Manufacturing and Design **NZ**

# MaD for the Future 2017: A National Conference for Innovation in Manufacturing and Design

10-11 May 2017

ANZ Viaduct Event Centre, Auckland

# With Our Thanks

MaD for the Future is proud to be partnered, sponsored and supported by:

## Partners

## Sponsors

### Gold

### Silver

### Bronze

### Other

## Supporters

The New Zealand Manufacturing and Design (MaD) Conference Committee and the MaD Driver Team (Steering Comittee) are delighted to welcome you to MaD for the Future 2017: A National Conference for Innovation in Manufacturing and Design.

This event will be pivotal in the ongoing process of defining who we are, and what we do. MaD for the Future 2017 is the national MaD Network's inaugural conference, and will be focused on the following outcomes:

| CONSOLIDATION | CONNECTION | COLLABORATION |
|---|---|---|
| Understanding the landscape of NZ manufacturing and design capabilities and expertise, as well as the needs of NZ businesses, in the areas of manufacturing and design | Creating a sense of belonging to the NZ MaD Network, including new and emerging researchers, both in academia and industry | Identifying areas for collaboration within the NZ MaD community following the conference, to lay the ground work for the NZ MaD Network as it develops towards a national Centre of Research Excellence |

The MaD Network is a newly formed community of New Zealand researchers in manufacturing and design, working in close collaboration with industry. Our MISSION is to develop expertise and capability in translational research, to grow New Zealand's high-tech manufacturing economy.

A committed multi-institutional team is building an enduring entity, which specifically aims to:

• Focus on identifying and developing high-value products and making New Zealand manufacturing sectors more competitive globally

• Carry out active, collaborative research in disciplines of manufacturing and design that contribute to the MaD Network Mission

• Conduct multi-disciplinary research, in the areas of Human Centred Design, Engineering Design, Manufacturing Processes, Manufacturing Systems and Innovation

The conference programme is designed to engage our rapidly developing national MaD community, to showcase MaD research nationally and to profile New Zealand's MaD industry innovators. We have designed an attractive programme (with a number of keynote addresses, from distinguished national and international speakers) for representatives from industry and academia, including students and emerging researchers, involved in manufacturing and design across New Zealand. Your presence and active engagement will be pivotal to the success of this inaugural New Zealand MaD Conference.

On behalf of the MaD Conference Committee and the MaD Driver Team, we wish to thank our partners, sponsors and supporters for acknowledging the importance of this inaugural event in our national manufacturing and design landscape.

Yours sincerely,
Professor Xun Xu, Chair of the MaD Conference Committee
Professor Simon Bickerton, Chair of the MaD Driver Team


## NZ's Manufacturing and Design (MaD) Network

Our MISSION is….

To develop expertise and capability in translational research, to grow New Zealand's high-tech manufacturing economy

Our VISION is…

For New Zealand to be recognised as a leading, technology empowered economy driven by innovative, high-value, niche manufacturing and design

MaD Driver Team (Steering Committee)

- Simon Bickerton, The University of Auckland
- Mark Battley, The University of Auckland
- Claire Reyneke, The University of Auckland
- Enrico Haemmerle, AUT
- Johan Potgieter, Massey University
- Don Cleland, NSC10 & Massey University
- Simon Fraser, Victoria University of Wellington
- Don Clucas, University of Canterbury
- Shayne Gooch, University of Canterbury
- Nathan Stantiall, Callaghan Innovation
- Kenneth Husted, The University of Auckland

MaD Conference Committee

- Xun Xu, The University of Auckland
- Simon Bickerton, The University of Auckland
- Claire Reyneke, The University of Auckland
- Marcel Schaefer, AUT
- Khalid Arif, Massey University
- Jim Johnston, Victoria University of Wellington
- Don Clucas, University of Canterbury
- Jesse Keith, Callaghan Innovation
- Tom McLeod, ATEED
- Jennifer Clamp, ATEED & Techweek'17

This network is being developed in collaboration with, and will grow from, the institutes represented above, and those listed below:

- University of Waikato
- University of Otago
- Otago Polytechnic
- GNS Science
- Scion



## Contents



MaD2017 is an official feature event at *Techweek'17, when New Zealand's brightest minds come together for nine days to find local answers to global questions. 6-14 May Techweek.co.nz*

tech-week 2017 OFFICIAL EVENT

***About Techweek:*** *Techweek is an annual week of curated events that exists to amplify NZ innovation that is good for the world. It's run by the tech ecosystem under the guardianship of not-for-profit NZTech, and is produced in association with MBIE, NZTE, ATEED, and MoE, and supported by New Zealand Tourism, Callaghan Innovation, WREDA, CDC, Hamilton City Council, Rotorua Lakes Council and Tauranga City Council. BNZ and SkyCity are Founding Patrons of Techweek.*

## WEDNESDAY 10 MAY 2017

| | | | |
|---|---|---|---|
| 8am | **Registration Opens (Level 3 Kawau 1)** | | |
| 9am | **Conference Opening (Rangitoto 1)** Professor Simon Bickerton (Chair, MaD Network) \| Professor Nic Smith (Dean of Engineering, The University of Auckland) \| Vic Crone (CEO, Callaghan Innovation) | | |
| 9.20am | **Keynote Speaker: Crispin Hales - Hales & Gooch Ltd**<br>**WHY FOLLOW WHEN YOU CAN LEAD? ADDING VALUE TO THE NEW ZEALAND GENIUS**<br>**Session Chair:** Simon Bickerton (Chair, MaD Network, The University of Auckland) **Room:** Rangitoto 1 | | |
| | 10am Morning Tea Break (Kawau 1) | | |
| 10.30am | Parallel Technical Sessions (Level 2) | | |
| | **Design and innovation**<br>**Session Co-Chairs:**<br>Shayne Gooch \| Mike Duke<br>**Room:** Rangitoto 1 | **Design and innovation**<br>**Session Co-chairs:**<br>Andrew Drain \| Michael Kingan<br>**Room:** Rangitoto 2 | **Product and process innovation**<br>**Session Co-chairs:**<br>Marcel Schaefer \| Alisyn Nedoma<br>**Room:** Rangitoto 3 |
| | **STAIRCASING INDUSTRY ENGAGEMENT: A BOTTOM-UP PRACTICE BASED MODEL FOR INTEGRATING DESIGN RESEARCH INTO INDUSTRY**<br>*Simon Fraser, Victoria University of Wellington* | **THE INVERSE ROUTE: FROM INDUSTRY FOCUS TO THE ACADEMIC WORLD. WHAT ARE THE BEST PROJECTS TO WORK IN?**<br>*Lorenzo Garcia, Auckland University of Technology* | **FAST NPD AND RISK; REDUCING RISK WHEN MOVING FAST.**<br>*Craig Shannon, Globex* |
| | **THE WHISPERGEN STORY. A NEW ZEALAND DESIGN AND MANUFACTURING SUCCESS?**<br>*Don Clucas, University of Canterbury* | **HUMAN-CENTERED-DESIGN: AN INSIGHT INTO SOUTH-EAST ASIAN RURAL MARKETS**<br>*Andrew Drain, Massey University* | **COLLABORATIVE INNOVATION AT THE CENTRE FOR AUTOMATION AND ROBOTICS ENGINEERING SCIENCES**<br>*Bruce MacDonald, The University of Auckland* |



| | | | |
|---|---|---|---|
| | **DESIGNING OUR FUTURE**<br>*Mark Battley, The University of Auckland* | **THE DEVELOPMENT OF A NEW DESIGN TOOL FOR ORGANIC RANKINE CYCLES**<br>*Wei Yu, The University of Auckland* | **INNOVATIVE DESIGN OF AIR COOLED HIGHLY FINNED TUBE CONDENSER**<br>*Haiam Abbas, Heavy Engineering Research Association* |
| | **HOW TO CREATE A SUCCESSFUL PRODUCT**<br>*Oliver McDermott, Blender Design Ltd* | **MODULAR LIGHTWEIGHT FURNITURE WITH INTEGRAL FASTENERS USING POST-TENSIONING**<br>*Hans-Christian Wilhelm, Victoria University of Wellington* | **ADVANCED BIOBASED PRODUCTS - COMBINING SUSTAINABILITY WITH PERFORMANCE**<br>*Florian Graichen, Scion* |
| | **MaD PIPELINES: EMERGING METHODOLOGICAL PIPELINES FOR DESIGN AND MANUFACTURING PROCESSES**<br>*Dermott Mcmeel, The University of Auckland* | **A CASE STUDY IN DESIGN-LED INNOVATION**<br>*Rob Heebink, Gallagher Group Limited* | **NEXT GENERATION SURFACE COATINGS BASED ON ZERO EMISSION AND NO WASTE MANUFACTURING APPROACH**<br>*Marcel Schaefer, Auckland University of Technology* |
| | **ON THE DESIGN OF ASSISTIVE DEVICES FOR PEOPLE WITH TETRAPLEGIA IN A NEW ZEALAND CONTEXT**<br>*Shayne Gooch, University of Canterbury* | **EARTHQUAKE BENCH PROTOTYPE: A RECONCEIVED DIGITAL WORKFLOW**<br>*Tonya Sweet, Victoria University of Wellington* | **SOUND CONCEPTS PLATFORM: VISUALISING SOUND CONCEPTS**<br>*Natasha Perkins, Victoria University of Wellington* |
| | **ADDRESSING A WORLDWIDE GEOTHERMAL ENERGY UTILIZATION PROBLEM BY PRODUCING A NOVEL PRODUCT WITH INDUSTRIAL AND CONSUMER APPLICATIONS**<br>*Jim Johnston, Victoria University of Wellington* | **HIGHLY STRETCHABLE 3D-PRINTED ELECTRICAL COMPONENTS USING CARBON NANOCOMPOSITES**<br>*Tim Giffney, The University of Auckland* | **INDUSTRIAL SCALE ION BEAM TECHNOLOGIES FOR NEW ZEALAND MANUFACTURING**<br>*John Kennedy, GNS SCience* |

| | | | |
|---|---|---|---|
| | **AERODYNAMIC AND STRUCTURAL DESIGN OF SMALL SCALE TURBINE FOR ORGANIC RANKINE CYCLE SYSTEM**<br>*Lei Chen, Heavy Engineering Research Association* | **ACOUSTICAL TESTING AND DESIGN FOR ACCEPTABLE NOISE**<br>*Michael Kingan, The University of Auckland* | **NANOSTRUCTURAL CONTROL IN PLASTIC ELECTRONIC FILMS**<br>*Alisyn Nedoma, The University of Auckland* |
| | **DIBBLER CASE STUDY – A DESIGN METHODOLOGY FOR DEVELOPING SPECIALIST, AUTOMATED, AGRICULTURAL MACHINERY IN NEW ZEALAND.**<br>*Mike Duke, Waikato University* | | |
| 12.30pm Lunch Break (Kawau 1) / Poster and Exhibition Viewing | | | |
| 1.20pm | **Keynote Speaker: Cather Simpson - University of Auckland**<br>**HIGH TECH INNOVATION IN AN INDUSTRIAL CONTEXT**<br>**Session Chair:** Simon Bickerton (Chair, MaD Network, The University of Auckland) **Room:** Rangitoto 1 | | |
| 2pm | **BREAK OUT SESSION 1** | | |
| | **Collaborative MaD**<br>**Session Co-chairs:** Jesse Keith (Callaghan Innovation) \| Steve Wilson (Talbot Technologies Ltd)<br>**Room:** Rangitoto 1 | **Future Young Researchers**<br>**Session Co-chairs:** Khalid Arif (Massey University) \| Shayne Gooch (University of Canterbury)<br>**Room:** Rangitoto 2 | |
| 3pm Afternoon Tea (Kawau 1) / Poster and Exhibition Viewing | | | |
| 4pm | **BREAK OUT SESSION 2** | | |
| | **IoT and INDUSTRY 4.0**<br>**Session Co-Chairs:**<br>Xun Xu ( The University of Auckland) \| Kevin Marett (LEAP Australia)<br>**Room:** Rangitoto 1 | **DESIGN FOR ADDITIVE MANUFACTURING AND THE FUTURE OF COMPOSITE MANUFACTURING**<br>**Session Co-Chairs:** Mike Fry (TiDA Ltd) \| Johan Potgieter (Massey University)<br>**Room:** Rangitoto 2 | |
| 6.30pm Conference Dinner (Rankino)<br>with inaugural set-piece, formal address by Hon. Minister Paul Goldsmith | | | |

