard engine. The Cetane Number of a fuel is an important parameter describing the ignition delay of the fuel in a diesel engine. The ignition delay has important effects on engine operation including efficiency, power output, and exhaust emissions. The ID 510 has facilities to change numerous characteristics including temperature, pressure and oxygen concentration in the oven. The objective of my research was to determine how these characteristics affected the ignition of the fuels. The challenges included:

Could different fuels, other than conventional diesel be used in the oven?

Would the measurements have any meaning?

How would our measurements of ignition delay compare with those of other researchers using different equipment?

What other fuels were available for use in the oven at appropriate costs?

The project succeeded in gathering extensive data which were compared against others, fitted into other published data, and using fuels which had not been used before in these types of experiments.

Dr Raine joined the University of Auckland in 1977 after receiving his PhD from the University of Southampton. He has taught mainly in thermodynamics, at all levels, and his main research interests are in internal combustion engines and alternative fuels. He was closely involved in the extensive programme of use of CNG (compressed natural gas) as a transport fuel in New Zealand in the 1980s. His awards for contributions to the field include the Crompton Lanchester Medal of the Institution of Mechanical Engineers and several Research Fellowships including from the UK Engineering and Physical Sciences Research Council, Oxford Colleges and the EPFL (Switzerland).

*Thursday, 10:45 – 11:15, room ALR1*
SESSION [2A] Flammability characteristics of wool fibre polypropylene composites using halogen-free fire retardants
Nam Nyeun Kim, Debesh Bhattacharyya and Richard Lin

Extensive studies have been conducted on the flammability characteristics of polymeric materials to enhance their fire retardant properties. Addition of fire retardant (FR), such as halogenated fillers, has reduced the flammability of polymer composites, but the additive had negative effects on environment and human health. This makes non-toxic and environment friendly fire retardant system desirable. Wool, as a protein based animal fibre, have inherent low flammability compared to those of other natural fibres. Relatively high contents of nitrogen (15-16 wt%) and sulphur (3-4 wt%), high ignition temperature (570-600 °C), low heat of combustion (4.9 kcal/g) and high limiting oxygen index (25.2%) contribute to the natural fire retardancy of wool. Cross-linking and dehydration tendency of wool under combustion also lead to char formation in intumescent manner. Furthermore, non-halogenated and intumescent FR can be a possible way to enhance the fire retardant effect of wool on composites flammability, thereby attaining satisfactory fire performance for strictly regulated applications.

Short wool fibre-polypropylene (PP) composites were fabricated by melt blending and compression/extrusion processes. The constituent materials are a commercially available PP, impurity-cleaned coarse wool fibres and ammonium polyphosphates (APP) as halogen-free FR. In order to investigate the effect of APP types on composites flammability, three APPs were selected based on different component (phosphorus and nitrogen) amounts and particle sizes of APP. Thermal characterisations of the raw materials and composites were conducted by thermogravimetric analysis and X-ray photoelectron spectroscopy to investigate thermal stability and chemical compositions, respectively. Flammability of the neat PP and composites was examined by a vertical burn test and cone calorimeter test. In particular, the cone calorimeter provided a large range of quantitative data of flammability parameters, such as heat release rate (HRR) and smoke production rate, to conduct a detailed analysis of composites flammability. Microstructure of fire residues was also observed under an environmental scanning electron microscope. In addition, the influence of APP on mechanical properties of the composites was evaluated by carrying out tensile tests. Synergistic effect of wool with APP on improving fire retardancy of the composites was confirmed by a direct self-extinguishment and significant HRR reduction. Moreover, charring effect of wool increased amount of residues containing homogeneous and compact char structure. Tensile moduli of the composites were also increased by adding wool and APP.

Thursday, 11:30 – 11:45, room ALR1
Natural fibre composites – fibre and interphase properties
Shyam Panamoottil and Raj Das

Conventional composites are already used in a wide variety of structural applications due to their high performance-weight ratio and tailorability, among other desirable properties. However, disposal of conventional composites at the end of their service life is a major concern, especially since glass-based composites leave a lot of ash on incineration. Natural fibre composites have been considered as replacements for synthetic fibres in certain applications due to their advantages including low density, renewability of source, and specific to this case, ability to be completely incinerated. Recent studies have shown that flax fibre composites produced from low twist yarns with a cellulose-based treatment could have properties comparable to glass-fibre composites.

Although natural fibre composites are not a new concept, their use in structural applications requires a prior understanding of their behaviour. Natural fibres are hierarchical structures themselves, composed of cell wall layers containing cellulose microfibrils, assembled to form a structure similar to a composite tube. Their elastic stiffness properties can be modelled using the composite laminate theory.

In addition to the fibres, the interphase region between them and the resin used is a very important part of the fibre behaviour. The interphase in composites is usually a region with a definite thickness, formed either due to the crystal nucleation at the fibres, or due to absorption of curing agents from the resin by the fibre sizing agents. There are several testing methods that could be used to test the interphase shear strength, among which the microbond test is a relatively convenient and simple one. Results from the microbond test can be analysed using variational mechanics, shear-lag equations, or using finite element (FE) simulations. We have used the Scheer-Nairn variational mechanics equations to calculate the interphase shear strength. An FE model of the test was also constructed to simulate the test, and solved using the Abaqus FE package. In the model, the droplet geometry was constructed from optical microscopy measurements, and a damage material model using was assigned to the interphase region.

Thursday, 11:45 – 12:00, room ALR1
SESSION [2A] Fire retardant characteristics of polypropylene/kenaf short natural fibre composites

Aruna Subasinghe and Debes Bhattacharyya

With the increasing concerns about the sustainability issues, during the last decade natural fibers have been used by the researchers for replacement of glass fibers. In recent years, environment friendly natural fibers, such as kenaf, flax, sisal and jute, have been used in polymer composites manufacturing to get desirable thermal, mechanical and functional properties. However, the limited thermal stability of natural fibers, which leads to degradation during processing beyond 200°C, also restricts the mass manufacturing methods, such as injection moulding.

Nowadays manufacturing applications demand high safety regulations, forcing worldwide researches to deal with finding new flame retardant additives to replace the existing ones, which are not highly effective with natural fibre based composites. Halogen based flame retardants are more effective in polymer composites with their potency in quenching flames, but the environmental regulations significantly limit their use in today’s flame retardant applications. Phosphorus based intumescent flame retardants (IFR), constitute one way of addressing this issue besides using inorganic fillers, such as aluminum trihydrate or magnesium hydroxide which always requires high quantities of filler to effectively protect a composite from fire.

The high efficiency of IFR system and the ability to produce low smoke and nontoxic gases lead them to wide usage in engineering applications. Even though, with these advantages of IFR system, high moisture sensitivity with poor compatibility cause problems in achieving homogeneous blend, when using IFR as flame retardant in polymer composites. The main goal of this work is to investigate the flame retardant effectiveness of ammonium polyphosphate (APP) based IFR systems on PP/kenaf composites and thereby develop natural fibre based flame retardant composites for industrial applications.

Thursday, 12:00 – 12:15, room ALR1
SESSION [2A] CPG-based control of a soft-bodied swallowing robot
Mingzhu Zhu and Peter Xu

Swallowing is vital for human daily life by supporting food and liquid. Dysphagia, the medical term for swallowing difficulties, has become a worldwide problem by affecting more than 15% of the population. Patients suffer from dysphagia have difficulties in achieving safety and successful swallows which can cause food remains in esophagus and death threaten. In order to help dysphagia patients to fulfill safety and successful swallows, one of the alternative approaches is applying food with proper viscosities.

In normal swallowing, food bolus is transported from oral cavity to stomach by primary peristalsis, and there is a secondary peristalsis generated if there was food remains in esophagus. The swallowing process is controlled by central pattern generators (CPGs) in brain stem and the local reflex center. CPGs are neuron networks which can generate rhythmic oscillations without rhythmic inputs or sensory inputs. Control systems based on CPGs can achieve natural rhythmic oscillations and adapt to changed environment.

A soft-bodied swallowing robot was proposed to explore the relationship between the viscosity of food bolus and the displacement of the conduit surface. The swallowing robot is made of silicon rubber, with 12 layers of inflatable chambers, 4 chambers each layer. It is pneumatically controlled to achieve a range of peristaltic waveforms to transport food bolus with different viscosities.

Initial experiments has approved that the swallowing robot can achieve continues peristaltic displacement by regulating certain air pressure in the inflatable chambers. When the robot is in work condition, three layers will be pressurized while the other layers keep steady. A back propagation neural network is established on the experiments data to relate the displacement to the corresponding air pressure.

A CPG model is proposed to generate desired conduit displacement for the swallowing robot. By given desired profiles, including amplitude, frequency, phase and an initial displacement, for a peristaltic waveform, the trained neural network can further determine the air pressure in each layer. The swallowing robot is divided into two parts to replicate both primary and secondary peristalsis according to human swallowing process. Primary peristalsis is propagated through the whole conduit to transporting food bolus while secondary peristalsis only propagated into button two thirds conduit to clear food remains. Flexible sensors are introduced to detect food remains and determine the location of food remains. By achieving primary and secondary peristalsis, the human swallowing process is simulated and a range of food bolus will be transported and tested by the swallowing robot.

Thursday, 12:15 – 12:30, room ALR1
SESSION [2A] Soft-bodied peristaltic actuator and pressure sensation system for biomimetic modelling of esophageal swallowing

*Steven Dirven, Peter Xu and Leo Cheng*

The communication of esophageal swallowing into the engineering domain through soft-robotic techniques presents a novel opportunity to investigate the flow and deformation of modelled boluses (food parcels). Rheology, the study of flow and deformation of fluid matter encompasses many aspects of the mathematical, physical, and engineering fields. However, inhomogeneous, multiphase, anisotropic, or shear-history dependant materials are challenging to characterise, model, or investigate by traditional methods, both physical and mathematical. In order to overcome limitations in the mathematical domain, for modelling the swallowing process, a physical model was proposed to deform boluses in a biologically-inspired manner.

In order to achieve the biomimetic target, new actuation and sensation structures were required to transport, deform, and measure bolus deformation in a peristaltic manner. An actuator with a linear peristaltic conduit was manufactured in a continuous architecture from silicone rubber, with embedded pneumatic actuation chambers. To augment the actuation capability, and facilitate evaluation of bolus transport contact pressure of the robot’s conduit surface on the bolus, a series of capacitive pressure transducers are located on the surface, which are distributed in an array format. The sensors and their supporting electrical structures are required to deform and take the shape of the conduit in the axial dimension, which is subject to sinusoidal peristaltic wave-front trajectories, inspired by mathematical models of the swallowing process. Additionally, they are required to have a very low profile so as not to disturb the bolus flow. These constraints present unique design challenges, unconventional to traditional off-the-shelf sensors and electrical termination methods.

The deformable, slim, capacitive pressure sensor array has a resolution of 3 sensing sites per linear array, each with an axial displacement of 50 mm, which is synonymous with the resolution of intra-bolus pressure measurement by the Manometry System (S98-200C, Sandhill Scientific, CO, USA). The intra- and extra-bolus pressure signatures are complementary in the measurement analysis. Interpretation strategies and visualisation methods have been developed to evaluate the salient features of the signatures. Establishing mathematical relationships between them, based on material parameters, is the topic of ongoing research.

*Thursday, 12:30 – 12:45, room ALR1*
SESSION [2A] Inverse dynamics of a redundantly actuated masticatory robot
Chen Cheng and Peter Xu

Redundantly actuated parallel robots own more actuators than needed to achieve the number of degrees of freedom (DOFs) of the movements. Compared with their non-redundant counterparts, they own higher nonlinearities and stronger coupling regarding both the kinematic and dynamic behaviours. Rather than being cumbersome, this actuation redundancy offers a potential to optimally distribute actuation across the actuators in terms of various dynamics performance wanted. From the viewpoint of mechanism, the human masticatory system is analogous to a redundantly actuated parallel mechanism, for the number of the chewing muscles being larger than that of the DOFs of the mandible movement. In the system, the base is the maxilla, the kinematic chains are used to model the chewing muscles, the end-effector is the mandible, and the point contacts model TMJs between the condyles and the maxilla. Based on this redundantly actuated parallel mechanism with two point contact HKPs, we built a prototype robot that is featured with the two HKPs and four DOFs of motion for spatial parallel mechanism.

In this presentation, the novel redundantly actuated parallel mechanism for mastication is exhibited. The inverse dynamics of the robot is analysed through the Lagrange’s equations of the first type. The actuating torques are acquired through the pseudo-inverse solutions.