## THURSDAY 11 MAY 2017

| | | | |
|---|---|---|---|
| 8.30am | **Registration Opens (Level 3 Kawau 1)** | | |
| 9am | **Introduction of Day (Rangitoto 1)** Simon Bickerton (Chair, MaD Network) | | |
| 9.10am | **Keynote Speaker: Eberhard Klotz - Festo**<br>**INDUSTRIE 4.0 IN ACTION (Sponsored by Festo)**<br>**Session Chair:** Xun Xu (Chair, MaD Conference Committee, The University of Auckland) **Room:** Rangitoto 1 | | |
| 9.50am Morning Tea Break (Kawau 1) | | | |
| 10.30am | Parallel Technical Sessions (Level 2) | | |
| | **FUTURE OF MANUFACTURING TECHNOLOGY**<br>**Session Co-Chairs:**<br>Kenneth Husted \| Don Cleland<br>**Room:** Rangitoto 1 | **ADDITIVE MANUFACTURING**<br>**Session Co-Chairs:**<br>Jim Johnston \| Khalid Arif<br>**Room:** Rangitoto 2 | **SPECIALISED MANUFACTURING PROCESSESS**<br>**Session Co-Chairs:**<br>Steven Dirven \| Chris Bumby<br>**Room:** Rangitoto 3 |
| | **INDUSTRY 4.0 - WHAT'S IN IT FOR US?**<br>Dieter Adam, NZMEA | **ADDITIVE MANUFACTURING AND INTERNET OF THINGS: ACCELERATING RESEARCH AND DEVELOPMENT THROUGH A CASE STUDY APPROACH**<br>*Steve Wilson, Talbot Technologies Ltd* | **FLUX PUMP BRUSHLESS EXCITERS FOR SUPERCONDUCTING GENERATORS**<br>*Chris Bumby, Victoria University of Wellington* |
| | **INDUSTRY 4.0 SMART MANUFACTURING SYSTEMS LABORATORY**<br>*Xun Xu, The University of Auckland* | **FREEFORM 3D PRINTING: TOWARDS A NEW PARADIGM IN MANUFACTURING**<br>*Tim Miller, Victoira University of Wellington* | **ENHANCED LASER ABLATION OF BONE TISSUE USING ULTRAFAST PULSED BESSEL BEAMS FOR APPLICATIONS IN LASSOS**<br>*Simon Ashforth, The University of Auckland* |

| | | | |
|---|---|---|---|
| | **POLYMER COMPOSITE MANUFACTURING TECHNOLOGIES FOR THE FUTURE**<br>*Simon Bickerton, The University of Auckland* | **THE USE OF COMPUTER AIDED ENGINEERING AND 3D PRINTING IN THE DEVELOPMENT OF A ROBOTIC KIWIFRUIT HARVESTING GRIPPER.**<br>*Mike Duke, Waikato University* | **DEVELOPMENT OF CONTINUOUS REEL-REEL PILOT MANUFACTURING PROCESSES FOR PRODUCTION OF SUPERCONDUCTING ROEBEL CABLE**<br>*Kent Hamilton, Victoria University of Wellington* |
| | **INDUSTRY 4.0 EASILY IMPLEMENTED WITH BECKHOFF**<br>*Steven Sischy, Beckhoff Automation Limited* | **MASSEY UNIVERSITY CENTRE FOR ADDITIVE MANUFACTURING: A REVOLUTION IN DESIGN ENGINEERING**<br>*Johan Potgieter, Massey University* | **NATURAL FIBRE AND NATURAL FIBRE COMPOSITES: SURFACE MODIFICATION, PROCESSING AND FUNCTIONALIZATION**<br>*Xiaowen Yuan, Massey University* |
| | **GIVING MACHINES EYES: HOW COGNITIVE COMPUTING CAN DETECT DEFECTS IN REAL TIME**<br>*Elinor Swery, IBM* | **EFFECTS OF LASER POWER ON GRAIN GROWTH DURING SELECTIVE LASER MELTING OF METALLIC ALLOYS: DIRECTION AND CELL SIZE**<br>*Zhan Chen, AUT* | **FUNCTIONALISED POLYMERS FOR MORE EFFICIENT NANOSECOND UV LASER MICROMACHINING**<br>*Hong Kang, The University of Auckland* |
| | **EXPLOITING DIGITAL TECHNOLOGIES TO INNOVATE IN MANUFACTURING**<br>*Mehdi Shahbazpour, Fletcher Building* | **HYBRID ADDITIVE MANUFACTURING: INTEGRATION OF MULTIPLE ADDITIVE MANUFACTURING TECHNIQUES TO ACHIEVE HIGH VALUE MULTIFUNCTIONAL OBJECTS**<br>*Jonathan Stringer, The University of Auckland* | **HIGH ACCURACY PERSONALISED MANUFACTURING TO ASSESS BALLISTIC DAMAGE TO THE HUMAN CRANIUM**<br>*Eryn Kwon, The University of Auckland* |
| | **INTERNET OF THINGS (IOT) ENABLED SMART MANUFACTURING FOR SMES**<br>*Ray Y. Zhong, The University of Auckland* | **AUT PROCESS AND MATERIAL ALTERNATIVES FOR ADDITIVE MANUFACTURING; THE ANOMALIES**<br>*Sarat Singamneni, AUT* | **PRESTRESS AND PRETORSION OF ELASTOMER COMPOSITES FOR SELF-MORPHING SOFT ROBOTIC STRUCTURES**<br>*Steven Dirven, Massey University* |
| | **MANUFACTURING IN A WORLD OF DISRUPTIVE TECHNOLOGIES**<br>*Kevin Marett, LEAP Australia* | **INVESTIGATION OF THE TEMPORAL SPACING EFFECT ON FUSED DEPOSITION MODELLED PART PROPERTIES**<br>*Arno Ferreira, Massey University* | **DEVELOPING A 3D PRINTER FOR THE MANUFACTURE OF CELLULOSE HYDROGELS**<br>*Tim Huber, University of Canterbury* |



| | | | |
|---|---|---|---|
| | **THE KEY ROLE OF TRADITIONAL INDUSTRIES FOR CREATING HIGH-TECH GROWTH**<br>*Kenneth Husted, The University of Auckland* | **CHARACTERISATION OF 3D PRINTED, RUBBER-LIKE MATERIAL FOR PRODUCT DESIGN AND FABRICATION**<br>*Frazer Noble, Massey University* | |
| | **INTEROPERABLE EXECUTION ON HETEROGENEOUS PLATFORMS IN MODERN INDUSTRIAL ENVIRONMENTS**<br>*Zoran Salcic, The University of Auckland* | **DEVELOPING THE 3D PRINTING ECOSYSTEM IN NEW ZEALAND**<br>*Jim Collins, Fuji Xerox New Zealand* | |
| 12.30pm Lunch Break (Kawau Room 1) / Poster and Exhibition Viewing | | | |
| 1.20pm | **Keynote Speaker: Ross Stevens - Victoria University of Wellington**<br>**3D AND 4D PRINTING PIONEERS**<br>**Session Chair:** Simon Fraser (Professor of Industrial Design, School of Design, Victoria University of Wellington)<br>**Room: Rangitoto 1** | | |
| 2pm | **PANEL DISCUSSIONS** | | |
| | **Industry 4.0: A Step-change for New Zealand Manufacturing**<br>**Room:** *Rangitoto 1*<br>***Lead: Dieter Adam (NZMEA)***<br>*Eberhard Klotz (Festo)*<br>*Nathan Stantiall (Callaghan Innovation)*<br>*Sayuj Nath (National Instruments)* | **NZ High Value-added Manufacturing and Design - Status Quo and into the Future**<br>**Room:** *Rangitoto 2*<br>***Lead: Catherine Beard (Business NZ)***<br>*Kim Campbell (EMA)*<br>*Kenneth Husted (The University of Auckland)*<br>*Steve Wilson (Talbot Technologies)* | **Design Innovations and Innovation for Design**<br>**Room:** *Rangitoto 3*<br>***Lead: Simon Fraser (VUW)***<br>*Crispin Hales (Hales & Gooch Ltd)*<br>*Ross Stevens (Victoria University of Wellington)*<br>*Jesse Keith (Callaghan Innnovation)* |
| 3pm Afternoon Tea (Kawau 1) / Poster and Exhibition Viewing / MaD CoRE Meeting | | | |
| 4pm | **Awards** *(sponsored by UniServices and presented by Dr Andy Shenk, CEO, UniServices),*<br>**followed by Conference Closing**<br>**Room:** Rangitoto 1 | | |
| Post Closing - Networking Cocktails (Marvel Grill, Wynyard Quarter) | | | |

## MaD BREAKOUT SESSIONS

The intention of the Breakout Sessions are to provide the opportunity to discuss challenges in manufacturing and design (MaD) and share expertise and experiences. Breakout Sessions may also provide a platform for future collaborations. In particular, the sessions will facilitate the identification of synergies and intersecting objectives for collaborations in a MaD context. The Breakout Sessions are related to a specific or combination of MaD conference themes.

There are four Breakout Sessions split across two one-hour sessions on the afternoon of Wednesday 10 May. Each Breakout Session will be of one hour duration and co-chaired by MaD industry representatives and/or MaD researchers, with delegates contributing to the informal discussion from the floor.

## Breakout Session Topics:

### COLLABORATIVE MaD (Rangitoto 1 | 2 – 3pm, Wednesday 10 May)

Co-chaired by:
Jesse Keith (Group Manager – National Technology Networks, Callaghan Innovation)
Steve Wilson (Executive Director, Talbot Technologies Ltd)

Our research institutions are a significant available resource for the New Zealand manufacturing and design industry. Tapping into these resources and getting the best results for both parties requires effective collaboration. This session will examine the challenges associated with working together and how best the industry and research communities can take on these challenges.

### FUTURE YOUNG RESEARCHERS (Rangitoto 2 | 2 – 3pm, Wednesday 10 May)

Co-chaired by:
Khalid Arif (Senior Lecturer in Mechatronics and Robotics, Massey University, Albany)
Shayne Gooch (Head of Mechanical Engineering Department, University of Canterbury)

The training of young researchers is at the crossroads between the apprenticeship model on one hand and an academic training at universities on the other. This session will look into the challenges and opportunities for young researchers from the perspective of their preparedness for careers in MaD and related areas be it at an academic institution or industry. The session welcomes young researchers and engineers who are keen to assume leadership roles in future MaD conferences in particular and MaD industry in New Zealand in general.

### IoT and INDUSTRY 4.0 (Rangitoto 1 | 4 – 5pm, Wednesday 10 May)

Co-chaired by:
Xun Xu (Associate Dean – Research, Faculty of Engineering, The University of Auckland)

Kevin Marrett (NZ PTC Manager, LEAP Australia)

Internet of Things (IoT), as one of the key technological pillars of Industry 4.0, is the intelligent connectivity of smart devices by which objects can sense one another and communicate. This "intelligent connectivity of smart devices" is currently being implemented by manufacturing companies in their factories and on the shop floor. This session will examine the challenges associated with IoT in the context of Industry 4.0 and will highlight opportunities for researchers and industry partners to come together to address some of the challenges facing New Zealand industry.

### DESIGN FOR ADDITIVE MANUFACTURING & THE FUTURE OF COMPOSITE MANUFACTURING (Rangitoto 2 | 4 – 5pm, Wednesday 10 May)

Co-chaired by:
Mike Fry (CEO, Titanium Industry Development Association Ltd)
Johan Potgieter (Associate Professor, School of Engineering and Advanced Technology, Massey University, Albany)

Additive and composite manufacturing has reached acceptance in industry for a number of applications, but designing parts for these processes and materials requires a substantial shift from designing for traditional manufacturing techniques. This session will discuss how our research organisations can assist industry with designing additive and composite manufactured optimised components. Topics of automation for composite manufacturing will be also discussed.



## MaD PANEL DISCUSSIONS

The intention of the Panel Discussions is to identify overarching approaches and trends on how New Zealand's manufacturing and design economy will retain and expand its global competitiveness. Each Panel Discussion will address a specific or a combination of MaD themes.

There will be three Panel Discussions split across a single one-hour session on the afternoon of Thursday 11 May. Each Panel Discussion will be of one hour duration and will be led by a MaD industry representative or a MaD researcher, with panellists selected by the Lead Panellists. Each panellist will introduce his/her insight into the topic for a few minutes followed by an open discussion. Delegates will be invited to contribute to the discussions from the floor.

The outcomes and findings of the Panel Discussions will be summarised during the conference closing ceremony.

## Panel Discussion Topics:

### INDUSTRY 4.0: A STEP-CHANGE FOR NEW ZEALAND MANUFACTURING (Rangitoto 1 | 2 – 3pm, Thursday 11 May)

Lead Panellist: Dieter Adam (CEO, New Zealand Manufacturers and Exporters Association)

Panellists:

Eberhard Klotz (MaD Keynote Speaker | Head of Industry 4.0 Campaign, Festo, Germany)
Nathan Stantiall (MaD Driver | Business Innovation Advisor, Callaghan Innovation)
Sayuj Nath (Academic Program Manager - ANZ and South East Asia, National Instruments)

### NZ HIGH VALUE-ADDED MANUFACTURING AND DESIGN - STATUS QUO AND INTO THE FUTURE (Rangitoto 2 | 2 – 3pm, Thursday 11 May)

Lead Panellist: Catherine Beard (Executive Director, ManufacturingNZ & ExportNZ)

Panellists:

Kim Campbell (Chief Executive, Employers and Manufacturers Association)

Kenneth Husted (MaD Driver | Professor – Innovation & Research, Faculty of Business and Economics, The University of Auckland)

Steve Wilson (Executive Director, Talbot Technologies Ltd)

### DESIGN INNOVATIONS AND INNOVATION FOR DESIGN (Rangitoto 3 | 2 – 3pm, Thursday 11 May)

Lead Panellist: Simon Fraser (MaD Driver | Professor of Industrial Design, School of Design, Victoria University of Wellington)

Panellists:

Crispin Hales (MaD Keynote Speaker | Author: Managing Engineering Design, 2004 | President and Principal Engineer, Hales & Gooch Ltd)

Ross Stevens (MaD Keynote Speaker | Programme Director – Industrial Design, School of Design, Victoria University of Wellington)

Jesse Keith (MaD Conference Committee Member | Group Manager – National Technology Networks, Callaghan Innovation)

## MaD CoRE MEETING
### (Rangitoto 3 |3 – 4pm, Thursday 11 May)

The MaD Network is planning to submit an application for a Centre of Research Excellence (CoRE) in manufacturing and design to the Tertiary Education Commission at the end of 2019. A CoRE is a collaborative organisation enabling scientists and researchers from Universities, Crown Research Institutes and other organisations to work together on research projects as well as train a new generation of researchers and innovators, for the achievement of internationally acclaimed research and an innovation-led New Zealand economy.

MaD2017 delegates interested in developments towards the MaD CoRE are welcome to attend this session to share observations and learnings gathered through the MaD conference, and to contribute to the next stage of MaD CoRE planning.

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

# Innovative Manufacturing and Materials Programme

**The Innovative Manufacturing and Materials (IMM) Programme is an interdisciplinary and industry-facing research programme based at the University of Auckland.** Led by Professor Simon Bickerton, our researchers are experts in manufacturing, materials, product and process development, as well as business and commercialisation.

We received a five-year University of Auckland Strategic Research Initiative Fund (2016 – 2020) with the aim of establishing a Manufacturing and Design Centre of Research Excellence (MaD CoRE).

**MaD CoRE aims to undertake high quality scientific research to transform New Zealand into an innovation-led economy and society.** Paramount to this process is the establishment of a national MaD Network, a newly formed community of New Zealand researchers in manufacturing and design who collaborate closely with industry, all working towards New Zealand's manufacturing economy of the future.

## EXPERT FOR A DAY

uniservices
IDEAS TO LIFE
THE UNIVERSITY OF AUCKLAND
NEW ZEALAND

The **Expert for a Day Programme (E4D)** is an IMM Programme initiative aimed at breaking down the traditional barriers between business and academia.

This involves your company being paired with a University engineer, scientist, or business expert for up to a day, giving them the opportunity to help you solve your business and/or product challenges. In return, the researcher will understand the commercial aspects of your organisation, as well as any issues you may have.

Benefits for industry include:

- Brainstorming and sharing of ideas
- Updates on the latest technology and processes
- Instant feedback
- Expert(s) visiting your site
- Advice on product development, processes, and business operations
- Access to key contacts at the University of Auckland

Email immprogramme@auckland.ac.nz for more information on our E4D Programme.

Visit immprogramme.auckland.ac.nz for more information on the programme, our initiatives, and regular events.

# Crispin Hales

## Why Follow, When You Can Lead?
### Adding Value to the New Zealand Genius

Crispin Hales
PhD, CEng, FIMechE. Hales & Gooch Ltd.Chicago, USA & Christchurch, NZ

New Zealand has a rich history of innovation and there is potential for improving its income from the development of innovative ideas in the future. However, the numerous obstacles faced by those trying to develop, introduce and market new products or systems from within the current New Zealand context can be so discouraging that the potential is lost.

From an overseas perspective, New Zealanders appear to have unique advantages which, if used to good effect, could overcome many of the apparent obstacles to product innovation. For example, the small, well-travelled and well-educated population, the compact supply network, the excellent communications system and an inherent teamwork approach to accomplishing tasks are all positive influences. A nationwide compilation of successful ventures would provide case examples for study and it should be possible to establish effective approaches and guidelines specific to the New Zealand context.

In this presentation some of the issues will be explored with reference to case examples and some suggestions for overcoming potential obstacles will be presented. The intent is to generate a positive discussion on how to encourage the further development of innovative ideas that abound in New Zealand and to ensure that the benefits are not simply lost to the outside world.

## Bio

Crispin Hales has over 40 years of experience in engineering design, principally in industry but also including research and teaching at undergraduate and postgraduate levels. For the past twenty years he has been consulting in failure analysis, engineering design, boiler explosions, safety of mechanical systems and accident reconstruction within the U.S and internationally. He joined Triodyne Inc. in 1989 and then in 2004 established Hales & Gooch Ltd. with Dr. Shayne Gooch in New Zealand, to focus more specifically on design issues. Recently he has been involved with a number of large investigations concerning the engineering design process and has helped to introduce improved approaches to engineering design within several manufacturing companies. In association with Cambridge University in the United Kingdom and Canterbury University in New Zealand, he has contributed towards more effective design teaching and professional training for young engineers.



## Notes

# Cather Simpson

## High Tech Innovation in an Industrial Context

Simpson, M. Cather
Photon Factory, School of Chemical Sciences, & Department of Physics, The University of Auckland. The Dodd Walls Centre for Photonic and Quantum Technologies, The MacDiarmid Institute for Advanced Materials and Nanotechnology, New Zealand

If the 20th century was the age of electronics, then the 21st is certainly going to be the age of photonics. Photonics is the creation, manipulation and detection of light. The Photon Factory at the University of Auckland is translating the fundamental power of photonics to industry advancement. Our core mission is to enable the R&D of all New Zealand scientists – academic, industrial, and national research lab-based – through the advanced use of ultrashort laser pulses to interrogate light-matter interactions and to manipulate and machine materials. Recent highlights include major initiatives to improve laser micromachining capability for industry and two high-tech spin-off companies. National and international award-winning Engender Technologies, Ltd. commercializes our ideas for microfluidic and photonic technology to improve sorting of sperm by sex for the dairy industry. The technology is now in the last lab demonstration stage before commercialization. Engender, with partnerships with three of the world's top artificial insemination companies, will give farmers an effective way to improve the genetic gain in their herds, add value to bobby-calves and reduce the impact of dairy upon the environment – all through the novel application of lasers. I will describe how the advances made in laser micromachining are contributing to the growth of the high-tech economy and to the success of NZ Inc.

## Bio

Cather Simpson joined the University of Auckland's Physics and Chemistry departments in 2007. She is founding director of the Photon Factory, a multi-user laser and microfabrication facility that provides advanced laser technology to all NZ researchers. She received her Ph.D. in the US, and after a DOE Distinguished Postdoctoral Fellowship, earned tenure at Case Western Reserve University. She is a Principal Investigator in the MacDiarmid Institute and the Dodd-Walls Centre, where she also serves on the Executive Committee. Recent awards include a NZ National Teaching Excellence Award and the 2016 Silicon Valley Forum first-place medal for Agtech. She was named the Baldwins Researcher Entrepreneur and the BNZ Supreme Award winner at the 2016 KiwiNet commercialisation awards. She is also a New Zealand Primary Industries Champion. She is the founding Chief Science Officer of Engender Technologies and co-founding scientist of Orbis Diagnostics, both spin-offs from the Photon Factory.NoteNotes



## Notes

# Eberhard Klotz

## Industrie 4.0 in Action

Eberhard Klotz
Head of Industrie 4.0 Campaign, Festo, Germany

The Internet of Things (IoT), smart factories, cyber-physical systems and big data define the Factories of the Future – with solutions in production industries that are ever faster, diverse, flexible and intelligent. Calls for greater availability, energy efficiency and just-in-time production are louder and clearer.

Festo plays a major role in shaping the Industrie 4.0 trend, and emphasises politics, products and technologies, training, didactic, learning systems and human-machine interaction. Festo is a member of the "Industrie 4.0" initiative of the German Federal Government, and is involved in all key standards associations and initiatives on this topic. Festo implemented first Industrie 4.0 mechanisms in their own new Technology Plant in Scharnhausen next to Stuttgart/Germany which will be shared: actions on maximised production flexibility by using C.P.S. (Cyber Physical Systems), retro fit projects for energy transparency, higher OEE and efficiency, mobile maintenance concepts, or AutoID functions for the digital twins – and a Learning Factory. This session provides a technology insight into Industrie4.0 today, latest product and C.P.S. developments, and concludes with visionary examples from the Festo bionic Learning Network.