Thursday, 12:45 – 12:30, room ALR1
A subject-specific biomechanical model to study ankle dynamics in robot-assisted therapy

Mingming Zhang, Shane Xie and Claire Davies

Accurate assessment of ankle parameters (joint dynamics, kinematics and kinetics of muscles and ligaments) is crucial in understanding ankle function, injury mechanisms, and the optimization of treatment and injury prevention programs for rehabilitating an injured ankle. Robot-assisted ankle assessment could be conducted by sensor based and model based methods. Existing ankle rehabilitation robots usually used torquemeters and multi-axis load cells for measuring joint dynamics. These measurements are accurate but muscle and ligaments were not taken into account. Some computational models have been developed to evaluate ligament strain and joint torque. However, these models did not include muscles and are not suitable for an overall ankle assessment in robot-assisted therapy. Method: This study proposed a biomechanical ankle model with 3 rotational degree of freedoms (DOFs), 13 muscles and 7 ligaments for use in robot-assisted therapy. This model combines sensor based ankle measurements and model based muscles and ligaments evaluations. It uses three independent position variables as inputs and output an overall ankle assessment. Subject-specific adaptation by scaling was also made to meet most population. Results: This model was evaluated using published results and experimental data from nine participants. Results show a high accuracy in neutral ligament length and the evaluation of passive joint torque. The subject-specific adaptation performance is high with each normalized root mean square deviation (NRMSD) value less than 10%. Conclusions: This model could be used to evaluate passive ankle torque for a specific subject and the characteristic of three independent angles required for inputs make it advantageous over other models when combined with robot-assisted therapy. This model can be also used to analyse kinematics and kinetics of muscles and ligaments as foot moves. These evaluation results could be for the quantification of ankle related disability level and provide foundation for physiotherapists and robots to adjust control strategies as rehabilitation progresses.
SESSION [2B]  **EMG-based human-robot interface for elbow joint and forearm rehabilitation**  
*Ran Tao and Shane Xie*

As the increase number of body-disabled diseases and the growing demand for accurate diagnosis, assistive robot for rehabilitation and disease diagnosis replaced the traditional artificial training and made a great contortion to disabled people. However, due to their complexity, most human-robot interactions require a lot calculation time and stronger tuning method to accommodate changes and variations. That leads to current interface lack of adaptability to individual subjects and hard to achieve real-time. In order to overcome these limitations and ensure the accuracy at the same time, an EMG-based (Electromyography) biomechanical human-robot interface is designed, which is specific about using EMG signal as the only input and neuromuscular skeleton model as control, to predict human elbow joint and forearm movements.

The interface contains nonlinear muscle activation dynamics for EMG signal processing, Hill-typed muscle-tendon dynamics to obtain muscle group force, geometry musculoskeletal model to calculate joint moment, kinematic model to predict movement angle, and simulated annealing algorithm for its parameters tuning. In addition, inverse dynamic will be added for making the interface a close control loop.

This design of interface is focusing on the accurate prediction, real-time tuning and individual subject adaptability. Therefore, the simplifying of human bio physiological structure, parameter feature analysis and grouping, tuning algorithm, and feedback occasion are the key point of my current research. In order to verify the performance, multi-task experiments and two-DOF-exoskeleton implementation will be developed in next year.

*Thursday, 11:45 – 12:00, room ALR5*
An effective biological command based controller for improving the effectiveness of human-inspired robotic rehabilitation after neurological disorders
Ye Ma, Shane Xie and Yanxin Zhang

This study proposed an effective biological command based controller (EBCC) for improving the effectiveness of human-inspired robotic rehabilitation after neurological disorders. Three novel characteristics are provided in this EBCC methodology, which are patient-specific properties, accurate dynamic modelling of the patient and patient’s intention involvement. In order to ensure the patient-specific properties and accurate dynamics modelling, a computer-based musculoskeletal model is implemented to provide patient-specific anthropometric parameters and muscle kinematics parameters. To detect the intention of patient, two methods have been developed. One is the patient-specific muscle force estimation (PMFE) method, and the other is the patient-specific EMG-driven musculoskeletal model. The PMFE is an inverse dynamics-based static optimization method based on the two dimensional musculoskeletal model. Lagrange Multiplier Method is implemented to solve the optimization problem and the musculoskeletal model is simplified to consist of two segments and four muscles in order to achieve the real-time calculation. The EMG-driven musculoskeletal model is built upon the computer generated musculoskeletal framework which provides patient specific musculo-tendon physiological, musculo-tendon kinematics parameters. Muscle force and joint moment during locomotion are predicted through activation dynamics and contraction dynamics based on the hill-type muscle mechanics model. The simulation results showed promising potential for the PMFE method and the EMG-driven musculoskeletal method to control the rehabilitation robot. The simulation results show that muscle forces estimated from the PMFE matched well with those from the computed muscle control method and the biological command based controller could track both desired knee angles and desired forces. The preliminary result showed that based on only a few EMG channels, the proposed model could efficiently predict joint moment and muscle forces. The proposed model has the potential to control the rehabilitation robot based only on a few of EMG channels from extensor and flexor muscle.

Thursday, 12:00 – 12:15, room ALR5
SESSION [2B] Movement planning in goal-directed reaching by people with cerebral palsy

Alexander R. Payne and Claire T. Davies

Cerebral Palsy (CP) is a common childhood physical disability. It is a generic term for a lesion to the infant brain affecting motor control, amongst other things. Understanding the exact eye-hand coordination difficulties faced by people with CP is important because it can be used to inform design, improving their self-efficacy and quality of life. This research aims to connect the way typically developed (TD) participants and participants with CP coordinate the timing of their eye and hand movements during goal-directed pointing tasks.

When humans make a hand reaching movements, generally the eyes start to move towards the target just before the hand does. This difference in timing is referred to as eye-hand movement onset asynchrony (onset asynchrony).

A systematic review into onset asynchrony has revealed that there may be a rudimentary ‘blank-slate’ onset asynchrony for a task where several conditions are met: the hand position is already calibrated (i.e. there is no reason to monitor the start of a movement), it is a one-off / discrete movement (i.e. there is no previous movement to monitor the end of), and the target location is unknown before trial start (i.e. no opportunity exists to enact a preplanned movement).

From this ‘blank-slate’ type movement it seems onset asynchrony may be reduced (i.e. the hand moves earlier compared to the eye) for conflicting reasons. One reason may be to provide feedback control for monitoring uncertainties, such as calibrating the hand position, or monitoring the end of a previous movement. The other reason is employing feedforward control; enacting a preplanned movement, and reducing onset asynchrony to reduce task time.

One factor that affects onset asynchrony in the latter way is the predictability of target location.

Following on from a pilot study, an experiment involving a pointing task with a touchscreen is taking place. It aims to establish what onset asynchrony values for ‘blank-slate’ movements are, and if they are a maximum. Also of interest is whether this value varies between TD and CP participant groups.

Furthermore, the experiment will seek to verify that a predictable target direction reduces onset asynchrony for both groups. The interaction between participant groups in this respect is of particular interest since it is anticipated that CP results in participants not reducing their onset asynchrony as much as TD participants.

Further experiments will seek to fit a model to this rate of onset asynchrony reduction and to quantify this ability to adjust coordination patterns.

Future experiments will also seek to create a situation for TD participants where they display similar behaviour to CP participants, thus suggesting how exactly CP is affecting this control mechanism. Given that CP seems to impair proprioception, two possible experiment set-ups for TD participants involve inducing uncertainty in effector positioning, and preloading the visuospatial sketchpad of their working memory.

*Thursday, 12:15 – 12:30, room ALR5*
Linear constrained Model Predictive Control (MPC) is presented as a solution to limits in ground traction for two-wheeled robots. Two-wheeled robots dynamically balance on two wheels. However, other controllers that have been implemented, whether linear or non-linear, have not accounted for ground traction or other possible system constraints such as motor limits, which can cause the robot to topple if allowed to tilt excessively.

Because MPC can inherently accommodate constraints, it can prevent toppling even when there are large changes in reference signal. Constraint tightening is used to implement a robust MPC controller which accounts for the non-linearity of the system. The design of the MPC controller allows real-time operation, and accommodation of traction given only the friction coefficient, even though there are more complex friction dynamics.

The MPC controller is experimentally compared to a matching discrete-time Linear Quadratic Regulator (LQR). Compared to LQR, MPC has identical performance at lower speeds, but prevents toppling at higher speeds and accelerations. To handle traction limits, it is compared to an LQR with a reference governor, another method to prevent toppling. While a reference governor can satisfy system constraints, it has less flexibility, affects performance, and interacts with the tuning of the controller. Experimental results show both solutions for traction can prevent toppling.
SESSION [2B]  **Time-domain flexural wave intensity estimation in plates**  
*Nicholas Ng, Roger Halkyard and Karl Stol*

The use of structural intensity measurement to quantify the arrival time, magnitude and propagation direction of a transient disturbance appears to be a promising tool in various applications.

In this work, a method for obtaining real-time estimates of flexural wave structural intensity in plates from surface measurements is presented. Plate response and energy flow are expressed within the framework of Kirchhoff plate theory. Plane-wave propagation is assumed, with a complex Fourier series used to represent the variation of wave amplitude with propagation direction. The outputs of a sensor array are digitally filtered and combined to obtain estimates of the relevant linear and angular velocities, shear forces and moments. These parameters are then combined to yield an estimate of structural intensity.

The performance of the approach such as its sensitivity to systematic and measurement error is investigated. It is shown that when the method is used to estimate the intensity due to a point excitation, the estimated intensity magnitude and direction are accurate when the measurements are taken at a distance greater than one wavelength from the source in the region where a plane-wave assumption starts to be valid.

*Thursday, 12:45 – 12:30, room ALR5*
Fibre reinforced polymer composites are used in a wide range of applications in a number of industries including automotive, aerospace, boating and sporting. They offer numerous advantages over more conventional materials, predominantly a significant decrease in mass, with an additional benefit of high stiffness and strength. Fatigue and impact resistance are also improved as well as resistance to corrosion.

The manufacturing processes of such materials varies immensely for different reinforcing materials and is still largely unrefined. In order to enable manufacturers to produce these materials in a more efficient manner, much greater understanding about the materials is required. One of the materials’ characteristics of interest is their permeability.

Permeability characterises the ease with which a fluid can flow through the reinforcement and is predominantly a function of the reinforcement architecture. It is an important material characteristic that determines the flow propagation of the resin through the reinforcing material. Traditionally it is obtained by conducting a large number of experiments, which are expensive, time consuming and often unreliable.

In order to address this issue, an automated tool has been developed and is presented, generating permeability predictions of unit cells using textile modelling techniques. This tool incorporates the functionality of TexGen (developed at the University of Nottingham) to generate unit cell geometries based on simple scanned images of the textile. Compaction simulations are initially applied to the unit cells, reflecting the change of geometry due to the textile compaction. Voxel meshes representing the volume of resin around the compacted geometries are then exported. The voxel meshes are then automatically cleaned, deleting any floating elements, and the boundary regions defined based on the unit cell size. By executing flow simulations on these meshes, the permeability characteristics of a large range of unit cells may be obtained.

This tool has been used to predict the permeability characteristics of a range of materials and these have been compared to results obtained from experiments conducted. The importance of capturing the structural variability within the reinforcing materials and its influence on the permeability properties is also illustrated.

Thursday, 14:00 – 14:15, room ALR1
Helicopters can reach locations with difficult access and/or challenging terrains. That is why they are widely used in military operations, rescue missions or transportation to offshore platforms. However, presence of unfavourable flight conditions or mechanical failure can lead to hard landing or even crashes. According to accident surveys conducted on the US and UK military helicopter fleets in the 1990s, 80% of the Navy crashes had occurred on soft soil and water. Understanding the mechanical response of helicopter structures in impact on soft surfaces is therefore essential to the development of multi-terrain crashworthy designs.

Fluid-Structure Interaction involves complex physics, which can be challenging to capture with current numerical methods. The Smoothed Particle Hydrodynamics method is a meshless approach that was initially developed to solve astronomy problems but appeared to be very suitable to represent free-surface flows interacting with complex helicopter structures.

Although the particle method has demonstrated great potential, reliable guidelines for numerical modelling of water impact involving composite helicopter structures are still required. A better understanding of the influence of numerical parameters is needed to allow the development of accurate and efficient models.

The work presented describes the development of these modelling guidelines through various test cases of increasing physical complexity to finally achieve predictive water impact simulations of a crashworthy composite helicopter subfloor.

The drop of a rigid sphere into a water pool is a typical test case from which many lessons can be learnt and therefore widely used to validate water modelling. The deceleration of the sphere during the impact event is calculated and compared to experimental data found in the literature. The test case was used to analyse the influence of key numerical parameters, compare equations of state to capture the water response and also to compare the meshless method to its most commonly used alternative approaches that are the Arbitrary Lagrangian-Eulerian method and the more classical Lagrangian Finite Element Method.