## Bio

Eberhard studied Communication Engineering first and did later an European Executive MBA at Henley Management College and University of West London. He has working experience with Mannesmann-Kienzle, Siemens, Bosch and started at Festo in 1990. He has been always in touch with latest fieldbus and communication technology. For 9 years he carried out R&D related tasks like project management in technical documentation and for further 7 years he was Product Manager for valve terminals, fieldbus systems and remote I/O products. More than 10 years ago he was appointed to the position as Head of Marketing Products and Technologies, and is now responsible for Festo's Industry 4.0 campaign.



## Notes

# Ross Stevens

## 3D & 4D PRINTING PIONEERS

### Additive manufacturing  applications in the film industry

Stevens, Ross
Victoria University of Wellington

Guy, Bernard
Victoria University of Wellington

Additive manufacturing - commonly known as 3D printing - has been in existence since the early 1980s. By 2013 at the height of its popularity it was widely publicised as the new way of making everything for both hobbyists and industry. However by 2017 the media focus had shifted to stories about its lack of adoption and limited commercial uses. While this perception might be true in the low cost consumer field, the industrial capabilities of additive manufacturing systems have grown exponentially.

These advancement are most evident in high end commercial printers that use controlled droplets of photopolymer to produce 3D objects. The latest multi-property versions of these machines are capable of depositing droplets of up to 6 material variation of colour, hardness and translucency during a single print process. Potentially this means that over a million variations can be programmed into a square inch of what its manufacturer (Stratasys) calls 'digital material'.

To explore the creative and commercial applications of these 'digital materials' Victoria University of Wellington's (VUW) Industrial Design staff have been collaborating with Weta Workshop and Stratasys Ltd to undertake research into 3D and dynamic 4D printing. The research aim was to explore the manufacture of film prosthetics and creatures that are 100% digitally constructed and require no post finishing or colouring after printing. This goal also extended into designing 4D qualities and internal mechanism directly into the prints that allowed them to move with activation from hydraulic of pneumatic systems. Experiments were undertaken with a 2 material in-house printing at VUW (Connex 2), 3 material printing at Objective 3D in Australia (connex 3), 6 material printing at Stratasys in Hong Kong (j 750) and experimental trials at Stratasys research centre in Israel.

As part of this research VUW was invited into the Stratasys 'voxel print research program' that offers beta test software to directly control each micro droplet (voxel) of resin. This area offers the greatest challenge and potential for collaboration because currently no computer software exists that is capable of defining so much data. Further research is also ongoing into soft materials that will allow for more complex and resilient structures to be produced.

This approach to research that combines world leading technical knowledge (supplied by Stratasys) with a direct commercial application (with Weta Workshop) offers a case study of how pure and applied research are both critical to a rapidly evolving field like additive manufacturing.

The role of Industrial Design in this instance was to envisage a potential collaboration between two different companies and make the opportunities explicit through physical and digital prototypes.

Whilst this research is still ongoing, results to date have been collated into short films. Due to the highly technical nature of multi-property printing a dedicated research program has been set up at VUW - called MADE (Multi-property Additive manufactured Design Experiments) -and work can be viewed on its website http://made.ac.nz/

## Bio

Ross has been a practicing Industrial designer for over 30 years with projects ranging from military urinals to designer televisions. During his diverse career he has worked with some remarkably creative people including Philippe Starck in Paris and is currently the Industrial design program director at Victoria University of Wellington (VUW) and co-owner/founder of Pureaudio. He has been focusing (some would say obsessed) with additive manufacturing for the past 15 years and specialises in multi-property 4D printing. Examples of his teams research can be seen at http://made.ac.nz/

## Notes

# Staircasing Industry Engagement: A bottom-up practice based model for integrating design research into industry

Fraser, Simon
VIctoria University of Wellington

Sponsored projects are a common model for industry collaboration in design schools worldwide. However the collaboration seldom proceeds beyond the immediate outcomes of the initial project. In responding to this challenge the School of Design at Victoria University of Wellington is implementing a 'staircasing' model for industry collaboration starting at undergraduate level before transitioning into industry focussed postgraduate research projects and internal capability building.

The model offers a number of benefits: for industry partners - new insights and scalable access to research networks; for students - financial support and focussed career pathways; for the University - an expanding research agenda that informs programme development.

Starting in 2015 the collaboration with the New Zealand Artificial Limb Service provides a practical case study for implementing the staircasing model. The case study tracks the initial summer research project which explored the new possibilities that 3D printing and associated digital technologies might offer in the design and manufacture of highly individualised prostheses, through to the overarching research objective of 'digitizing' their service offering and with it the transformation of a whole industry sector. https://www.beehive.govt.nz/release/3d-printing-helping-amputees

The case study explains the framework and mechanisms of engagement - including internal capability building, co-funding strategies, creative outputs, synergies between bigger picture government-funded research initiatives and reflects on potential longer term outcomes for the NZALS and New Zealand companies.

The staircasing model represents a practical response to the Danish Design Centre's Design Ladder[1] which identifies the different levels in which companies engage with design; transitioning through four steps, from non-design through to design as styling, design as process and ultimately design as innovation.

[1]The Economic Effects of Design. National Agency for Enterprise and Housing/Danish Design Centre, 2003

## The WhisperGen Story. A New Zealand Design and Manufacturing Success?

Clucas, Don
University of Canterbury
don.clucas@canterbury.ac.nz

In 1989 the presenter embarked on a PhD project that ultimately led to the development and production of the WhisperGen™ micro combined heat and power system. Whisper Tech Ltd. was incorporated in 1995 and with significant investment of money and human resources took the product from concept to full scale manufacture. The company began with developing a DC system for quietly charging batteries on yachts and other remote applications, many of these systems are still in use. In 1997 a project was started to develop an AC system that would be used in European homes. By replacing the gas fire boiler the WhisperGen™ fulfilled the heating requirements and as a by-product produced approximately 1 kW of electricity to be sold to the local power company or used inside the home. A manufacturing plant was set up in New Zealand to manufacture the DC WhisperGen™ and ultimately a full mass manufacturing plant was established in Spain by a joint venture partner. Whilst the product was successfully developed and met the customers' needs the global financial crisis killed the market. A brief summary of the WhisperGen™ product development will be presented.





## Designing Our Future

Battley, Mark
Centre for Advanced Composite Materials,
The University of Auckland
m.battley@auckland.ac.nz

Quality design is crucial to a successful product – consumers need to want to buy it, the product needs to actually perform as required, and it also needs to be cost competitive in the market. This requires a wide range of skill sets and tools, from understanding the users' needs, defining a suitable solution to meet those needs, through to the detailed engineering to ensure that performance requirements can be met at an acceptable cost.

In the digital world the workflow associated with this process is becoming increasingly integrated. We can start from scanned or conceptual geometry, move through various types of geometric modelling tools, undertake complex engineering calculations to optimise functionality and performance, and then output data directly to digital manufacturing processes such as numerically controlled machining or additive manufacturing.

While this process might sound good, in practice it's not always so easy. Even the education process is somewhat disjointed, with "Industrial Design" often being taught separately to 'Engineering Design', and there are many different types of software used at different stages, some of which don't integrate very well. When it works well though, it can be a very powerful collaborative process.

Mark will present case study examples of "designed" products from sectors including transportation, sports and equipment for direct use by humans. These will highlight how various digital tools can be used to benefit the development process and the product performance, and also identify gaps where further research and collaboration is needed. The examples will also highlight the importance that experimental characterisation plays in the product design process, both for determining key user requirements and input parameters, and also to validate the actual product performance and reliability.

# How to create a successful product

McDermott, Oliver
Blender Design Ltd
ollie@blender.net.nz

Background
Times are changing, more quickly than ever before, and the way products are developed is no exception. Product design and development is constantly changing and evolving. One can no longer simply make a product and later present it to the sales team to sell. In this day and age, markets are highly competitive, and consumers highly connected. The expectations from customers now are higher than ever - if a product is not developed, designed or manufactured right it will fail. Due to these new demands and expectations, it is becoming increasingly more difficult to create a successful profit generating product.

Currently, in New Zealand, we constantly see a breakdown in communication and vision between the different disciplines within the product development process. Marketing, Designers, Engineers, Production and so on. In order to make great products, everyone involved needs to work seamlessly together and have a better understanding of ALL the steps involved. There also needs to be more focus on design thinking throughout.

Approach, findings or results
With ten years of experience turning ideas into successful products, Blender Design Ltd has formulated a winning New Product Development process. A four step process where there is an importance placed on true problem solving, user experience and design led engineering.

Blender's proven NPD process delivers products with the right product market fit & true competitive advantage. Following the right process can also reduce risk, speed up time to market, and therefore increase the chance of success.

A tighter loop on all disciplines within a product development process means making less mistakes which saves a lot of pain and costs later on.

Conclusion
It's not just about the idea, the design, the engineering or manufacturing - it is about solving the real problem and coupling the different disciples together with user centred design. Through following a process and aligning the motivations of everyone involved in the product development and manufacturing process, a higher percentage of successful products will be created. This will allow New Zealand companies to really show the world how great products are made. In order to do this though, it does start at the top and our organizations must be structured to appreciate and support design throughout.

The winning formula for a successful product is that everyone involved in the process must know why they are doing what they are doing. Everyone involved must think about solving the real problem for the user and place an importance on user experience.





# MaD pipelines: emerging methodological pipelines for design and manufacturing processes

McMeel, Dermott
The University of Auckland
d.mcmeel@auckland.ac.nz
Shao, Xi
The University of Auckland
iffalseelsetrue@gmail.com

This article reports on our work in progress developing automated manufacturing and design 'pipelines.' The pipeline concept is already used within the sound design and visual effects industries. It has proven, in that context, highly successful at retaining creative freedoms throughout processes that are inherently specialised and complex. We draw parallels between this industry and manufacturing, arguing there are significant gains to be made through the strategic implementation of similar pipelines within design and manufacturing. We report here on a proof-of-concept implementation, creating a manufacturing and design (MaD) pipeline to make a small self-supporting panelised shell structure. The pipeline is created by combining Rhinoceros 3D modelling software with Grasshopper data flow modelling software. When the shell structure is redesigned the MaD pipeline enables two otherwise complex and specialised processes to occur automatically. It extracts the precise data required for fabrication of the shells 30 unique panels by 3D printing. It also automatically creates a full instruction set for uploaded to an ABB industrial robot, enabling the precise positioning of each unique panel to assemble the shell. This research is investigating question such as: How do these pipelines affect knowledge, skill and traditional value frameworks as they migrate to new industries? How does it impact traditional manufacturing and design organisational and cultural practices? Preliminary findings suggest implementing a pipeline concept requires significant computational skills, which may be unusual for particular industries and could cause an organisational clash of cultures. Also significant manufacturing happen regionally whereas most computer professionals operate in cities and population centres – the migration required to bring both together may be problematic and requires further research. Implementing the MaD pipeline needed detailed initial and interim discussions between designers, the pipeline programmers and manufacturing specialist. This was critical to ensure the creative freedom and specialist knowledge needed for success were not restricted. One of the most powerful features of the pipeline concept is enabling both the construction and deconstruction data for export and import into and out of the pipeline. Thus next phase of the research will work with structural and composite material experts to investigate automating and streamlining the structural and material simulation and optimisation of the design. Pipelines are beginning to demonstrate success at leveraging creative capital and delivering personalised production in other industries. Ultimately we are trying to understand how the pipeline concept might be implemented by MaD industries, what are the benefits, and what are the organisational consequences.

# On the design of assistive devices for people with tetraplegia in a New Zealand context.

Gooch, Shayne
University of Canterbury
shayne.gooch@canterbury.ac.nz

Dunn, Jennifer
University of Otago
jennifer.dunn@otago.ac.nz

Tetraplegia results in the partial or complete loss of function of all four limbs of a person who has suffered a major injury or illness involving their spinal cord. Each year a significant number of people are affected by tetraplegia worldwide. For example, the annual incidence of Spinal Cord Injuries (SCI's) in the U.S. is approximately 54 per million population [1] equating to 17000 new cases per year. The most common incidences of SCI from traumatic causes occur in the cervical spine and more specifically at the neurological level corresponding to the fourth cervical vertebrae (C4) [2]. The incidence of C4 injuries accounts for approximately 18% of all injuries followed by 14% at C5 and 6% at C6. People who have suffered a complete break of their spinal cord have complete paralysis below the injury level. For example, a person with a complete SCI at C4 level has complete paralysis of all four limbs and a person with a SCI at C5 generally has active biceps but little or no other arm function.

When considering SCI's from traumatic causes by age group, the highest incidence recorded is in the 15-24 year age group [2]. This is twice the incidence level for the 25-34 year age group. Young people with SCI's have reduced capacity to perform normal activities for daily living and they generally have a strong desire to become active and live as independently as possible.

This study has established a new means for the characterisation of the strength capabilities of people with tetraplegia. The research was initiated to determine the effectiveness of new surgical procedures conducted at the Burwood Spinal Unit in Christchurch New Zealand. In this research, human force was measured in the sagittal plane and force maps were created that quantitatively demonstrate the strength of a human subject in the seated position. The research shows that people with SCI's similar strength profiles to other individuals with injuries at a similar neurological level. The study shows that some assistive devices, such as standard manual wheelchairs, are not particularly suitable for people with tetraplegia because they require human force to be exerted at anatomical positions where the user has very low strength. This highlights an opportunity for the development of new solutions for assistive devices for people with tetraplegia.

Engineering design tasks have been set for design students at the University of Canterbury to help people with tetraplegia cope with activities for daily living. These projects have, in some cases, led to the successful commercial development of new assistive devices. New Zealand manufacturers are well placed to design and manufacture new assistive devices for people with tetraplegia. Assistive devices are high value and manufacture is at a production scale that matches our existing industry.

[1] (2016) Facts and Figures at a Glance, National Spinal Cord Injury Statistical Center, Birmingham, AL: University of Alabama at Birmingham, USA.
[2] Norton, Lynda (2010), Spinal cord injury, Australia 2007–08, Injury Research and Statistics Series, Number 52, Canberra, AIHW (INJCAT





# Addressing a worldwide geothermal energy utilization problem by producing a novel product with industrial and consumer applications

Johnston, James; Borrmann, Thomas
School of Chemical and Physical Sciences, Victoria University of Wellington, New Zealand
jim.johnston@vuw.ac.nz

Geothermal energy is a significant renewable energy resource worldwide. Since the early 1950's New Zealand, through innovative science and technology, has led the world in the development and utilisation of geothermal resources for electricity generation. A major world-wide problem here is the unwanted precipitation of silica from the cooled geothermal water after the heat energy is extracted from the steam and hot water phases to generate electricity.

In geothermal electricity generation, sub-surface superheated geothermal water at about 250-350 oC, saturated in dissolved silica, is piped to the surface where some 30 % of the water is flashed into steam which drives a turbine to generate electricity. The remaining 70 % of water, now at about 120 oC, containing the dissolved silica, flows through the heat exchangers of a binary cycle turbine to extract further heat energy and generate additional electricity. It is then reinjected to recharge the reservoir. Unfortunately, this water is supersaturated in silica which precipitates out and blocks pipework, heat exchangers and reinjection wells. This major problem limits energy recovery and generates high maintenance and operating costs. It has not been addressed satisfactorily by the industry.

Through innovative science and technology, we are turning this problem into an opportunity by precipitating a nano-structured calcium silicate material which does not adhere to pipework, heat exchangers or block reinjection wells. More heat energy can also be recovered from the resource.

The nano-structured calcium silicate particles do not stick together or onto metal surfaces as precipitated silica particles do, but remain suspended in the geothermal water and are subsequently separated as a useful product. The material has excellent whiteness, chemical reactivity and physical absorbent properties. It is an environmentally attractive material produced from a natural silica source with a low manufacturing energy footprint. Applications we are developing include its use: as a functional filler in tyres, plastics, paper, concrete and thermal insulation; in the recovery of dissolved phosphate from waterways and lakes, and base metals from mine waters; as a general absorbent; and a soil conditioning agent.

We have successfully developed the science and technology on a laboratory and small field scale, and have provided nano-structured calcium silicate materials to various NZ and international materials companies for evaluation.

We are currently scaling the technology up to pilot scale operation and implementing it in particular NZ geothermal fields. This will prove the technology on a meaningful scale, demonstrate it to the geothermal industry worldwide and provide larger quantities of the nano-structured calcium silicate material for end-user testing.

We have recently been awarded a substantial MBIE Endeavour Fund Research grant and are working closely with the Heavy Engineering Research Association, MB Century and various geothermal energy companies to make it happen.

Our approach has the potential to provide a paradigm shift in the New Zealand and international geothermal industry as well as providing a material with unique properties for a wide range of applications.

# Aerodynamic and Structural design of Small Scale Turbine for Organic Rankine Cycle System

Lei Chen
Heavy Engineering Research Association, NZ
lei.chen@hera.org.nz

The Organic Rankine Cycle (ORC) has been considered to be the most feasible technology among the existing approaches to convert low temperature heat source (such as geothermal energy and industrial waste heat) into electricity. Turbine is one of the significant components in ORC system to convert heat energy into mechanical energy and drive the generator to produce electricity. For a small scale ORC system with a general power range of 50kW to 500kW, radial inflow turbines with the features of low mass flow rate and high pressure ratio, are applied more frequently than other types of turbines, because they are more efficient, adaptable, stable and cost-effective for this power range. When developing such a turbine, the aerodynamic design and the stress analysis are the steps of vital importance to achieve a high efficiency and highly durable turbine.

This paper showcases the aerodynamic design and stress analysis of a small scale radial inflow turbine with the power output of about 100kW, the first attempt of its kind in NZ to develop turbines for the application in ORC. Having an advantage in the ORC field means NZ gaining a significant leadership position in low enthalpy and turbomachinery technology, producing more power from clean energy. This paper starts from the aerodynamic design which is to achieve the geometry of turbine with a high efficiency. In the design, Computational Fluid Dynamics (CFD) was used to conduct one dimensional preliminary design, and three dimensional modelling of stator and rotor blades and volute. An effective one dimensional preliminary design greatly benefits the development of turbines and it provides a good base for three dimension modelling where the turbine performance was optimised. After obtaining the turbine geometry, stress analysis of turbine blades was performed by using Finite Element Method (FEM) to evaluate its structural strength and prevent blade failure during turbine operation. In this step, the material selection of each component (volute, stator and rotor impeller) of turbine was completed and the stress distribution and deformation of turbine blades were analysed to confirm the safety of turbine under the condition of high stress from aerodynamic load. The simulation results of aerodynamics and stress analyses show that turbine has the power output of 103kW with the efficiency of 88% and its safety factor is 4.7 satisfying the requirement of industrial application. This turbine has progressed to the manufacturing phase and we are working in collaboration with our industrial partner to get this turbine built and tested out this year.



ORAL ABSTRACT - PARALLEL SESSION 1a *RANGITOTO 1*

# Dibbler case study – a design methodology for developing specialist, automated, agricultural machinery in New Zealand

Duke, Mike and McGuinness, Benjamin
University of Waikato
dukemd@waikato.ac.nz

Much of New Zealand's agricultural sector uses antiquated machinery that needs replacing with modern, automated machines. This paper presents a case study of how a mechatronic, hole drilling machine (dibbler) for a forestry nursery was developed, to replace an old, inefficient machine. Based on discussions with the client, the key requirements for the dibbler were identified as reliability, flexibility and repairability. To achieve these requirements, a robust, industrial programmable controller was used to provide flexibility, giving the client the ability to reprogram for different hole spacing. All bought in parts were supplied by leading brands to ensure quality and availability for repair. Computer Aided Design, coupled with CNC machining and laser cutting, ensured any replacement parts could be rapidly manufactured and installed by local companies. By following this simple methodology, the requirements of the client were met and an effective machine produced. The dibbler is in its 4th season of operation and drilled over 15 million holes. It is suggested that the proposed methodology is effective for producing one-off or small batches of specialist agricultural machinery.

# The inverse route: from industry focus to the academic world. What are the best projects to work in?

Garcia-G, Lorenzo M
White, David
Whittington, Chris
BioDesign Lab, School of Engineering, Computer and Mathematical Sciences, Auckland University of Technology
lorenzo.garcia@aut.ac.nz

The interests of the academic world are not the same as those of the industry. To obtain economically profitable products is not within the main obligations of the universities. The research in the university is marked by a service to teaching and by a growing pressure to obtain scientific publications. However, there are mechanisms where both interests, academic and business, could converge. What are the best projects to get involved in? What characteristics should they have? How to transfer easily research to industry?

In this intervention, the author will expose his experience after having spent more than ten years combining his work purely towards the industry, combining the role of technology transfer manager with his role as a design engineer. He will present his vision and he will particularise for the case of his research area: biomedical design.

Three study cases are going to be presented. The first one in the area of medical imaging and related with a patent he had to manage for more than 10 years, from the idea to the marketplace. The second one related to an audiovisual system for impaired people and finally, the third one based on a new air-pressure device for obstructive sleep apnea.

All cases came from not-applied (yet) research and turn later on into applied research. However, the same pattern is found: to transfer technology from university to industry is extremely complicated if there are not companies involved in the early stages of development.

Running away from the topical debate within researchers, looking an industrial project to collaborate with, the inverse route is going to be expounded in this session. Answers are straight forward translated to industry: the more attractive projects from a company's perspective in terms of academic collaboration.

As an evidence of facts, best projects to participate have to have the same characteristics: Clearly deduced added value, early stages engagements and scientific profitability.

In BioDesign Lab we are trying to break those barriers thanks to the experience of each integrant. Built it within the school of engineering apart to perform blue-sky research in biomedical design there is a strong commitment to developing projects in collaboration with industry pulled from clinicians and end-users needs.

Although it is articulated in different sections, breathing therapy devices development, musculoskeletal pain relief solutions and advances in the design of surgical tools are among some of our current research areas.





# Human-Centered-Design: An Insight into South-East Asian Rural Markets

Drain, Andrew
School of Engineering & Advanced Technology, Massey University
a.drain@massey.ac.nz
Jones, Ian
Agile Development Group, Cambodia
ian@agiledg.com

Underserved end-users at the bottom-of-the-pyramid represent a huge market opportunity for New Zealand designers and manufacturers. Over 4 billion people live on less than $1,500 USD per annum (Prahalad & Hart, 2002) with a large number of these individuals engaged in subsistence farming practices on small plots of land. In Cambodia, Gross Domestic Product (GDP) per capita has almost doubled over the last 15 years with annual GDP growth predicted to remain at around 7% growth per year (WBG, 2016); all of this in a country where 79% of its population lives in rural farming areas. While servicing the bottom-of-the-pyramid agricultural sector is deemed a flagship priority of New Zealand Aid (MFAT, 2015) and a focus of a number of the United Nations Sustainable Development Goals (UNDESA, 2015), it is a market-based approach that will truly begin to serve this group effectively. New Zealand is a world leader in rural technologies and has both the manufacturing power and logistical ability to service this large target market.