Hydroelasticity is introduced in the following test case considered which is the slamming of flat deformable panels at various deadrise angles and velocity. It teaches how the particle method is capable of capturing the correct deformation of the fluid and its interaction with the structure during impact. Experimental data obtained through slamming tests with the Servo-hydraulic Slam Testing System, located at Callaghan Ltd in Auckland, are used for validation of the models.

Once the modelling methodology is validated, it is employed to understand the mechanical response of a crashworthy composite helicopter subfloor onto water. The impact loads experienced on water remain below the triggering level of the energy absorbing components of the structure. The energy is essentially dissipated by large deformations of the skin panels and the fluid itself. Although decelerations are significantly lower than in hard ground impact, the subfloor does not show dramatic failure that would reduce the floatation capability of the aircraft after impact and therefore the chances of survivability of the occupants.
SESSION [3A] Micromechanical modelling of closed-cell foams
Youming Chen, Raj Das and Mark Battley

Cellular materials exist in nature on a large scale such as woods, bones, leaves and stalks. Creatures evolve into cellular structure to satisfy the special demand of the environment, such as specific stiffness and strength, fluid transport, thermal insulation and surface area. Human beings commenced to use cellular materials since early time. Until 1930’s human-made foams began to be produced and commercialized. Over the last decades, great progresses have been made in foam manufacturing and processing, making foam materials more commercially available and inexpensive. Nowadays, almost any solids including polymers, metals, ceramics and even glasses, can be foamed, giving a wide selection of foams. More importantly, weight savings are becoming increasingly critical in automotive, aerospace, marine and aircraft industries. Materials of high specific stiffness and strength are in a great demand. Sandwich panels with composite material skins and foams cores are a significantly competitive candidate in this respect and thus have substantially boosted the use of foams.

Foams generally play a role in load-bearing in structures; hence the mechanical behaviour of foams is a major concern for engineers. The insufficient understanding of foam mechanics would either cause conservative designs with excessive size and weight, or lead to the catastrophic failure of structures. Conventional mechanical tests are not very suitable for the investigation on properties-microstructure relationship of foams as well as failure mechanism. Micromechanical modelling which predicts the response of heterogeneous materials based on the constituent material properties and microstructural geometry, has been widely applied to a variety of heterogeneous materials. It is very helpful in the understanding of the properties-microstructure relationship and failure mechanism of heterogeneous materials. However, the complexity of foam microstructures poses enormous difficulties in the micromechanical modelling of closed-cell foams. Consequently, most of pioneering work was virtually based on simplistic models and thus the results of prediction are considerably rough and even fail to capture the response of real closed-cell foams. The present study will centre on the development of a micromechanical modelling framework for closed-cell foams, and the investigation on the relationship of foam mechanical properties with relative density and microstructures, as well as deformation and failure mechanism at microstructural level.

*Thursday, 14:30 – 14:45, room ALR1*
SESSION [3A] **Individual pitch and trailing edge flap control on upscaled wind turbines**

Jeremy Chen, Karl Stol and Brian Mace

The most visible trend in wind turbine design over the past few years has been the increasing size of the turbines themselves. Larger turbines offer several advantages, such as increased generation capacity, the ability to maximise land usage (e.g. for turbines placed on ridgelines) and the ability to take advantage of increased wind speeds at higher altitudes due to wind shear.

One of the challenges facing designers of large turbines is the increasing mass of turbine components with scale. This ‘square-cube’ law places an upper limit on turbine size, meaning that innovative methods for reducing turbine component mass are important for the future development of larger turbines.

Of particular interest in this research are the blades of the turbines. Advanced load reduction methods, such as the use of individual blade pitching (IPC), whereby the blades of the turbines are pitched independently of one another, have been shown to be capable of reducing fatigue loads in the blade root which originate from low frequency disturbances, such as that from wind shear. Newer concepts such as trailing edge flaps (TEF), collectively termed ‘Advanced Aerodynamic Load Control’, have been shown to be capable of reducing loads stemming from higher frequency disturbances due to factors such as turbulence.

These methods of load control have been investigated on turbines with ratings up to 5MW, though future turbines are expected to be significantly larger. With increasing scale, the performance of current load reduction methods may be affected by factors such as lower natural frequencies, or by the increased variation in wind speed throughout the swept area of the rotor. As such, the focus of this research currently is to assess the performance of load control using individual pitch and trailing edge flaps on upscaled wind turbines.

10-20MW wind turbine models are generated from a baseline 5MW wind turbine design using geometric self-similarity (known as classical scaling), whereby all dimensions of the turbine are scaled up by a constant factor. Scale invariant IPC and TEF controllers, used to ensure ‘fair’ control effort regardless of scale, are designed for turbines using linear models generated via system identification. The performance of the load control methods are assessed based on fatigue loads and actuator usage using simulations with the HAWC2 aeroservoelastic code.

Future work will involve developing a lighter blade model for turbines which integrate known load reductions from classically scaled turbines, to see if the additional flexibility expected from lighter blades has an impact on the performance of IPC and TEF. The overall goal of this research is to attempt to quantify the benefits of IPC and TEF (realised through development of lighter blades and the potential for improved turbine performance due to reduced rotor inertia) to see if these load control methods (in particular, the use of TEF) are viable on current and larger turbines.

This presentation will cover the modelling, identification, and controller design for IPC and TEF on classically upscaled turbines, along with initial results from simulations conducted throughout the operating range of the turbines.

*Thursday, 14:45 – 15:00, room ALR1*
SESSION [3A] The effect of preheating on micro combustion
Zerrin Turkeli-Ramadan, Rajnish Sharma and Robert Raine

As technological improvements are made, our lives become more and more comfortable. At the same time, our dependency on existing energy sources increases day by day. In particular, the need for efficient and compact power supplies for portable electronics and miniature mechanical devices such as notebooks, micro robots and micro aerial vehicles is increasing. Currently, the energy requirement for these devices is met by batteries, however batteries are not compact and appropriate because of high recharging times and lower energy and power densities. On the other hand, hydrocarbon combustion-based ultra micro gas turbine (UMGT) is emerging as one of the most promising energy technologies for portable electronics and miniature mechanical devices because of both its high power and energy densities.

However, in order to utilize the micro-scale UMGT technology as a power source, the components of the UMGT have to be developed since downscaling to smaller scales reveals new problems that do not occur at conventional size gas turbines. As the micro combustor is one of the key components of UMGT, it needs to be improved in order to achieve high combustion efficiency, wide flame stability, clean combustion with low pressure loss, in a small volume. Smaller residence time is one of the most important downscaling problems of micro combustors, which results in incomplete combustion and high pollutant emissions. In order to overcome the issue of smaller residence time, preheating the reactants was investigated both experimentally and numerically.

Experimentally, the effect of preheating on the flame stability and combustion characteristics was investigated. Alumina ceramic, sintered stainless steel and perforated plates with different pore sizes and thicknesses were used as flame holders. The effects of different flame holders were investigated in terms of pressure loss through them, and their usability as flame holders for UMGT applications. The flame shape and behavior with different air mass flow rates and air to fuel ratios were observed. The experimental results showed that preheating widened the flame stability limit. Furthermore, a new correlation for flat flames was developed between the mass flow rate, reactant temperature, air to fuel ratio and diameter of the micro combustor which is a major contribution to the design of micro combustors. This study shows that flat flame burning method provides very clean combustion with a combustion efficiency of 99%.

The two-dimensional numerical investigation of the effects of preheating was performed within a 2 mm diameter micro combustor tube with both adiabatic and non-adiabatic walls. A comparison of flame temperature, flame thickness and major species concentrations obtained by employing three different reaction mechanisms was presented. Flame temperature and main species concentrations were obtained with different initial temperatures and incoming flow velocities, as well as air to fuel ratios. It was found that preheating the reactants widened the flame stability limits, thus allowing stable flames within a 2 mm diameter micro combustor over a range of conditions. In the non-adiabatic case, the effect of heat loss through the outer wall was investigated.

This study shows that the sustainability of stable flames with clean exhaustion, which is a requirement of micro combustors for UMGT applications, can be achieved at small scales by preheating the reactants.

Thursday, 15:00 – 15:15, room ALR1
Session [3A] Performance of a Hybrid Residential Water Heater
Grant Bourke, Robert R. Raine and Pradeep Bansal

Water heating is up to 40% of the energy used in a house. Water heating will be the largest or second largest consumer of energy depending on the amount of space heating. Space heating loads are being reduced in homes as building codes require higher standards of insulation and features such as double glazing. In these lower energy homes water heating will be the largest energy use. Homeowners are becoming more conscious of both costs and carbon dioxide emissions from energy use. Against this background, this presentation examines a hybrid residential water heater. This consists of an air-source heat pump water heater feeding a thermal storage vessel, combined with a gas instantaneous water heater.

The performance of an air-source heat pump water heater will degrade as ambient air temperature drops and the temperature of the water to be heated rises. Gas instantaneous water heater performance reduces with higher incoming water temperatures and falling fluid energy requirements. The complimentary nature of many of these performance factors provides an interesting opportunity.

A novel and low cost control system is developed to optimise the performance of the hybrid water heater. This uses only components already incorporated in the individual products. The system can be optimised to reduce either primary carbon dioxide emissions or operating cost.

Each individual component of the water heater is tested experimentally and its performance characterised across a wide range of operating conditions. These characteristic equations of performance are combined with the proposed control system in a simulation model. Annual operating cost and emissions are modelled for 9 cities worldwide. These cities represent a wide cross-section of climates, electricity and gas energy tariffs, and importantly, emissions from electricity generation.

The hybrid water heater delivers the lowest operating cost and carbon dioxide emissions in most cities when compared to both the individual water heater types making up the hybrid, and an electric resistance element storage water heater.

The main advantage of the hybrid water heater is the ability to aggressively reduce the size of the thermal storage vessel and hence the associated energy losses to atmosphere. This can be done as the gas instantaneous water heater will always ensure an adequate supply of hot water for the consumer.

Further opportunities for optimisation of this type of water heater will be discussed. These including learning algorithms to predict water use patterns and integration of the control system with weather forecasting, energy tariff, and primary emission real-time data.

Thursday, 15:15 – 15:30, room ALR1
SESSION [3B] 3D printed conducting polymer micro-structures as low velocity fluid flow sensor
Harish Devaraj, Kean Aw, Jadranka Travas-Sejdic and Rajnish Sharma

The demand for sensing for lower velocity fluid flow has been ever increasing with developments in the micro and nano-fabricated devices employed in various biological and engineering domains. Bag-valve mask resuscitators, though can successfully resuscitate, when being employed in neo-natal care, demand extreme caution as the premature neo-natal alveoli is prone to collapse under excessive inflow of the supplied air. Absence of disposable sensors in electromechanical neo-natal resuscitators demand highly trained professionals to apply resuscitation, as any oversight in setting up the controller can aggravate the patients’ medical condition. A sensor which can shut down the air supply when specific limits (PEEP, PIP) are reached would thus prove to enhance the safety of these devices. In these lines, a disposable digital sensor, with high sensitivity to low velocity flows, is developed from 3D printed conducting polymer micro-structures.

Taking inspiration from nature, hair and hair-like structures, in many species, play a vital role in sensing any change (flow, pressure, tactile, aiding balance, enhancing chemical reception, etc.,) in their surroundings. These hair-like structures increase the exposed surface area thereby allowing a greater interaction with the physical quantity being sensed. For instance, flow sensing hairs amplify the torsional forces experienced as a result of the fluidic drag around it, to enhance the stimulus of the mechanoreceptors at the base (hair-cells).

Towards using these hair structures as sensors, conducting polymer PEDOT:PSS is chosen as they have high electrical conductivity which can be enhanced by the addition of DMSO and possess good flexibility and high elasticity. These micro-hair structures are direct 3D printed using a custom built printer having three micro-stages for X, Y and Z movements and a more accurate nanocube that moves the printing head that disperses PEDOT:PSS-DMSO dispersion onto a gold substrate. The printing head here is a laser puller micro-pipette with orifice diameter controlled by the manually set pulling temperature and breaking force. The micropipettes used for the developed prototype sensor are 5um in orifice diameter. 4 micro-hairs are 3D printed on four individual gold traces running along the length of a common microscope slide. Towards using the micro-hairs as micro-switches, these hairs are printed at specific distances from a fixed contact terminal (here, a thin platinum wire running) in such a way that each hair makes an electrical contact with the contact terminal at a specific flow velocity. Predetermining the amount of deflection of the hairs under air flow is achieved using two way fluid structure interaction simulations on ANSYS software. From the numerical simulations and experimental verifications of this simulation, the data is carried over while developing the sensor to detect specific flow velocities (prototype senor designed to detect flows from 0.67 m/s to 1 m/s had an actual flow sensing range of 0.65 m/s to 0.97 m/s). To further improve the sensitivity to much lower flow velocities, testing on the effects of using a venturi to simply amplify the velocity and research into developing high aspect ratio nano-hairs are underway.