The use of traditional approaches to product development in developing markets have proven ineffective at meeting user needs and gaining market acceptance (Burgess & Steenkamp, 2006; Chandra & Neelankavil, 2008; Nakata & Weidner, 2012). Many products have failed to gain a long-term position in the market, for example, Tata's Nano 'worlds cheapest car' (Chakravarthy & Coughlan, 2012) or the playground water pumping system the 'Play pump' (Brocklehurst & Harvey, 2007). Others have been more successful such as the Nokia Life Tools system (Chandra & Neelankavil, 2008), Unilever's single serve shampoo (Payaud, 2014) and Arvind's 'make your own jeans' product (Schafer et al., 2011). One of the main differences between these failed and successful ventures is the use of a human-centered design-mindset throughout the design and development process. The mindset of truly understanding the contextual and societal complexities of a foreign target market have been shown to be critical in a products success (Schafer et al., 2011; Klein et al., 2012). It is the leveraging of existing strengths, such as informal communication networks and traditional hands-on skills, as well as delivering the core functionality required and servicing the aspirational values of the user that will increase the likelihood of product success. But how do practitioners actually go about understanding a foreign target market? What are the enablers and barriers to product acceptance? What tools should be used to facilitate this process?

This study utilizes an ethnographic approach with two main data collection techniques. Firstly, semi-structured interviews have been undertaken with a number of development experts in Cambodia to understand qualitatively the key enablers for project success. Projects included the design of a bio-digestion unit, sanitation equipment and improvements for grain processing. Secondly, three field trips to rural Cambodia were undertaken to follow a human-centered-design process in the design of appropriate technologies for rural communities on the Mekong River. While the design process was small scale, a number of insights were gained into effective human-centered practice. Findings include the need for end-user aspirations to be clearly defined, product durability and maintenance in rural areas to be a priority and for collaboration between international and local organizations to be utilized throughout the design and implementation process.

References
Brocklehurst, C., & Harvey, P. (2007). An Evaluation of the PlayPump® Water System as an Appropriate Technology for Water, Sanitation and Hygiene Programmes. Retrieved from
Burgess, S., & Steenkamp, J. (2006). Marketing Renaissance: How research in emerging markets advances marketing science and practice. International Journal of Research in Marketing, 23, 337-356.
Chakravarthy, B., & Coughlan, S. (2012). Emerging market strategy: innovating both products and delivery systems. Strategy and Leadership, 40(1), 27-32.
Chandra, M., & Neelankavil, J. (2008). Product development and innovation for developing countries: Potential and challenges. Journal of Management Development, 27(10), 1017-1025.
Klein, W. v. d., Chevrollier, N., & Collée, L. (2012). Inclusive Innovation. Retrieved from
MFAT. (2015). New Zealand Aid Programme Strategic Plan 2015-19. New Zealand: New Zealand Government.
Nakata, C., & Weidner, K. (2012). Enhancing New Product Adoption at the Base of the Pyramid: A Contextualized Model. Journal for Product Innovation Management, 29(1), 21-32.
Payaud, M.A. (2014). Marketing Strategies at the Bottom of the Pyrimad: Examples From Nestle, Danone and Proctor & Gamble. Global Business nad Organizational Excellence, January/February, 51-63.
Prahalad, C.K., & Hart, S.L. (2002). The Fortune at the Bottom of the Pyramid. Strategy+Business Magazine, 26, 2-14.
Schafer, C., Parks, R., & Rai, R. (2011). Design for Emerging Bottom of the Pyramid Markets: A product service system (PSS) based approach. Paper presented at the International Design Engineering Techincal Conference, Washington D.C., USA.
UNDESA. (2015). Sustainable Development Goals. Sustainable Development Goals. Retrieved from https://sustainabledevelopment.un.org/sdgs
WBG. (2016). Cambodia. Retrieved from http://data.worldbank.org/country/cambodia

## The development of a new design tool for organic Rankine cycles

Wei Yu

Department of Chemical and Materials Engineering, The University of Auckland | w.yu@auckland.ac.nz

Shoulong Dong

Department of Chemical and Materials Engineering, The University of Auckland | sdon683@aucklanduni.ac.nz

Boaz Habib

Heavy Engineering Research Association of New Zealand
boaz.habib@hera.org.nz

Brent R. Young

Department of Chemical and Materials Engineering, The University of Auckland | b.young@auckland.ac.nz

BioDesign Lab, School of Engineering, Computer and Mathematical Sciences,
Auckland University of Technology
lorenzo.garcia@aut.ac.nz

Over the past several decades, the organic Rankine cycle (ORC) has attracted increasing interest and has been considered to be a promising technology for converting low-grade heat sources into electricity. In the present work, a new design tool, called the Expert Design Tool (EDT), is proposed for ORC power systems design. The purpose of developing the EDT is to provide a feasible, reliable and accessible tool for industry and academia. It is also a critical deliverable of the Above Ground Geothermal and Allied Technologies (AGGAT) programme which is an industry led research and development initiative being championed by the Heavy Engineering Research Association (HERA). The EDT is an interactive tool which incorporates the expertise and judgment of experts with domain-dependent knowledge, for example the information associated with the equipment selection and performance assessment. It involves several domains including turbine design, heat transfer, control scheme, materials/fluids selection and process configuration. Moreover, it integrates relevant technical information into one platform, such as component models, pre-defined process algorithms, evaluated data and experimental results.

The EDT is intended to have two levels, namely an online version for general users and an offline version for professional users. Currently, a preliminary online EDT has been completed and deployed online successfully. This version demonstrates the basic capacity of the EDT to produce relevant technical information as well as practical recommendations. It is a potentially suitable tool for early stage feasibility assessment which does not require large investment in engineering hours and software and can be employed to assist general users in carrying out preliminary design exercises and performance evaluation for ORC power systems. The development of the online EDT is associated with different software/databases. Consequently, software integration into the online environment is explored as a central task in order to ensure the feasibility, compatibility and functionality of this tool. With respect to the offline EDT, it will be developed by means of some mature commercial libraries and will feature a more powerful functionality compared with the online version. This version will integrate decision-making and multi-objective optimization algorithms and can provide a comprehensive and systematic analysis for a certain ORC system, including thermodynamic analysis, economic feasibility assessment, and environmental impacts assessment. Furthermore, preliminary component design also can be performed based on users' specifications. The commissioning of the EDT will facilitate the development of low-grade thermal energy applications based on ORC technology.





## Modular lightweight furniture with integral fasteners using post-tensioning

Wilhelm, Hans-Christian
Victoria University of Wellington, Faculty of Architecture and Design
hans-christian.wilhelm@vuw.ac.nz

While modular organisation of spaces and structures stems from a broad precedence in ar-chitecture history, industrialisation and functionalism in western architecture made modularity flourish as an overarching design concept in many architects' minds in the 20th century. However, pre-fabricated buildings developed towards mid-century remained commercially unsuccessful due to lack of flexibility in design and a financial break-even threshold driven up by high upfront investment for industrial production. What still today draws interest to these investigations is a unique detail design, resulting from integrating modularity, pre-fab/knock-down, material and manufacturing criteria. Concepts for pre-fab structures, e.g. by K. Wachsmann and F. Haller, have directly inspired some modular furniture systems – which eventually were more successful than their large scale siblings. Transfer of scale, alongside with the aforementioned integrative approach to modular design, also forms a base for this research.

More recently, digital design and CNC fabrication have resulted in changing paradigms. This has allowed for small scale constructions showing complex geometries driven e.g. by bio-mimicry or structural form-finding principles (Schwartz, 2016) Against this background, the research tries to bridge the gap between large-scale production and sculptural one-off pieces, integrate structural principles from building constructions (such as separation of forces to dif-ferent members) and criteria driven by CNC manufacturing techniques. The research result-ed in two modular knock-down lightweight furniture designs with integral fasteners.

A preference to thin sheet materials such as plywood or sheet metal was given which saved material, weight and machining time (router, laser-cutter). By way of an iterative design and prototyping process in collaboration with small enterprises two distinct geometrical and con-structional systems have been developed whose technical innovations have been acknowl-edged by registered patents (No.s DE102012103596.2 and DE202015008665.9). The first design is a shelving system from stainless steel sheets, fabricated by CNC laser-cutting. A deployed 3d-shape was used to create cutting patterns. The cuts are then formed to a structural panel with integrated fixings. The design process moved from an early friction-fit only to a combination of friction and form-fit controlled by radial post-tensioning. The second design features a system of interlocking horizontal and vertical panels to create shelves, coffee-tables, storage units. While the first design, in addition to generic metal forming tools, requires a single non-standard press-mould, the second can be manufactured solely with laser-cutting sheet materials. Layout and shape of members were reduced in analogy to orthogonal struc-tural building frames on a modular grid. Again, mechanisms for jointing and fixing use a com-bination of friction and form-fit fastening principles by way of post-tensioning. Both systems may be rearranged in horizontal and vertical directions to suit changing user demands and show distinct design features which result from integrating design criteria identified at the out-set, including structure and jointing.

The results of the research indicate that transfers between building and furniture scale offer technical and design innovation potential under a changing design-manufacture paradigm. Moreover, digital design and manufacturing techniques open up a new take on modularity, in that parametric design controls allow for both: flexibility and modular organisation. Regarding manufacture, small batch production is achievable by using primarily standard CNC ma-chines. As further step, more complex parameters like material properties or user require-ments may be integrated.

REFERENCES:
BERGDOLL, B., CHRISTENSEN, P., BROADHURST, R., & MUSEUM OF MODERN ART. (2008). HOME DELIVERY : FABRI-CATING THE MODERN DWELLING / BARRY BERGDOLL AND PETER CHRISTENSEN ; [EDITED BY RON BROADHURST]. NEW YORK: MUSEUM OF MODERN ART.
HALLER, F., & BEYERLE, T., ET AL. (1988). FRITZ HALLER. BAUEN UND FORSCHEN. DOKUMENTATION DER AUSSTEL-LUNG. SOLOTHURN: KUNSTVEREIN SOLOTHURN IM KUNSTMUSEUM SOLOTHURN.
SCHWARTZ, J. (ED.) (2016). KLEINE TRAGWERKSOBJEKTE. ZÜRICH: PARK BOOKS.
WACHSMANN, K. (1961). THE TURNING POINT OF BUILDING: STRUCTURE AND DESIGN. NEW YORK: REINHOLD.
WACHSMANN, K., GROPIUS, W., & TOWER, M. (2003). THE PACKAGED HOUSE SYSTEM (1941-1952). PER-SPECTA, 34, 20-27.

## A Case Study in Design-led Innovation

Heebink, Rob
Gallagher Group Limited
rob.heebink@gallagher.com

Following a strategic review of Gallagher, the company committed to develop world-class innovation capabilities with the aim to become leaders in continuous product innovation. Supported by the Better by Design programme of New Zealand Trade and Enterprise Gallagher embarked on the 'Design journey'. Over a number of years Gallagher adopted Design, Lean and Agile philosophies and principles and developed the "Gallagher approach" by adopting and blending a range of methodologies such as Design Thinking, Voice of the Customer, Scrum, Kanban, Learning First Product Development, and Rapid Learning Cycles. This case study looks at how the implemented philosophies, principles and methodologies were applied to the re-development of a highly commoditised portable fencing product. The tangible outcome of this project was a significant increase in market share with a product that addresses real problems for the end-user and delivers a respectable margin for Gallagher.





## Earthquake Bench Prototype: A Reconceived Digital Workflow

Sweet, Kevin
Victoria University of Wellington
kevin.sweet@vuw.ac.nz

Sweet, Tonya
Victoria University of Wellington
tonya.sweet@vuw.ac.nz

Today's designers are inundated with a plethora of CAD/CAM software capable of meeting a variety of needs within the design process. In academia, it is commonplace for students to learn as many as ten different software applications in order to develop their design from conceptualisation to digital model and, ultimately, to the production of a material output. With each shift from one application to another, the risk exists for valuable information to be lost in order to suit the limitations of the chosen software.