Thursday, 14:00 – 14:15, room ALR5
SESSION [3B] Impact-based frequency up-conversion for low frequency energy harvesting
Bryn Edwards, Kean Aw and Aiguo Hu P.

The development of small and portable systems for harvesting low frequency vibration energy is an attractive idea, due to the ubiquity of such energy sources in daily life. One of the most abundant sources of vibration energy in this category is human motion, with a frequency range of 3 to 7Hz. At frequencies as low as these, it is difficult to implement the traditional resonant cantilever approach to vibration energy harvesting at a portable scale. A popular question for researchers in the field is therefore how to improve the power density of an energy harvesting device, where the resonant frequency of the vibrating element is necessarily higher than the excitation frequency.

The mechanism presented here utilises a cantilever beam and an end stop to limit the displacement of the beam end mass in one direction. The effect of this is as a momentary stiffening of the beam as the mass and end stop come into contact. This results in an increase of the vibration frequency during one half of the excitation cycle. Simulation results have indicated that, with such a system, when the excitation frequency is sufficiently below the resonant frequency of the cantilever beam, then a greater RMS mass velocity can be achieved than for a simple cantilever under the same excitation conditions. This effect has been demonstrated experimentally, with a maximum gain in RMS velocity of 150.

Thursday, 14:15 – 14:30, room ALR5
SESSION [3B]  PCB Inductive sensor for IPMCs displacement sensing  
Jiaqi Wang, Andrew McDaid and Kean Aw

This study reports an integrated inductive sensor for IPMCs tip displacement sensing. Traditional sensing methods, such as laser or strain gauge, are not suitable for integrated IPMCs driving devices due to various issues. Typical laser sensor, which has the sensing range of 75 to 125 mm would constrain the whole system from being compact. In addition, although strain gauge is applicable in most compact devices, there are two shortfalls that prohibit it to be implemented in IPMCs driving devices. First, strain gauge is usually glued near the fix end of IPMCs and could act like a mechanical resistance consuming sizable energy which is costly for IPMCs, which have limited force output. Secondly, the strain gauge actually detects deflection rather than tip displacement. It is acceptable to use strain gauge for sensing of displacement as long as the IPMC behaves similar to an ideal beam. However, IPMCs, has variable and non-uniform bending behaviour and does not follow typical beam bending principle. Therefore, inductive sensor is a direct, reliable and with practical significance sensing method for IPMCs.

The principle of inductive sensing is quite simple. An AC current flowing through a coil will generate an AC magnetic field. If a conductive material, such as metal target, is brought into the vicinity of the coil, this magnetic field will induce circulating currents (eddy currents) on the surface of the target. These eddy currents are a function of the distance, size and composition of the target. These eddy currents then generate their own magnetic field, which opposes the original field generated by the coil. This mechanism is best compared to a transformer, where the coil is the primary core and the eddy current is the secondary core. The inductive coupling between both cores depends on distance and shape. Hence the resistance and inductance of the secondary core (eddy currents) shows up as a distant dependent resistive and inductive component on the primary side (coil).

In this study, a copper coil with 85 turns and 2 layers were printed on PCB. Experimental results indicate that both the resistance and inductance read match well with laser sensor read-out and therefore can be implemented as IPMC tip displacement sensor. Also, since the PCB coil is only 1.5mm, it can be easily integrated with the IPMC without much lost in space cost.

*Thursday, 14:30 – 14:45, room ALR5*
SESSION [3B]  The smart Peano fluidic muscle: A low-profile flexible orthosis actuator that feels pain
Allan Veale and Shane Xie

Robotic orthoses have the potential to provide effective rehabilitation while overcoming the availability and cost constraints of therapists. However, current orthoses use actuation components designed for industrial applications, not interacting with humans. The result is heavy, rigid and bulky actuators whereas an effective orthosis must be light, compliant and portable.

Pneumatic muscle actuators (PMAs) are a popular orthosis actuator because of their inherent compliance, high force and muscle-like load-displacement characteristics. However, the circular cross-section of PMA gives them a large dead volume to surface area. This increases PMA’s bulk and reduces their flexibility. PMA are also notoriously unreliable, but their soft nature makes monitoring their physical state to improve their robustness a challenge.

Here the concept of the smart Peano fluidic muscle, a new low profile yet high surface area to dead volume PMA geometry, is introduced. The muscle uses soft capacitive strain sensing, a miniature pressure transducer and an analytical quasistatic model to estimate its internal force and displacement without compromising actuator flexibility. This smart PMA sets a precedent for flexible and unobtrusive orthosis actuation that uses embedded sensors to prevent damage to the actuator and its environment.

Thursday, 14:45 – 15:00, room ALR5
SESSION [3B] Iterative feedback tuning of position control on a redundantly actuated ankle rehabilitation platform

Charles Zhe Lu and Shane Xie

Most classical tuning methods rely on accurately determining the model of the system using system identification processes. However, the identification of an accurate model of a system is often difficult to achieve due to its complexity. Iterative feedback tuning (IFT) is a black-box approach to the issues of control system tuning. It is automatic, model-free, and relies only on information obtained from the closed-loop response of the system being controlled. It has been proven to work well in various applications since its introduction in 1994, and it has been shown that it can be used online.

In this presentation, automated tuning of the position control on a three degrees-of-freedom redundantly actuated ankle rehabilitation platform is investigated. Inverse kinematics of this platform is analysed in order to establish joint space position control. A normalised IFT algorithm is used to tune one of the actuators online in real-time, and its controller gains are then propagated to the other actuators.

One of the shortfalls of the IFT approach is that IFT may perform poorly if the system being tuned is highly non-linear. As the ankle rehabilitation platform is of a complex and highly non-linear nature, it is also important to investigate the performance of the IFT tuning method under the presence of some form of compensation in the control loop.

The platform inverse dynamics is analysed using LaGrange's method, and force profiles for each actuators are generated based on a set of pre-defined angular trajectory. The generated force profiles are used as dynamic compensation in the control system and the platform is tuned again using IFT.

The results show that the IFT algorithm is somewhat able to cope with the non-linearity of the platform and is able produce a set of tuned controller gains for the platform position control. Additionally, there is a significant improvement in the performance of the tuning process and of the platform response when dynamic compensation is added to the system.

In the future, the IFT algorithm will be applied to all actuators to investigate the simultaneous tuning performance of multiple instances of the IFT algorithm.

Thursday, 15:00 – 15:15, room ALR5

Jinghui Cao and Shane Xie

The gait rehabilitation robot is an ongoing research project within the biomechatronics group in the Department of Mechanical Engineering. The aim of this project is to develop a sound exoskeleton robot platform, assist-as-needed control strategies, and integrating them to a robotic system for clinical studies. Pneumatic muscle actuators (PMAs) have been utilised as the actuators for our application due to their high power to weight ratio and intrinsic compliance. Due to the high joint torque requirement of lower limb joints during human gait, PMAs manufactured by FESTO are adopted in the current development.

The problem has been encountered is that the dynamic model of FEST PMAs, which is important to control performance, has not been researched extensively. Hence, a testing device was designed and built to investigate PMA’s dynamics. The device automates the experimental process by providing motions and recording pressure, force, position and velocity data. The gathered experimental data enable the authors to validate a previous PMA dynamic model. Meanwhile, new models are developed from the original model. Statistical analysis proves that the new models can better represent the PMA dynamics during the experiments.

With the developed dynamic model of PMA, the model of the analogue directional control valves of the PMA and the dynamics of the exoskeleton, a control simulation was performed in MATLAB to simulated the single input single output behaviour from input voltage of the valve to the trajectory of the knee joint of the exoskeleton robot with a sliding mode controller. With the satisfying results of the simulation, the models and sliding mode controller are now being migrated to the actual robot. In the near future, it is planned to extend the SISO sliding mode controller to a MIMO one to control both trajectory and actuator compliance with two valves for a single lower limb joint.

Thursday, 15:15 – 15:30, room ALR5
SESSION [4A] A Smart CNC System
Zhiqian Sang and Xun Xu

G/M code as the language of controlling CNC machine tools prevails more than 30 years. It only contains basic information, i.e. programmable logic control commands and machining toolpaths which are usually provided by computer aided manufacturing (CAM) system. It is straightforward that the G/M code loses all the high level information e.g. geometry and tolerance after being generated and is highly machine tool dependent. When machining stoppage incidents happen the operator has to scroll back the programme from where the machining stops and make necessary changes. This process highly relies on the operator’s experience and is very time consuming. If the nominated cutter is not available or the machine tool is damaged because of the incident, to recover the machining new toolpaths need to be generated by CAM system making the recovery more complex. STEP-NC as a new standard for part program defines the machining of a workpiece by features and corresponding working steps which contains all the high level information. The smart CNC control system being developed takes advantages of STEP-NC to realize feature based machining. It dynamically generates toolpaths according to the availability of cutters and machine tool status. When stoppage incidents happen it uses different strategies to retract the cutter and regenerate tool path to resume the machining. By keeping tracking the machining process and storing the machining history, the machine tool independent recovery can also be realized.

Thursday, 16:00 – 16:15, room ALR1
Currently in industry, design and communication of a product assembly is through the use of computer-aided design (CAD) systems. However, there are no commercial systems that have the capability to automatically generate feasible assembly sequence plans. Assembly sequence planning using a commercial system often relies on an experienced expert manufacturing engineer. In practice, assembly sequence planning carried out by an expert is predominantly done manually. This requires a great amount of time, expert knowledge and plans generated may not be the most efficient. The ability to automatically generate assembly sequence plans will reduce planning time, amount of knowledge required, provide better plans and produce plans at earlier stages of the design process. CAD models represent assemblies based on feature constraints and contain information necessary for assembly sequence planning. A system has been developed which analyses and utilises assembly data available from a CAD model to generate assembly sequences automatically. This system also considers user input as a type of assembly constraint to provide flexibility. The system is capable of producing a set of ranked feasible assembly sequence plans for an operator to evaluate. A matrix approach has been adopted to process the information retained from a CAD model. Interference and stability studies are carried out during the creation of assembly sequence plans. The outputs are ranked based on the ease of assembly and the stability of the generated assembly sequence plans.
Open cloud manufacturing environment for future manufacturing business
Yuqian Lu and Xun Xu

Manufacturing is, like all economic activities, in a stage of constant change. In recent years, the growing demand for integrated and customised solutions has forced manufacturers to provide highly customised product-service systems (PSS) to the competitive market. The industry has noticed this necessity and some entities have started to upgrade their production models to increase responsiveness to the dynamic market and therefore achieve great business flexibility and agility. An analytic study carried out by International Data Corporation (IDC) in 2012 indicates a fundamental evolution in production model towards make-to-individual. Make-to-individual refers to a new product realisation strategy in which a company designs and manufacturers a product based on individual needs and preferences of consumers. In particular, the delivery of personalised PSS solutions involves the contribution from the consumer and other stakeholders in an ever-increasing networked and crowd-sourced environment.

Zooming into the manufacturing paradigm to support make-to-individual strategy, cloud manufacturing could be fit-for-purpose. Cloud manufacturing bridges the gap between isolated enterprises allowing collaborative product development and therefore facilitates make-to-individual strategy for service consumers. It is a service-oriented production model, in which distributed manufacturing resources are encapsulated as consumable services over the Web. This production model is expected to bring unique opportunities to make-to-individual adopters; it turns a capital investment model, which manufacturing business is often characterised as, into a recurring expenditure model.

This research aims to develop an open cloud manufacturing environment that brings manufacturing resources into a global manufacturing cloud through which configurable production networks can be formed to suit facilitate make-to-individual manufacturing. The platform is able to support a heterogeneous business environment with private, community, and public models all supported. In this talk, system framework, enabling technologies and some case studies will be introduced.

Thursday, 16:30 – 16:45, room ALR1
Functionally graded materials (FGMs) are advanced engineered materials whereby material composition and properties vary spatially in the macroscopic length scale to meet desired or application-specific performance criteria. Due to the absence of sharp discontinuities and interfaces in FGM that reduce material property mismatch, this kind of materials have significant advantages in a range of engineering and scientific applications, including mechanical and thermal systems. Some merits of FGM are improved residual stress distribution, enhanced thermal properties and high fracture toughness.

Due to the formation of cracks during processing or operation, fracture remains an important failure mechanism in FGMs. On the other hand, meeting target mechanical performance depends on a high theoretical understanding of the fracture behaviour and reliability of FGMs. Moreover, the phenomenon of damage inherently involves multiple length scales due to the presence of micro cracks (at micro scale) and global damage (at macro scale). So damage of heterogeneous materials such as FGM is an important aspect in many design applications of load bearing structures, where fracture failure is common.

Fracture in FGMs is complex and appears to be natural candidates for multi-scale modelling. There are several methods for analysing damage in materials such as cohesive zone modelling (CZM) and continuum damage mechanics (CDM). One of the major limitations for CZM approach is that the crack propagation path needs to be known a priori to lay specialized cohesive elements within that path to simulate the fracture. But due to the stochastic and randomness behaviour in some FGM configurations, the crack path and its growth is obscure. For such cases CDM offers a better approach for damage modelling. The base concept of CDM is introducing effective stress that considers a fictitious undamaged configuration of a body and comparing it with the actual damaged configuration.

For studying damage mechanics of FGM, obtaining effective properties of FGM is necessary at a first step. But a crack in FGM may have significantly different energetics, depending on whether the crack tip is located at matrix or particles for a particle reinforced composite FGM. Therefore, assuming homogenized properties for the entire material may not provide accurate or adequate measures of crack-driving forces. Due to sharp discontinuities in the material properties at the microstructural length scale (e.g. particle-matrix interface), a multi-scale analysis is required. Also, FGM microstructures can be inherently random and can, in fact, be viewed as inhomogeneous random field. Therefore, this aspect will be accounted for in the damage development of FGMs. The project will develop multi-scale models to address these aspects in polymeric FGMs, which is a relatively unexplored subject area.

It is important to investigate and understand the behaviours of the FGMs subjected to damage or fracture for appropriate design inputs. The objective of this research is to investigate damage development in FGMs using the multi-scale, multi-material coupling, i.e. coupling between CDM and multi-scale modelling for FGM analytically and numerically that can be used for improved understanding of structural response and fracture behaviour of new polymer based FGMs and contribute to the design of novel high strength and fracture resistant polymeric materials, particularly targeted for biomedical and mechanical applications.
SESSION [4A]  **Brain computer interface using steady state visual evoked potential (SSVEP)**

*Kiran Atal and Shane Xie*

**Motivation:** A Brain-computer interface (BCI) is a communication system in which the brain activity is recorded directly from the scalp and transformed into a control signal so that the user can communicate with a computer or an external device. It provides a communication system for those with neuromuscular disorders since the normal channels of communication such as speech and movement are not used. Present day non-invasive BCIs determine the intent of the user mainly from three different electrophysiological signals: Visual P300 potentials, Sensory Motor Rhythms (SMR) and Steady State Visual Evoked Potential (SSVEP). SSVEPs are brain signals that are natural responses to visual stimulation when the retina is excited by a visual stimulus ranging from 4 Hz to 75 Hz. The SSVEP paradigm is used due to its strong immunity to noise, high information transfer rate (ITR) and simple system configuration.

**Problem Statement:** SSVEP based BCI performance is assessed in terms of accuracy, speed and the number of available targets. Accuracy in terms of a BCI is the correct selections per time interval and speed is the number of selections per minute and are both limited by the low signal to noise ratio (SNR). The number of targets available is directly related to the visual information processing mechanism and is limited by the stimulation frequency band.

**Approach:** The enhancement of the low SNR to increase the accuracy and speed of the system is proposed on two levels. (i) The visual stimuli and (ii) signal processing algorithms. (i) The visual stimuli: In order to enhance the signal strength we propose to vary independently the stimulation parameters such as colour, shape, size, luminosity. (ii) Signal processing algorithms: (a) Single channel ssvep: Fourier based transform is used widely for feature extraction due to its ease of implementation and small computation time. However Fourier transform was originally designed for linear, stationary signals while ssvep is nonlinear and non-stationary. We propose the implementation of wavelet and Hilbert – Huang Transform (HHT) for feature extraction and compare the performance of the three algorithms. (b) Multi channel ssvep: The three signal processing methods mentioned above are commonly used to process single channel SSVEPs. However ssvep response is user variable and this variability is overcome by determining the optimal electrode combination from the multi-channel ssvep. Spatial filtering methods such as Minimum Energy Combination (MEC) and Maximum Contrast Combination (MCC) are available to extract features for multi-channel SSVEPs. Several studies proposed improved Canonical Correlation Analysis (CCA) methods. However, these studies used only the maximum canonical correlation coefficient. The use of other canonical coefficients will be investigated and compared to the MEC and MCC methods.

System capacity limitations will be addressed by using the higher frequency band (30 – 60Hz) for visual stimulation. The use of the higher band also addresses the problem of visual fatigue and epileptic seizures that can be provoked by visual stimuli at lower frequency band.

*Thursday, 16:50 – 16:55, room ALR1*
SESSION [4A]  A new approach to sound and vibration shielding using
non-linear mechanical metamaterials
Arnab Banerjee, Raj Das and George Dodd

Metamaterials are special type of designed composites, having some unconventional
behaviours and responses which are not commonly encountered in natural materials. Frequency
dependent mass, Young’s modulus, and Poisson’s ratio are those key features, exhibited due to
the presence of a series of resonators inside metamaterial, which are responsible for the unusual
out of phase response of metamaterials, whereas natural materials react in same phase with
the excitation. Due to those properties, metamaterials have been effectively used for cloaking,
wave guide and vibration absorption in the field of optics, electromagnetics, acoustics and
elastodynamics. Specifically, mechanical metamaterials have a comprehensive range of appli-
cations in sound, vibration and seismic engineering; however, one of the key limitations is that
their effectiveness limit to a relatively narrow frequency band as they are generally based on
linear resonance mechanisms. On the other hand, the sound insulation capability of lightweight
double-leaf wall is poorer, mainly in short frequency range, compared to the conventional con-
crete or masonry wall. The main aims of the present study are to enhance the performance
of mechanical metamaterials by widening the attenuation band, and to improve the acoustical
performance of double-leaf wall using this metamaterial.

According to our hypothesis, there are two ways of widening the frequency bandwidth of
mechanical metamaterial by either distributing the resonance over a large range of frequency
or introducing nonlinearity in the resonating units. In the metamaterials periodic arrangement
of linear resonating units can confine energy from only a small band of excitation which implies
a proper distribution of resonances can widen attenuation band. On the other hand, in linear
systems, energy cannot be transferred from one vibrational mode to another which compels
each linear mode to interact independently. Generally, nonlinearity can be induced by four
major ways. These are nonlinear material properties, large displacement or rotation, fracturing
and alteration of boundary conditions. Among them only nonlinearity due to change in bound-
ary condition is achievable in the case of small amplitude vibration. Some electromechanical
(e.g. magnetic levitation, bistable response of piezoelectric or dielectric materials) or purely
mechanical (e.g. vibration of buckled, curved or layered beam, friction, impact) systems can
be designed to achieve the small amplitude nonlinearity for broadband metamaterials. It can
be expected that the acoustical performance of a double-leaf wall can be improved by proper
coupling of this nonlinear metamaterial with double-leaf wall.

The scope of this work is to understand these nonlinear energy transfer effects in the con-
text of metamaterials under various excitation spectra, and apply this knowledge to develop
a novel nonlinear metamaterials for wideband acoustic wave shielding to improve the sound
insulation of lightweight double-leaf wall for enhanced building acoustics.

The outcome of this project will contribute significantly to develop the novel nonlinear meta-
material as well as to apply it for improving the acoustic privacy of buildings. Countries, for
example New Zealand, England, Japan, etc. where lightweight double-leaf walls are used as a
partition walls, will be benefited from the developed nonlinear metamaterial based technology,
in terms of reducing or shielding acoustic noise.

Thursday, 16:55 – 17:00, room ALR1
Computer simulations can demonstrate the fundamental mechanisms involved in deformation and damage in crystalline materials, using first-principles and empirically-accurate models. A detailed analysis at the atomic scale is often technologically or commercially infeasible using experiments alone. Deformation and damage in metals is dominated by the cumulative effect of ‘meso-scale’ interactions between atomic-scale defects in the crystalline lattice. Bonding defects called dislocations are highly mobile defects that mediate the majority of deformation in metals, beyond the elastic limit. Discontinuities in the orientation of the crystalline lattice create interfacial defects called grain boundaries, which can strongly influence dislocation processes by acting as a source, sink or barrier. There remain many questions regarding the way the processes at this fundamental, atomic scale cause the macro-scale effects observed at length scales 7-11 orders of magnitude higher. Dislocations are key to understanding deformation mechanisms, and grain boundaries are particularly complex and misunderstood. This study aims to improve the understanding of the physical and energetic characteristics of dislocation generation (i.e., nucleation) from grain boundaries in metals, with atomistic simulations. Specific objectives include evaluating the key predictive parameters, the threshold conditions, and the most statistically significant features of dislocation – grain boundary interactions, at the atomic scale. Molecular Dynamics (MD) simulations have proven an extremely effective tool for replicating the atomic structure and energy characteristics of grain boundaries, and for studying fundamental properties of single dislocations. This study is based on MD simulations of ‘bi-crystals’ of FCC metals, with planar grain boundaries which eliminates many independent variables. A series of bi-crystal studies, based on independent analysis of user-specified grain boundary variables will be subjected to uniaxial stress. At an atomic scale, simulations are inherently limited to very short timeframes, requiring the use of extremely high strain rates. The nudged elastic band (NEB) technique is a time-independent technique which can be used with MD simulations to evaluate the thermal activation parameters (i.e., activation energy) required for atomic processes. Atomic mechanisms and parametric analysis of the variables which influence interactions between atomic-scale defects are a critical first step towards ‘comprehensive’ understanding of the phenomena that cause deformation and damage in crystalline materials. By elucidating these fundamental-scale characteristics, MD-based studies can inform larger-scale simulations to enable predictions of material failure, design of new components and, potentially, the opportunity to tailor the properties of new alloys and materials.

Thursday, 17:00 – 17:05, room ALR1
SESSION [4A] Localization of an Autonomous Mecanum wheel forklift
Theng Kiat Chua and Peter Xu

Localization is to identify the position of the robot and its heading. It is very important for an autonomous mobile robot, as the robot constantly need its current location and heading to calculate the direction and movement for it to take in order to reach its targeted position. For vehicle with normal wheel, localization can be calculated from the amount of rotation of each wheel. However, for mecanum wheels it is not feasible because of slippage in the lateral movement. According to Literature reviews, inertia sensor or visual sensor which is not affected by friction is a feasible method of localization. However it is not accurate and should be combined with a more reliable dead-reckoning method.

In this project, a spherical ball sensor is designed and fabricated to provide a reliable dead-reckoning method. The wheel position dead-reckoning method (wheel position sensor) was used as a secondary method. A low-cost inertia sensor was also investigated.

The spherical ball sensor gives good reliable results but is affected by the friction of the flooring and gives different reading for different floor surface. The wheel position sensor provides very reliable results in the forward and backward movement. For the left-right movement, due to slippage of the wheel, the actual distance travelled by the vehicle is lesser than the calculated valued. The amount of slippage (the different in value) is dependence on the floor friction. The error can be corrected calibrating the wheel position sensor for different floor surface. The inertial sensor rotational data is good, but its positional data were very inaccurate and has unlimited drift. An algorithm was developed to reading the acceleration reading only during the acceleration and deceleration period. The position data was also set to the combined data of the other two sensors.

As the experimental running of the vehicle is mostly in the lab, both the spherical ball sensor and wheel position sensor were calibrated for the carpet flooring of the lab.

Although the spherical ball sensor is sensitive to friction, its response to friction is different to the wheel position method. A weighted average method is used to fuse the left-right position data of the wheel position method and the spherical ball sensor. Kalman filter was used to fuse the inertia sensor data to the combined data from the spherical ball sensor and wheel position.

Further work is needed to improve the data from inertia sensor and the spherical ball encoder, by the use of the location information of external references using laser sensor or Kinect sensor.

Thursday, 17:05 – 17:10, room ALR1
SESSION [4A]  
**A performance characterisation of a vertical axis wind turbine with variable pitch blades**  
*Simon Corkery and Richard Flay*

In New Zealand wind energy has rapidly grown to meet the need for cost-effective emissions-free energy. Advances in horizontal axis wind turbines (HAWT) have supported this growth by increasing turbine size, generating capacity, and lifespan. However, at a much smaller scale these turbines are not well suited for use in built up areas where gusty winds and environmental impacts such as noise generation are more problematic.