Emergent innovations in digital design tools are compressing the design workflow and allowing for greater flexibility and variability. Within the scope of these software options, parametric design tools have garnished increased validity and applicability across various disciplines of design: they afford the benefit of adaptability within the design process as well as highly customisable outcomes. Despite their recognised value, these tools remain secondary to their established counterparts. Designers are required to side-step through an inefficient series of procedures as they translate data between programs. In order to generate design outputs in a truly efficient manner, design practice (and, subsequently, design education) must capitalise on the potential of parametric software that supports a streamlined flow from design conception to production.

Through a case study this paper will explore how such a system was applied from design conceptualisation to fabrication of a bespoke furniture object – the Earthquake Bench. The Earthquake Bench project utilises a "simplified" digital workflow in which the entire process, from design to fabrication, was parametrically programmed and remained intact until the file was sent to the manufacturer, thus ensuring that all changes were consistently updated throughout the process. The case study identifies the shortcomings and benefits achieved from this process, as well as how this proposed system may begin to reshape design practice and education.

# Highly stretchable 3D-printed electrical components using carbon nanocomposites

Giffney, Tim
Department of Mechanical Engineering, The University of Auckland
tim.giffney@auckland.ac.nz

Aw, Kean
Department of Mechanical Engineering,
The University of Auckland
k.aw@auckland.ac.nz

The developing fields of wearable electronics and soft robotics have created a strong demand for flexible and stretchable electrical components. This work presents a printing technique and conductive carbon/silicone polymer nanocomposites applied to achieve embedded conductive interconnections in silicone parts, printable resistors, large strain sensors, and dielectric elastomer electrodes.

A highly adaptable process for printing stretchable electrical components has compelling advantages: multiple layers of cured electrical components can be embedded inside a solid mechanical part, arbitrary geometry can be precisely reproduced under computer control, and multiple types of components can be fabricated in one process. Together, these features will allow the integrated fabrication of significantly more complex devices than could be created with previous methods.

By controlling the type and concentration of carbon nanoparticles (e.g. carbon black, carbon nanotubes, graphene nanoplatelets), printable mixtures with a wide range of mechanical and electrical properties have been developed for various applications. Printed structures can withstand stretching of up to 300 %, with gauge factor varying from <2 (for conductive interconnect) to > 100 (for strain sensing and switching). Successful fabrication of demonstration devices such as resistive stretch sensors and dielectric elastomer actuator electrodes illustrates the potential of this technique

Figure 1: Embedded resistive strain sensor

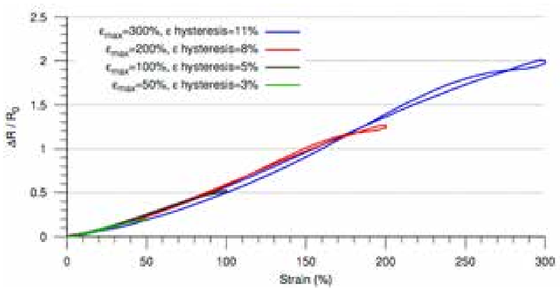



Figure 2: Resistive change and hysteresis for printed sensor



ORAL ABSTRACT - PARALLEL SESSION 1b *RANGITOTO 2*

# Acoustical Testing and Design for Acceptable Noise

Kingan, Michael
The University of Auckland
m.kingan@auckland.ac.nz

Mace, Brian
The University of Auckland
b.mace@auckland.ac.nz

The level of unwanted sound or 'noise' produced by a product (e.g. a car or aeroplane) or the ability of a product to exclude unwanted noise (e.g. headphones, building walls/floors) is often a key factor in determining a person's perception of the quality of this product. Noise can also be a health issue if levels are too high and exposure is too long. These problems are exacerbated with current trends for lighter, more efficient structures: examples include the use of composite materials and the growth in lightweight, timber framed building constructions. Thus, the design of a product to minimise or exclude noise is often highly desirable or essential to maintain competitive advantage.

Various numerical CAE tools (e.g. finite element analysis, boundary element analysis, ray tracing) are available to the engineer, together with methods for the higher audio-frequency range such as Statistical Energy Analysis. However, these often fail to address problems especially for larger structures in the "mid-frequency" range. This drives current research, which is briefly reviewed, including recent and current developments at the University of Auckland. Attention is focussed on our hybrid wave and finite element method, which is being applied to predict noise transmission through complex panels, glazing systems, and extruded truss, honeycomb core and laminated panels. The method allows a wide range of parameter studies to be undertaken without the need for extensive physical prototyping and testing.

Despite the above, the need for acoustical measurement and testing remains and will remain as an essential part of the design process. The Acoustics Laboratories at the University of Auckland and the expertise of its staff are described. The laboratories consist of 3 reverberation chambers which can be used to conduct tests to international standards to measure sound transmission loss through wall and floor/ceiling systems, impact noise produced by walking on a flooring system, sound power measurements and the absorption provided by sound absorbing treatments. The laboratories also have a large anechoic chamber which can be used to measure noise produced by various devices (e.g. appliances and UAV rotors).

This talk will describe the capabilities of the laboratories and its staff and will discuss several case studies of successful industry focussed research projects undertaken by staff associated with the labs, recent examples of which include:

• The development of a method for assessing the effectiveness of windscreens for reducing the flow noise measured by smartphone microphones.

• The development of quiet UAV rotors and a microphone system for recording audio from a UAV mounted microphone system

• The development of numerical methods for predicting sound transmission through various structures (panels, double-glazed windows, double leaf walls, floors).

# Fast NPD and Risk; Reducing Risk When Moving Fast

Shannon, Craig
Globex Engineering
Craig.shannon@globex.co.nz

Sometimes due to opportunities or commercial pressures, classical product development processes like stage gate processes cannot be followed. With these time pressures and removal of structure, the level of risk for a project increases. From our experience, to try and get the highest likelihood of success in these fast-moving hardware situations there are some key factors and techniques that contribute significantly to minimising the risk of the situation. The most common of these are;

- Prototyping early and making early failure acceptable
- Timeline planning using historical data and bias reducing techniques
- Building close relationships with high competence key suppliers
- Clear specifications of key features and planning knowledge gaps work
- Correct personnel selection and organisational support
- Involving manufacturing and production early for costings and reviews

Most of these items have been known about for a long time, but are, generally poorly implemented, supported or not practiced at all.

This presentation will consider two factors, to illustrate our approach, feature selection and personnel selection.

Feature or requirement changes in fast moving product design cycles are a regular cause of wasted effort and lost time. Details that are found out as the project progresses can be important but must be carefully weighed against their cost to the project for time. Often these could have been foreseen with early investigation. Flushing out these details early by taking the time at the start of project with some systematic tools significantly reduces risk. Team specification drafting sessions to get everyone on the same page for the product brings early clarity and direction to the project. Doing pre-mortems for the product development plan can bring large numbers of issues to the surface allowing them to be accommodated.

Picking experienced personnel with limited ego and who are driven to get the best results are needed to lead these types of fast development projects. They need to be able to move through issues efficiently, be calm when failure happens and be willing to kill their "idea children". Personality profiling can help show up these types of people and training can further refine it. These personnel also need space and management help to be focused. For the fast-moving projects, you, as a manager, want to limit non-engineering distractions and generate space with supporting staff, so they can react quickly to help the engineers. You want engineers to be engineers and do what they are good at.

For this presentation, we will go through above factors in more detail and the practical steps that we take to reduce the ever-present risk for our fast-moving projects.





# Collaborative innovation at the Centre for Automation and Robotics Engineering Sciences

MacDonald, Bruce and Soriya Em
Centre for Automation and Robotics Engineering Sciences, The University of Auckland
b.macdonald@auckland.ac.nz

The Centre for Automation and Robotics Engineering Sciences (CARES) is an innovation hub housing a multi-disciplinary group with a mission to create innovative and inspiring robotic technologies that improve physical, psychological, economic and overall societal well-being. CARES has proven experience in delivering high calibre research to an international audience and fosters academic and industrial collaborations around the world. Research areas focus on healthcare technologies, software systems, robots in primary industry, robotic device technologies and human-robots interaction. Our research is driven by a strong purpose to deliver meaningful solutions to end users through the widespread adoption of our technology.

Collaborative innovation is a core asset of our centre, with research capabilities spanning from health, software and technologies applicable in manufacturing such as machine learning, artificial intelligence, sensors and data analytics. Uptake of our technology is a key objective, therefore stakeholder engagement is integral to the execution of our projects. We are developing real-world test facilities with partners for technology evaluation.

Current projects include carving out a pathway to commercialisation for our software which manages health conditions on robotic platforms. Knowhow in this area has led to a number of commercially funded international projects with broad applications in health and social robotics. Our solutions are user-centric, incorporating factors such as human behaviour, emotion and a clinical perspective to ensure successful outcomes. Additionally, we are delivering research that will ultimately develop autonomous robotic solutions for applications in agriculture and horticulture, advancing our knowledge in vision processing, machine learning, and automation. Our competencies across applied robotics and automation represents an opportunity to develop smart operational solutions applied broadly in many industries including manufacturing.

# Innovative Design Modifying Air Cooled Highly Finned Tube Condenser

Abbas, Haiam
Heavy Engineering Research Association (HERA)
haiam.abbas@hera.org.nz

Farid, Mohammed
The University of Auckland/ C&M Engineering
m.farid@auckland.ac.nz

The work presented here is to improve thermal performance and decrease size of a special air cooled condenser used in Organic Rankin Cycle (ORC), where power output is compensated by reducing the operating pressure at the condenser. This usually leads to a decrease in the refrigerant condensation temperature, and hence, a decrease in the thermal driving force resulting in a constrained thermal duty at the condenser.

Industrial applications aim to maximise heat transfer by providing large heat surface areas. An example of this is the air cooled finned tube condenser, where thermal duty is constrained by air side key parameters, most importantly, inlet temperature, mass flowrate, surface area, thermal conductivity, and geometry configuration On the refrigerant side (inside the tubes), little was done to enhance heat transfer because heat transfer coefficient is much higher than that at the air side. Therefore, industry is normally focused on increasing the surface area at the air side by using fins along the tubes.

Using straight long tubes leads to flow development inside the tubes associated with an increase in the thermal boundary layer thickness near the wall, where molecular conduction becomes significant. This with the low fluid thermal conductivity decreases heat transfer rate significantly, requiring large number of tubes. The size of 500 kW air cooled condenser is about 8 times larger than that of similar duty evaporator).

Innovation in heat transfer can significantly benefit air cooled condensers through size reduction leading to reduced footprint. Our objective was to increase heat transfer at both air side and refrigerant side by increasing the effective thermal conductivity using porous media, decreasing the thickness of the thermal boundary layer and by inducing turbulence.

In a cost effective method, using computational fluid dynamics (CFD) studies, the use of expensive materials such as graphene, which is globally recognized for its high thermal conductivity (about 1000 W/mK), was evaluated and compared with the use of copper or aluminium mesh. ANSYS/CFX and high performance computing of NESI Cluster of Auckland University were used for the simulation. The influence of several parameters of commercial available porous metal foams on heat transfer and pressure drop was examined. The refrigerant R245fa was used as a working fluid. A condensation temperature of 45.7°C at a pressure of 3 bar was selected for performance assessment. Total condensation was achieved using half the number of tubes. Thermal performance increased by more than 3 times with reduction in tube length by a factor of 4. While the pressure drop increased considerably it was maintained within an acceptable range depending on the mass flowrate (1.2 and 10 kPa at the air and tube sides, respectively, using more than double the flowrates). Further investigations will optimize the design and operating conditions for final experimental examinations.