In residential areas vertical axis Darrieus type turbines are more suitable as they are omnidirectional, quiet, and have a high peak efficiency. However, poor low speed performance and an inability to self start are major drawbacks of this design. This research investigates improving the performance of a straight bladed Darrieus type turbine by cyclically pitching the blades using a linkage system. A momentum based mathematical model was used to simulate the effects on turbine performance due to the blade pitch system.

While taking into account factors such as dynamic stall and finite blade length, modelling indicates a significant increase in low speed torque compared to the standard Darrieus turbine. A full scale prototype turbine has been designed and constructed, as well as an electromagnet brake and power measurement system. This setup will enable turbine power to be measured directly with minimal parasitic drag and drive train loss, as well as simple turbine torque and speed control. By experimental wind tunnel testing of the system, it is hoped that the theoretical gains in performance due to the variable pitch system will be confirmed.

*Thursday, 17:10 – 17:15, room ALR1*
SESSION [4A] Soft-bodied peristaltic XY machine table
Zhichong Deng and Peter Xu

Manipulate objects in a defined space has always been a task of great interest for robotics and numerous techniques had been developed to achieve this. Robotic arms are able to pick up objects and re-orientate them with several degrees of freedom. This technique is limited by the size of arm and the type of end effector attached to the arm which is designed specifically for certain type of object. Decent control algorithm is required to pick up objects without damaging them. XY table is another method that desires object position is achieved by moving the entire platform on which the object rests on. This method is generally used for experimental setups as it has high precision and only provides a small movement range.

Soft robotics is a growing field in robotics. Currently the main research direction is in biomimetic soft robots. These researches aim to have better biological understanding of soft animals and to inspire new applications by replicating the functions of these animals. Many of these researches are conducted in the science perspective, a few of the soft robots developed have industrial application in the engineering perspective.

This research proposes a soft-bodied machine table that inspired from soft animals and can be used for industrial applications. The proposed table is capable of manipulating objects in the XY directions on the table surface through peristaltic motions which are generated by the deformation of the soft surface. Each cycle of the peristaltic motion generates a small horizontal displacement and with repetitive cycles and different deformation patterns, objects can be manipulated through translational and rotational movements. Multiple objects can be manipulated simultaneously as the entire table surface can be deformed. The softness of surface enables the table to handle delicate objects such as vegetables, fruits and animal organs without damaging them. A potential application would be a sorting table within industry production lines.

A prototype of the soft table is built to prove such concept. The prototype table is made up of a number of actuator modules. Each module is able to move objects in the X and Y direction on the horizontal plane. The modules are driven by pneumatics. Silicon rubber is used to form the table surface.

*Thursday, 17:15 – 17:20, room ALR1*
Combustion and heat exchange processes in an ultra-micro gas turbine

Valerio Giovannoni, Rajnish Sharma and Robert Raine

Over the last 20 years the development of portable devices such as smartphones, laptops, biomedical diagnostic sensors, and GPS (Global Positioning Systems) receivers has led to a miniaturisation of their components and to a higher demand of electricity supply that accumulators and batteries cannot fulfil anymore, even if they are still widely used today. The most suitable devices to provide electric power to the above mentioned small and portable applications seem to be Ultra-Micro Gas Turbines (UMGTs) in fact they are able to generate power in a range from 10 W up to 1 kW with a high energy density. Hydrocarbons burned in air have 20 to 30 times the energy density of the best current lithium chemistry based batteries, so that fuelled systems need only to be modestly efficient to compete well with batteries. Furthermore an UMGT can be fuelled with different types of fuel as liquid or gaseous hydrocarbons, biogases or hydrogen.

Other possible applications include power supply for emergency devices, robots, exoskeletons for last generation warriors, micro cooling and they could also be used as propulsion systems for small-scale air vehicles as Unmanned Air Vehicles (UAV). Today there are only few and incomplete prototypes of UMGTs and most of them do not reach acceptable performances. The most common problems that need to be solved are related to combustion instability at micro-scale, rotor failure in operating conditions, bearings wear and lifetime due to high rotational speeds, aerodynamic performances and high strength materials. Major advances have been made in the last two decades by several universities including M.I.T. Massachusetts, Stanford University, University of Tokyo, K.U. Leuven in Belgium (with the PowerMEMS project) and Università degli Studi “La Sapienza” of Rome, Italy, however good performances still need to be achieved.

A research on UMGT was recently commenced at the University of Auckland through a Ph.D. thesis work in the Mechanical Engineering Department. The above mentioned work is focusing on component (e.g. combustor) issues, such as flame stability limits surrounding flat flame combustion that is typically employed or proposed for a UMGT. The proposed research topic will focus on the interactions between combustion, heat transfer and cycle regeneration, as they greatly influence combustion dynamics and efficiency. Thermal losses have a great impact on the overall combustion process as they could affect the reaction times and flammability limits by lowering the temperature and this could eventually lead to quenching of the flame. In this research, a combustion chamber incorporating a heat exchanger will be developed and optimized to achieve an adequate regeneration rate of the reactants and its behaviour under actual operating conditions of the UMGT will be investigated.

Thursday, 17:20 – 17:25, room ALR1
SESSION [4A] Designing an adaptive controller for the ankle rehabilitation robot using FEA and MB Dynamics
Soroosh Haji Hosseinejad and Shane Xie

Although many investigations have been tried to improve the performance of robots for the ankle joint rehabilitation, surprisingly the most advanced ones nowadays still suffer poor dynamic stability due to their high weight, ineffective controlling strategies and limiting the essential movements of human leg. Moreover, while many investigations have been reveal a lot of detailed information about the biomechanics of the ankle joint using finite element and rigid body motion methods, none of the mentioned approaches have been used to facilitate the development of robot controllers. Even more advanced current robot controllers are still based on the simplified mathematical model of the ankle joint neglecting the effect of the soft-tissue deformity on the joint motion which may lead to ineffective rehabilitation and causing new injuries. Finally, current robots which are programmed based on a generic model of ankle joint without considering the variety of the mechanical characteristics between individuals are not able to provide a proper subject-specific rehabilitation program and sometimes threat the safety of the patient during rehabilitation.

Therefore, the ultimate aim of the current study is to design a novel adaptive controller for the ankle rehabilitation robot using finite element and rigid body motion methods in order to optimise the effectiveness of the rehabilitation programs for patients suffering ankle related disorders with minimum hardware and software modifications.

Thursday, 17:25 – 17:30, room ALR1
Lateral and directional control of the aircraft using synthetic jets
Ptitat Itsariyapinyo and Rajnish Sharma

In an aircraft, hydraulic actuators are used to deflect the control surfaces which ultimately control the flight path of an aircraft. Due to its superior responsiveness, hydraulic actuators are commonly used on commercial aircraft. However, as some fatal accidents are caused by the failure in hydraulic system, a novel flow control device known as “synthetic jet actuator” is proposed in the current study as part of an alternative flight control system which can be operated independently from the hydraulic system.

In the current study, the phenomenon known as “virtual aeroshaping” which can be triggered by the actuation of a synthetic jet, was found to have a substantial effect in modifying the aerodynamic forces on an aerofoil. Similar to a high-lift or high-cambered aerofoil, “trapped vorticity concentration”, which is characterised by a lump of highly rotated air particles formed during the virtual aeroshaping, can simultaneously modify the camber and the aerodynamic forces of an aerofoil. Furthermore, as a synthetic jet actuator can be easily switch on and off, the concept of on-demand actuation can be further investigated to develop the next generation flight control system.

Thursday, 17:30 – 17:35, room ALR1
SESSION [4B] Effect of curvature on structural loading of prismatic bodies subjected to water slamming

John Weber, Mark Battley and Raj Das

Water slamming is a load case encountered in a variety of structural applications and is especially pertinent to marine vehicles and structures. Ocean going marine vehicles generally encounter slamming as a result of waves and high speed travel. Much research has been directed at understanding and predicting slamming loads for a range of geometries of varying rigidity and construction. Analytical and numerical studies focused on slamming of curved rigid bodies are present in literature but there are relatively few experimental studies useful for validation purposes. Despite the current understanding of slamming loads and structural responses, high speed marine vehicles still experience slamming related failures in operation.

In this study, nominally rigid, singly curved prismatic specimens of varying curvature are subjected to water slamming at a range of velocities relevant to those encountered by high performance offshore racing yachts. The experimental aspect of the study is carried out using a Servo-Hydraulic Slam Testing System (SSTS) which is capable of slamming specimens large enough to accurately represent full scale structures such as yacht hull panels. Numerical simulations of this fluid-structure interaction problem are conducted using a coupled Finite Element - Smoothed Particle Hydrodynamics approach and compared to the results of the experimental study. Numerical simulations are performed and validated using the LS-DYNA finite element solver for the well documented case of a rigid sphere impacting water.

Results of panel modelling show that curved bodies experience a much higher initial loading than rigid wedges, which then abates to a quasi-constant residual load. In the design of yacht structures this difference in load profile, in addition to an inherent shift in stress distribution due to curvature induced stiffness, indicates a load case which varies significantly from that found in non-rigid flat panels. These factors, when considered in the design of structures which incorporate curvature, have the potential to produce more optimized and failure resistant structures.

Thursday, 16:00 – 16:15, room ALR5
SESSION [4B] Manufacturing process of kenaf/polypropylene honeycomb cores
Nabihah Sallih, Peter Lescher and Debes Bhattacharyya

Light weight and sustainable sandwich panels are increasingly sought for an extensive range of applications, from structures in airliners to wall linings in buildings. A study on the development and mechanical performance of honeycomb cores manufactured from very thin kenaf/polypropylene (PP) sheets is presented here. The manufacturing process involves production of flat composite sheets using an extruder, thermoforming the flat sheets into half-hexagonal corrugations and joining of the corrugations using an ultrasonic welder to form honeycomb cores.

The effects of PP melt flow index (MFI) and die temperature on tensile and flexural properties, as well as in-plane and out-of-plane shear properties of the flat sheets have been analysed. The thermoformability of the sheets has been examined in the context of single curvature V-bending using an Instron machine. The effects of pre-heat temperature, forming rate, punch tip radius and bending direction on both shape conformity and tensile/compressive instabilities have been examined, both instantaneously and over a short period of time. A method to produce good quality corrugations using a hydraulic press has been developed and the best combination of ultrasonic weld time, amplitude and trigger force in terms of the joint strength of flat sheets has been determined using a lap shear test. This combination has been applied in joining multiple corrugated sheets to form core materials. The influences of directionalities, the thickness-to-length ratio of cell walls and the depth to cell size ratio on the stiffness and strength of the structures under flatwise compressive and shear loadings have been examined to produce desirable core properties for manufacturing sandwich panels.

Thursday, 16:15 – 16:30, room ALR5
Fibre reinforced plastics (FRPs) have become increasingly popular as alternatives to conventional materials, such as steel and aluminum. In automotive, marine, building and construction industries, FRPs have shown advantageous characteristics compared to conventional materials in weight reduction potential and high standard mechanical properties.

However, from an environmental perspective, since the environmental and energy issues have become serious globally, it is necessary to consider whether the usage of FRPs would have environmental benefits. Therefore, the environmental impacts of FRPs need to be assessed before using FRPs in certain applications.

Life cycle assessment (LCA) is an environmental analysis tool which has been widely used in various cases to analyse the environmental impacts of a material or product system during their entire life cycle, including raw material acquisition, production manufacturing, usage and disposal. However, there is little information on the LCA results of FRPs due to the complexity in manufacturing process of these materials. Furthermore, some limitations with regard to the current LCA methodology and framework lead to the fact that research outcomes from different studies are mostly incomparable due to the different functional units and system boundaries.

Regarding these issues, a manufacturing processes based life cycle assessment framework for fibre reinforced plastics has been developed. In the framework, current life cycle assessment methodology has been identified to accommodate the complex fibre reinforced plastics system.

Preliminarily a “cradle to gate” life cycle analysis of bamboo fibre reinforced polypropylene composite has been conducting under the new methodology and framework. Major interest of this case study is to explore the interaction between manufacturing parameters, energy consumption and mechanical properties. Measurement of energy consumption has been undertaken during the composite manufacturing process and hence a series of energy indexes of tensile property of bamboo polypropylene composites with different fibre weight faction have been calculated. The results indicate that the change of manufacturing parameters is influential to the energy consumption of manufacturing large amounts of bamboo polypropylene panels.

*Thursday, 16:30 – 16:45, room ALR5*
Failure and residual strength prediction of carbon-epoxy composite materials
Kariappa Maletira Karumbaiah, Raj Das and Stephen Campbell

Continuous growth in the use of fiber reinforced polymer composites in advanced structural applications, such as aerospace, marine, and automotive are observed in past two decades. Composite materials offer numerous advantages when compared to conventional materials available in manufacturing industries. A significant decrease in mass, increase in strength and stiffness are some of the main advantages of composite materials. Additionally the ply orientation can be preferably tailored to the loading conditions, so the laminates have desired stiffness, ability to form complex shapes and durability.

Composite materials are relatively complex in comparisons with metals. It involves detailed skills in the area like design, analysis, production and quality-control. In several mechanical designs, a strong requirement is the ability to predict the durability and damage tolerance of the structural component. One of the main hindrances to the well organised use of fiber reinforced polymer is their proneness to catastrophic failure under various loading conditions. To predict different failure modes, expensive testing is routinely performed by the industry costing them millions of dollars.

The key objective is to evaluate the accuracy and predictive capabilities of finite element models and failure modelling of composite materials using the ABAQUS software. A set of unidirectional and multidirectional composite laminates made of IM7/977-3 has been selected. The numerical simulations are carried out by using the Hashin’s failure criterion (Hashin, 1980). The use of failure criteria assists in predicting four different failure modes, such as matrix and fiber failure modes under tension and compression. The development of damage is monitored with continuous loading for the different cases. The numerically simulated results are compared against carefully conducted experimental data shared by Defence Technology Agency (DTA), New Zealand.

The unidirectional composites, i.e. 0 and 90 degrees composite laminates, are numerically tested under displacement controlled monotonic compressive and tensile loading. The maximum stress obtained by the finite element models are compared with the experimental results. Good correlations between the modelled and experimental results are observed. The average percentage difference between the numerically simulated results and the experimental results is within 9.07%.

The multidirectional composite laminates are analysed, with and without the presence of open hole under constant displacement monotonic compressive and tensile loading. The damage initiation and propagation are compared with the experimental results for the selected layup configurations. A noteworthy similarity in the damage propagation is observed.

This work will lead to the development of well-validated computational tool to predict deformation and failure behaviour of range of composite materials. As a result, this modelling tool can be used for the prediction of structural integrity and durability of various critical components used in aerospace, mining, marine and automotive industries.
SESSION [4B] Development of physical and numerical model to study cranial backspatter
Eryn Kwon and Raj Das

In forensic ballistics, the impact of a bullet to the human cranium is of high interest, as the fatality rate is significantly higher when compared to bullet wounds to other body parts. Of the various cranial ballistic impact results, the measurement of retrograde spattering of the biological target material, known as backspatter, provides high forensic interest. This is due to its value as evidence during crime scene reconstruction.

Unfortunately, due to the nature of how this data is created, live human samples are not available for use. Therefore, in order to aid crime solving, it is important to have accurate models representing the human cranium to better understand backspatter mechanisms. However, modelling is made difficult by the complex anatomy and physiology of the human cranium. The cranium is a highly irregular geometric shape, composed of inhomogeneous and anisotropic biological materials. As a result, the cranium possesses a unique set of ballistic responses. The accurate encapsulation of the desired ballistic response in the models is a difficult task. To resolve this problem, development of equivalent physical and virtual models is proposed. Creating these equivalent models concurrently allows for cross-validation, controlled experimentation, and more in-depth data collection.

For the physical model development, establishment of a comprehensive comparison criterion to validate the suitability of each simulant candidate is of prime importance. This is because the ballistic response of the physical model is largely determined by the properties of the simulant materials used. Once the criterion is established, the most suitable simulants will be selected and constructed into anatomically correct physical models, with a specific interest in the skin simulant. Extensive ballistic experimentation on the anatomical model will establish a final physical model that successfully mimics the cranial ballistic response, including the backspatter.

For the virtual models, ballistic impacts will be simulated using a Smoothed Particle Hydrodynamics (SPH) method to allow conservation of mass, leading to more realistic backspatter modelling. To improve on the accuracy of the ballistic simulation, dynamic material characterisation of the physical simulants will be used to inform the virtual model. The unique advantage of the SPH model is to provide quick modification and personalization, in conjunction with comprehensive energy exchange, stress and strain data.

Both the physical and virtual models will contribute hand in hand to increase the understanding on the backspatter mechanisms, increasing the evidential value of the backspatter. This will provide a valuable resource, relating actual events in crimes scenes with the bloodstain pattern observed, thus bolstering the credibility of this form of forensic evidence in courtrooms worldwide.

Thursday, 16:50 – 16:55, room ALR5
In medical field, force sensing feedback is critical for surgeons to detect tissues’ hardness and properties, which allows them to apply appropriate forces when they operate surgical devices. Unfortunately, force sensing is constrained severely in Minimally Invasive Surgery (MIS). Therefore, it is necessary to develop suitable force sensors for MIS.

Generally, the existing possible solutions for micro force sensor are based on the following two main categories, which are traditional electronic force sensing and optical force sensing mechanisms. However, conventional force sensors are often not capable for surgery environment since they are highly influenced by electromagnetic interference noise induced by common used magnetic resonance (MR) imaging devices. While optical sensors are immune to this type of noise, which enables them a great potentials in this aspect. Fabry-Perot interferometric (FPI) sensor is one of important optical force sensing techniques. Apart from immunity of MR impact, its miniaturized capability is another significant advantage compare with traditional force sensors, which makes FPI sensor suitable for embedding into the medical instruments.

Generally, force sensors can be integrated in various positions, such as actuation mechanisms driving a joint, instrument shafts out or inside the patients’ body, and instrument tips. However, if the detection is focus on sensing small forces, the results will be influenced by trocar, inertial and friction forces when force sensors are not integrated with surgical tools’ tips. Therefore, the best solution, and also the most challenging, is integrating force sensors into tool tips.

The FPI based force sensor is designed for identifying tissue types during MIS by analyzing insertion forces. It will be first integrated in the tip of a puncture needle to study sensor properties. And the FPI signal will be analyzed by Fourier transform and wavelet transform for the sake of precise and denoised signal. After resolving all the obstacles, the sensor will be exploited and integrated into different medical instruments for detecting contact force or recognising various tissues.

The FPI working principle and force loading model was simulated for estimating the FPI signal behaviour. Then the first FPI sensor was fabricated and embedded in the tip of a 16 gauge puncture needle, fixed by using epoxy. The sensor was tested through a mechanical force loading configuration. The calibration results show that it works as it was estimated but with two main issues, which are temperature influence and interferometric phase recognising. In further research, more attention will be paid on tackling these obstacles, followed by tissue insertion experiments for data collecting used for tissue identification.

Thursday, 16:55 – 17:00, room ALR5
SESSION [4B]  Static and dynamic characterisation of novel composite materials  
Md. Zillur Rahman, Brian Mace, Krishnan Jayaraman and Debes Bhattacharyya

With the advent of relatively strong, lightweight materials and increased knowledge of the material properties and structural loading, the mass of a structure built to fulfil a particular function has decreased. However, reducing the mass can cause noise and vibrational problems in structures, machines or any dynamic systems. It is therefore essential to consider the reduction of vibration levels while designing structures to avoid resonance and undesirable dynamic performance. Failure to address vibration issues can create dynamic stresses and strains which may lead to fatigue or failure of the structure or machine, can cause fretting corrosion between contacting elements and unacceptable noise transmission. To reduce the vibrations to a desirable level, damping may be added to a structure to dissipate vibrational energy.

The aim of this research is to produce natural-fibre-reinforced polymer composite materials through compression moulding. Mechanical properties in terms of tensile and flexural, and vibration damping behaviour will be experimentally evaluated and then compared to theoretical predictions and existing analytical models. Furthermore, the aim is to develop materials that optimise the mechanical performance and damping response.

Structural damping measurements using experimental modal analysis are used to estimate damping from the measured frequency responses. The extraction of the modal parameters such as natural frequencies, damping loss factors and modal constants of the structure from the measured data will then be carried out using the circle-fit method. High damping capacity of these composite materials could be beneficial in many automotive and aerospace applications in which noise and vibration are critical issues for the comfort of passengers, and can also be useful in many sporting and other applications.

*Thursday, 17:00 – 17:05, room ALR5*
Wearable control device with haptic feedback for unmanned underwater vehicle
Syed Mohamad Shazali and Shane Xie

Over the past decades, the employment of teleoperation systems has spread to numerous domains. Teleoperated vehicles have been employed in warfare and underwater exploration. Unmanned underwater vehicles (UUVs) are robotic vehicles that can operate underwater. They are controlled either remotely by a human operator i.e., remotely operated vehicles (ROVs) or autonomously through software (i.e., autonomous underwater vehicles (AUVs). Over the past decade, UUVs have been increasingly used for conducting military operations as well as light working underwater vehicle in scientific application such as intelligence, surveillance, and reconnaissance (ISR), oceanography data collection, and most notably, mine countermeasures (MCM). Navigating and maneuvering an ROV is a difficult task. Aside from the visual limitations the operator must control the robot along six degrees of movement freedom: surge (forward/backward), heave (up/down), sway (left/right), pitch, roll, and yaw. At the same time, the operator must also attend to the vehicle’s velocity, altitude, and position in the water. Water currents continually apply force to the vehicle such that the operator must constantly make small positional and attitude adjustments to compensate. In addition, the vehicle’s buoyancy and the occasional contact with debris can also affect the maneuverability of the ROV. It is well known that ROV control and umbilical cable entanglement are problematic. Moreover, AUVs have been reported lost at sea due to system failures; sensor failure, blocked or flooded thrusters, lost or stuck fin, rotor failure, and hardware / software crashes. While maneuvering the ROV, the operator must concurrently also manage the umbilical cable, to allow the ROV to move as required, by providing it with just enough slack to allow the vehicle to move freely, but also to limit umbilical cable entanglement. Poor umbilical cable management can cause significant drag and affect the vehicle’s performance. When tasks must be carried out in the deep ocean or hazardous marine environments, teleoperated robotic systems are necessary. In most applications a pilot resides at the surface while an ROV carries out functions like munitions remediation, oil and gas operations, studies of hydrothermal vent colonies, and construction of ocean observatories which are a subset of underwater applications that require teleoperation. In particular, manipulation is often necessary for operating tools, opening valves, mating cables, or simply moving objects from one place to another. Subsea manipulation is a challenging and expensive endeavor that relies on expert pilots with substantial experience. The cost of operating ships and robotic systems often drives crews to operate 24 hours/day and highlight the importance of avoiding mistakes. Advanced tools that lower the burden on pilots, increasing safety, reliability and efficiency of operations, has potential to dramatically reduce cost and increase feasibility of complex tasks performed underwater. Although there are efforts had been done on teleoperating the tools on an ROV with haptic feedback, there is no work, to the best of my knowledge, on the same approach for driving and maneuvering the ROV itself. The resulting approach should be able to ease the operator to control ROV and at the same time getting feedback from the vehicle. The system should allow immediate response from the operator. This research aims to investigate whether the wearable assistive controller would improve in human-robot interaction of UUV by improving operator experience through force feedback system. The works would include development of wearable assistive controller with hand-and-finger interaction techniques. The thesis would also discuss the strengths and weaknesses of two types of cruising controller, the traditional joystick-keyboard controller and wearable assistive controller.

Thursday, 17:05 – 17:10, room ALR5
SESSION [4B] Effective control of end-effector robots for upper limb rehabilitation
Bo Sheng and Shane Xie

Background:
In New Zealand, an estimated 6000 stroke cases occur every year with approximately two thirds of these cases being non-fatal. The Stroke Foundation of New Zealand estimates that the number of stroke survivors in New Zealand has reached 45,000 in 2011. With the tendency of aging society, the number of elderly in the population is expected to increase in the next few years. Since the high mortality rate and the high disability rate, the life equality of people who get stroke is seriously impacted. Applying assistive robotics to rehabilitation can not only release rehabilitation physicians from the heavy burden of training mission, but also provide a platform to evaluate the convalescence results by analyzing the data recorded during the training process. Due to their various advantages in terms of high accuracy and reliability, rehabilitation robots are able to provide an efficient and convenient way to improve the recovery performance of patients after stroke.

Objectives:
1. Development of two end-effector robots based on universal robots with musculoskeletal and neurological upper limb disorders. The robot design is required to be flexible (Own universal motions), safety, low cost and human friendly with respect to use and appearance;
2. Design the whole structure of upper limb includes the wrist, below and shoulder;
3. Design an ‘assistance-as-needed’ controller for providing seamless adaptive robotic assistance by automatically assessing the patient’s disability level during upper-limb training; multiple training modes including patient-passive, patient-active, bilateral trajectory tracking control and bilateral impedance control will be investigated and performed according to the patient’s movement ability and recovery conditions;
4. Development of a series of virtual-reality training games to interest the patients;
5. Clinical trails on subjects with musculoskeletal or neurological upper limb disorders for evaluation of the new robotic design, intelligent control system and virtual-reality training environment.

Methodology:
Design: Refit the wrist prototypes (Add two pneumatic muscle actuators to realize rehabilitation of the wrist) and install them at the tip of universal robots. Moreover, the structure of end-effector robots can be easily controlled by the PolyScope system, which can provide foundation for real-time monitoring and data collection. The robot data including position tracking errors, velocity and interaction force, which will be recorded by the PolyScope system. And the patient’s recovery conditions such as the muscle activity will be evaluated by EMG signals.

Control: The proposed research will develop ‘assistance-as-needed’ control for providing seamless adaptive robotic assistance during training. This controller can adapt the robotic assistance to the patient’s disability level. Four control modes for patients with different recovery stages will be conducted, including the patient-passive, patient-active, bilateral trajectory tracking and bilateral impedance control method, with the consideration of patient’s movement ability and muscle activity assessment.

Thursday, 17:10 – 17:15, room ALR5
The area of automated guided vehicle (AGV) systems is a hotspot research applied in logistics systems. AGV systems with full automation solution to logistics flows have the advantages of high efficiency, stability and accuracy. It is creating enormous economic benefits for many fields. The Mecanum wheels have been applied in AGV for many decades, mainly on account of its great omni-direction maneuverability, which prioritizes itself over conventional locomotion solutions. Omni-directional mobility is an outstanding ability for the mobile robots to conveniently transport in the congested, confined or highly dynamic environments such as workshops, warehouses and hospitals. However, its first inherent problems - random wheel slippage and high-speed vibration hinder the Mecanum wheel’s further autonomous application.

A lack of heavy-duty Mecanum robot research on autonomous navigation demands a robot platform to conduct experiments. The first stage of the research is to design and manufacture a heavy-duty omni-directional autonomous mobile robot platform based on Mecanum wheels for autonomous navigation research of the next stage. A robust precise position control for the robot platform is expected to be achieved by overcoming the slippage problem. The random wheel slippage introduces a severe position error in the optical encoder dead-reckoning method, which is very commonly applied in the position control of wheel mobile robots. Appropriate solutions to cope with high-speed vibration of the Mecanum wheel are also expected to be found. High-speed vibration creates noise and electric power safety issue for heavy-duty tasks. At the moment not much research focuses on the high-speed vibration of the Mecanum wheel yet. A computer virtual simulation is also necessary to be set up. Safety should be guaranteed in the simulation before conducting heavy-duty experiments.

The Mecanum wheel trades off maneuverability against energy efficiency. It is very necessary to optimize the trajectory planning and trajectory following for heavy-duty cases to achieve energy optimization. The autonomous robot platform based on the Mecanum wheels provides a holonomic mobile system. The trajectory planning and following have way more options than the conventional motion system. From a starting position to a goal position with a desired posture, there are too many possibilities of motion plans. In the second stage of the research, an energy-optimal autonomous navigation is to be developed to reduce the energy consumption. Furthermore, behavior-based navigation will be considered to be developed in the future.
SESSION [4B] Oscillatory flow through sharp edged orifices
Kartik Yajnanarayan and Rajnish Sharma

Many studies have been conducted into steady flows through orifices and sudden constrictions in pipes and hence the flow and loss characteristics are very well defined and well understood. However, the flow and loss characteristics of unsteady flows and especially oscillatory flows through orifices and sudden constrictions are still yet to be fully understood and defined. This study aims to understand oscillatory (sinusoidal) flow through an orifice at low frequencies using air as the working fluid. As part of the study, experiments have been conducted at a range of oscillating frequencies and Reynolds numbers. Numerical CFD techniques have also been utilised for flow visualisation purposes.

The experimental rig, essentially consists of a driving mechanism and the test section; the driving mechanism consists of a scotch yoke mechanism with flywheels of two different sizes attached to a piston through a slot. The rotation of the flywheel allows the piston oscillation. The flywheel is attached to a DC motor with a variable speed controller. The experimental parameter such as the oscillation frequency can be varied by varying the speed of the DC motor and the oscillation amplitude can be varied by setting the piston at different diameters on the flywheel. Using this arrangement, the following range of oscillation frequencies and oscillating Reynolds numbers in the orifice have been tested: f(Hz):0.5-3.14, Re : 1500 – 6000. The test section consists of two acrylic tubes of 14mm I.D. and a length of 763mm each. An orifice with a beta ratio of 0.5 is sandwiched between these two sections. The pressure data upstream and downstream of the orifice is collected by using an 8 channel pressure transducer system.

In addition to the experiments, transient CFD simulations using the ANSYS CFX package were setup for flow visualisation. Multiple domains were set up for the simulation. The first included a full 3D domain which was an exact match of the experimental test section. In order to reduce the size of the mesh, input and results files, an axisymmetric domain was used with a symmetry plane. The domains were meshed using ICEM CFD and consisted of hexahedral elements with approximately 2.5million nodes. The boundary conditions consisted of a sinusoidal velocity condition at the inlet, a no slip, smooth wall condition at the walls and an opening condition at the outlet. In addition to this due to the oscillating nature of the flow, both the Shear Stress Transport (SST) and Scale Adaptive Simulation SST (SAS-SST) turbulence models have been tested for each case. Currently, initial sets of data have been gathered from the experimental setup and are currently being compared with the CFD simulations.

Thursday, 17:20 – 17:25, room ALR5
Over the past years, conventional finite element analysis (FEA) has been widely applied in solving for the dynamic response of structures and for optimizing the design of structural components. It is unlikely that FEA alone can be used to solve for the dynamic response of all structures, especially at higher frequency or for structures involving complex construction, due to large model size and consequent high computational cost or modelling limitations. At higher frequencies the size of the model becomes large and alternative approaches become useful. One approach is the Wave and Finite Element (WFE) method. In this an FE model of a small segment of the structure is used to determine wave propagation characteristics. From these, other approaches can be used to calculate response.

The goal of this thesis is to develop the WFE method to the prediction of noise transmission through structures, particularly those of complicated construction, such as honeycomb or corrugated cores, and to periodic structures.

My provisional year is focused on literature review about WFE method and application to wave modelling. The method will then be extended to predict noise transmission through simple panels (e.g. thin isotropic plates) for which analytic solutions are available. It will then be extended to more complex structures such as laminates and honeycomb, corrugated or foam cored structures, periodic structures or cases where fluid-loading effects are important.

*Thursday, 17:25 – 17:30, room ALR5*
In nowadays competitive market, one-of-a-kind production (OKP) companies are striving to deliver customizable products with better quality, more personalized and innovative designs. To achieve this, customers’ involvement in product design stage plays a significant role. It not only provides valuable information for designers to capture customers’ latent needs in the context, but also offers chances for customers to fulfil their satisfaction by designing for themselves during the co-creation process. However, current OKP companies still lack much support.

Mass personalization (MP), a recently emerged manufacturing paradigm, emphasizes exploitation of customer’s implicit data and aspires to create unexpected user experience (UX), which provides useful guidelines for customer involvement in product design and potentially benefits the OKP companies in creating more personalized value-added products. However, despite its advantages, there was no comprehensive study on the recent development of customer-centric design for MP.

To fill this gap and provide support for OKP companies, this research work mainly focused on developing quantitative and qualitative approaches and web-based software tools to enhance UX, co-design participation, and interaction between customers and designers in the customer-centric design process, especially in the early stage of the product development for MP.

*Thursday, 17:30 – 17:35, room ALR5*
List of Presenters

Amirpour, Maedeh (#31) - p37
Atal, Kiran (#32) - p38
Aw, Kean (#1) - p8
Banerjee, Arnab (#33) - p39
Billac, Thomas (#16) - p23
Bourke, Grant (#20) - p27
Burberry, Nathaniel (#34) - p40
Cao, Jinghui (#14) - p33
Chan, Ronald Ping Man (#24) - p20
Chen, Jeremy (#18) - p25
Chen, Youming (#17) - p24
Cheng, Chen (#8) - p15
Chua, Theng Kiat (#35) - p41
Corkery, Simon (#36) - p42
Deng, Zhicong (#37) - p43
Devaraj, Harish (#21) - p28
Dirven, Steven (#7) - p14
Edwards, Bryn (#22) - p29
Giovannoni, Valerio (#38) - p44
Hosseinejad, Soroosh Haji (#39) - p45
Itsariyapinyo, Pititat (#40) - p46
Karumbaiah, Kariappa Maletira (#41) - p50
Kim, Nam Nyeun (#3) - p10
Kwon, Eryn (#42) - p51
Lu, Charles Zhe (#13) - p32
Lu, Tiange Jack (#52) - p49
Lu, Yuqian (#51) - p36
Ma, Ye (#11) - p18
Mo, Zonglai (#43) - p52
Ng, Nicholas (#25) - p21
Ou, Mick (#30) - p35
Panamoottil, Shyam (#4) - p11
Payne, Alexander R. (#26) - p19
Rahman, Md. Zillur (#44) - p53
Raine, Robert (#2) - p9
Sallih, Nabihah (#28) - p48
Sang, Zhiqian (#29) - p34
Shazali, Syed Mohamad (#45) - p54
Sheng, Bo (#46) - p55
Subasinghe, Aruna (#5) - p12
Swery, Elinor (#15) - p22
Tao, Ran (#10) - p17
Turkeli-Ramadan, Zerrin (#19) - p26
Veale, Allan (#12) - p31
Wang, Jiaqi (#23) - p30
Weber, John (#27) - p47
Xie, Li (#47) - p56
Yajnanarayan, Kartik (#48) - p57
Yang, Tony (#49) - p58
Zhang, Mingming (#9) - p16
Zheng, Pai (#50) - p59
Zhu, Mingzhu (#6) - p13
Associate Professor Robert Raine

‘Hands-on research of diesel-like fuels’

In 2012, I spent seven months sabbatical leave at the University of Castilla-La Mancha in central southern Spain. This talk will give some idea of the nature of the experience of that leave, including technical and social aspects.

A commercial high pressure oven (Cetane ID510TM) was used to measure ignition delay of diesel and diesel-like fuels. The design purpose of the ID510 is to measure a derived cetane number for diesel fuels, avoiding the very expensive standard method of measuring cetane number which uses a standard engine. The cetane number of a fuel is an important parameter describing the ignition delay of the fuel in a diesel engine. The ignition delay has important effects on engine operation including efficiency, power output, and exhaust emissions. The ID510 has facilities to change numerous characteristics including temperature, pressure and oxygen concentration in the oven. The objective of my research was to determine how these characteristics affected the ignition of the fuels. The challenges included:

• Could different fuels, other than conventional diesel be used in the oven?
• Would the measurements have any meaning?
• How would our measurements of ignition delay compare with those of other researchers using different equipment?
• What other fuels were available for use in the oven at appropriate costs?

The project succeeded in gathering extensive data which were compared against others, fitted into other published data, and using fuels which had not been used before in these types of experiments.

Biography

Associate Professor Robert Raine joined the University of Auckland in 1977 after receiving his PhD from the University of Southampton. He has taught mainly in thermodynamics, at all levels, and his main research interests are in internal combustion engines and alternative fuels. He was closely involved in the extensive programme of use of CNG (compressed natural gas) as a transport fuel in New Zealand in the 1980s. His awards for contributions to the field include the Crompton Lanchester Medal of the Institution of Mechanical Engineers and several Research Fellowships including from the UK Engineering and Physical Sciences Research Council, Oxford Colleges and the EPFL (Switzerland).

Associate Professor Kean Aw

‘Polymer-based Memories and Transducers’

Polymer is widely used in our daily life. However, since the last decade, polymers have been increasingly being used in electronic devices. Here, two different applications of polymers will be presented, i.e., electronic memory devices and transducers. Polymethylsilsesquioxane, which is a type of dielectric is used together with gold nanoparticles as optically transparent or mechanically flexible memory devices. Various configurations to achieve these memory devices will be discussed. Finally, ionic polymer metallic composite (IPMC), which is a type of functional polymer, will be presented. Applications of IPMCs as sensors and actuators will be discussed.

Biography

Associate Professor Kean C. Aw has been with the Department of Mechanical Engineering, University of Auckland, New Zealand since 2004. Prior to his academic position, he worked at Intel, Altera and Navman for a total of 11 years. His main interests are in micro-systems and deployment of smart/functional materials and structures such as conducting polymers, metallic oxides etc as sensors and actuators in various applications such as bio-sensors, medical/rehabilitation robots, micro-pumps, micro-manipulators, MEMS, energy harvester, etc. He has over 130 refereed publications.

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