ORAL ABSTRACT - PARALLEL SESSION 1c *RANGITOTO 3*

# Advanced Biobased Products - combining sustainability with performance

Graichen, Florian
Scion

Scion's biomaterials and bioproducts research focuses on supporting New Zealand's manufacturers and brand owners with innovative technologies that utilise sustainably-derived, biobased resources.

This presentation will highlight nine success stories from Scion's research that are differentiated by the:

- Size of the product: from a designer tree to small molecules
- Scale of the product: from commercial scale to experimental 3Dprinting approaches
- Value of the product(s): from speciality/high performance materials to an "adding value to waste" concept.

All these products need proven green credentials, freedom from harmful chemicals and have to be cost-effective. By building on features designed by nature, we aim to develop products that deliver performance additions beyond the sustainability and renewability claims; products that will meet the demands of the global market place.

Aspects of our research take a different approach to many countries in how we use, manufacture and develop bioproducts as New Zealand is not set up for refining petroleum to chemicals and polymers. Thus, we have leading expertise in extrusion processing of biomass, biopolymers, fillers, novel biobased additives and fibre addition. We are continuing to expand our capability, adding new manufacturing technologies to our processing portfolio. A good example in 3D printing, a rapidly developing and highly disruptive manufacturing technology that is expected to change much of the way business is done.

# Next Generation Surface Coatings Based on Zero Emission and No Waste Manufacturing Approach

Schaefer, Marcel
Auckland University of Technology
marcel.schaefer@aut.ac.nz
Bovin, Nicolai
Auckland University of Technology
nicolai.bovin@aut.ac.nz
Henry, Steve
Auckland University of Technology
stephen.henry@aut.ac.nz
Croft, Stephanie-Anne
Auckland University of Technology
stephanie-anne.croft@aut.ac.nz

The 19th and much of the 20th century saw technological advances that were made largely without attention to their environmental effects. The challenge for the generations of the 21st century, however, is to reconcile technology with environmental consequences. This requires integration of technology with ecology such, that the two are mutually advantageous.

People of the 21st century face two challenging trends, an increasing scarcity of almost all essential resources and a rapid accumulation of atmospheric CO2. Business-as-usual scenarios predict an increasing demand of every material used in manufacturing and unprecedented extremes in the human environment.

This study investigates the potential in mimicking the shell-manufacturing process of marine diatoms, a microalga, to develop the basis for next-generation protective surface coatings. For this manufacturing process, we are mimicking nature's closed biogeochemical cycles . Coatings will be manufactured at room temperature and atmospheric pressure, and the manufacturing process does not produce any waste or toxin.

The predominant form of dissolved silicon in marine and freshwater environments is monosilicic acid, Si(OH)4, which also represents the source for the cell wall formation of diatoms. This silica exoskeleton, called a frustule, has been studied over the last decade and has informed our current knowledge on biosilica formation at the molecular level. Such studies include the identification of organic biomolecules involved in biosilica formation such as silicic acid transporters (SITs), proteins, polysaccharides, long chain polyamines (LCPAs) and silacidins, and the self-assembly behaviour of these biomolecules.

The applications for such next-generation coatings are very broad. They range from self-healing corrosion-protection coatings for offshore structures to highly efficient solar cells and sensors.

Another study is investigating self-assembling molecules to form atomically flat surfaces, so called tectomers. This technology will allow to introduce a new generation of computing elements that are based on a combination of molecules with nano-crystals instead of bulk silicon. Today's best transistors have a gate that is at least 10 nanometres in width, which is close to the theoretical lower limit for silicon transistors. Therefore, the potential to reduce the size of regular circuits, has been exhausted.

Assembling molecular sized computing elements with a <<10 nm accuracy is only possible on an ideal surface-templates with the roughness corresponding to the size of the nano-device. Only two surfaces have the required roughness: freshly cleaved facets of mica and graphite. Both materials are minerals, and consequently cannot be used for industrial applications because of their inconsistency, and since polishing methods are incapable of producing atomically flat surfaces. Our invention, the tectomers, is the missing link for atomically flat surfaces.



ORAL ABSTRACT - PARALLEL SESSION 1c *RANGITOTO 3*

# Sound Concepts Platform: Visualising Sound Concepts

Perkins, Natasha
Victoria University of Wellington
Natasha.Perkins@vuw.ac.nz
De Guzman, Raul John Immanuel
Victoria University of Wellington
deguzraul@myvuw.ac.nz

A case study project to support knowledge acquisition of acoustic design principles and materials within an open source online platform. It discusses the opportunities and implications around the theme of Cloud Technologies for Design and Manufacturing as part of an online process system that seeks to develop a novel approach to visualisation of acoustic knowledge within education and practice for novice to intermediate designers and specifiers. User Interface design (UI) of this online platform will support educational efforts to teach acoustics where information gets increasingly difficult to grapple with.

The project is part the Sound Concepts Research Programme that is made up various research to develop products that combine applied science, creativity, and cultural aspects to support acoustic treatment in interior environments. Whether new fit-out or retrofitting spaces the overall aim is to increase general knowledge and understanding of the need for better acoustics in the built environment. Projects so far have concentrated on: (1) the development, installation and testing 3D acoustic forms in primary school classrooms , (2) Cultural Codes - an installation that explored cultural aspects and simulations to connect traditional values with contemporary practice using a design methodology centred around the narrative of Te Whare Pora (the house of weaving) and, (3) advanced research on the role of acoustical design within architectural design in the early design phase .

Sound Concepts Platform (SCP) extends the parametric framework behind Cultural Codes into a flexible mass-customisation online tool. A 2014 feasibility study highlighted the scope of creating such a tool, and now serves as a starting point for the beta test consisting of proof-of-concept code, a parametric model, and a suite of design tools. It allows users to manage 3D parametric models and study their acoustic suitability without investing in high-end software packages. SCP began through an analysis of existing web technologies to find solutions in: (1) managing 3D parametric models, (2) calculating for acoustic parameters given a parametric model, (3) and mapping front-end UI for the overall application. The current version of SCP is a front-end application that utilises the Three.js JavaScript library to manage 3D parametric models, and the Angular.js JavaScript framework to manage the front-end user interface. SCP calculates acoustic parameters through JavaScript alone, and currently supports the calculation for Reverberation Time (RT) based on the theory of Sabine.

The goal of the Sound Concepts R&D programme is to commercialise the research in the form a database driven website where architects and designers can insert acoustic forms into building models and test for RT values with a direct link to production. Not intended to replace Acousticians role in large projects, but educate and offer an option in smaller projects were acoustic consideration of space is predominantly non-existent. Future development includes base line testing of existing spaces using cost effective digital technologies and the simulation of this information in a Virtual Reality setting to enable immersive user design.

Perkins N S, Halstead M, Merwood, Y. Sound Concepts - Design and Testing: Acoustics form development, testing and pilot installation in primary school classrooms. (pgs. 90) Wellington: Oticon Foundation of New Zealand, 2012.

Perkins, N., Spell , R., Bartlett, J., Meadows, j., Welch, C., & Petrovic, E., 'Cultural Code', (M. Jackson, & J. Anderson, Eds.) iijournal: international journal of interior architecture + spatial design, 3, November (2014). www.iijournal.org.

Wright, O., Perkins, N., Donn, M., Halstead, M. (2016). 'The Role of Acoustical Design within Architectural Design in the Early Design Phase.' World Academy of Science, Engineering and Technology, International Science Index 114, International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, 10(6), 780 - 785.

## Industrial scale ion beam technologies for New Zealand manufacturing

Kennedy, John; Leveneur,Jerome; Futter, John; Markwitz, Andreas
National Isotope Centre, GNS Science j.kennedy@gns.cri.nz

Ion beam technologies utilizes energetic beams of ions (positively charged atoms) to modify surface structure and chemistry of materials and deposit films at low temperature. Many surface properties can be improved with ion implantation: these include enhanced hardness, wear resistance, reduced friction and resistance to chemical attack. The process can be applied to virtually any material, including most metals, ceramics and polymers. However, the effects of the process are typically material-specific.

In the recent years, GNS Science has used their expertise in ion beam and materials science to deliver new materials and functionalised surfaces at the lab scale. While the team's initial focus has been on developing new semiconductor and nanostructured materials for microelectronics and sensor applications, we have been developing new equipment and methods to be adopted at the industrial scale processing.

In this presentation, we will review some of the processing methods that have been demonstrated in the lab, including examples drawn from our experience. We will also discuss how, moving forward, this technology could be up-scaled and transferred to industry and what challenges lay ahead.



ORAL ABSTRACT - PARALLEL SESSION 1c *RANGITOTO 3*

## Nanostructural control in plastic electronic films

Nedoma, Alisyn
The University of Auckland
a.nedoma@auckland.ac.nz
Hong, Jen Sun
The University of Auckland
jhon973@aucklanduni.ac.nz

Plastic electronics encompass a range of light weight, flexible devices; such as solar cells, transistors and batteries; that promise inexpensive energy generation and storage. Controlling the nanostructure of polymeric composites is essential for maximising the efficiency and lifetime of devices. Scalable manufacturing processes must fabricate large-area films with highly controlled nanostructures. Printing remains the most viable production technique; however, irreproducible drying conditions lead to low-performing devices. This work examines the fundamental kinetic and thermodynamic interactions that control the nanostructures in a drying film. Conductive fullerenes are dispersed within a water soluble polymer and dried using various techniques.The resulting structures and electronic conductivities are characterised towards developing a general process for drying plastic electronic films.

# Industry 4.0 – What's in it for us?

Adam, Dieter
NZMEA
dieter.adam@nzmea.org.nz

Nathan Stantiall
Callaghan Innovation
Nathnan.stantiall@callaghan
innovation.govt.nz

Technologies subsumed under the Industry 4.0 term carry the promise of manufact¬uring productivity increases unheard of in recent decades, plus the ability to expand or re-invent business models by remaining digitally connected with your product once it leaves the factory. In Germany at least, the development of these technologies is also strongly support-ed by government with the explicit aim to boost the international competitive positon of manufacturing SMEs. In reality, however, there is an increasing number of reports of SMEs in Germany failing to take up the offer. And at first glance at least it is a lot easier to envis¬age how the benefits of these technologies can be exploited by larger manufacturers.

The NZMEA, working with Callaghan Innovation and the School of Engineering at Auckland University, has been working with New Zealand manufacturing companies to help them to get their heads around Industry 4.0 technologies, and how they could be utilised, adopted and adapted in their operations. We'll report on our work done to date, including an industry readiness survey and accompany in a group of NZ manufacturers on a study tour to Germa-ny. We'll undertake an initial assessment of which of these technologies are most likely going to help our manufacturers increase productivity and profitability, especially in the near term.





# Industry 4.0 Smart Manufacturing Systems Laboratory

Xun Xu
Department of Mechanical Engineering, The University of Auckland, New Zealand

Industry 4.0 is one of 10 "Future Projects" identified by the German government as part of its High-Tech Strategy 2020 Action Plan. The concept of Industry 4.0 was initially proposed at the Hannover Messe trade fair in 2011 as a smart manufacturing paradigm for the future.

Industry 4.0 refers to the fourth industrial revolution, a new phase in the organization and management of the entire value chain over the full product life cycle. This cycle is geared towards individual customer requirements and extends from ideas, orders, development and manufacturing to end-customer product delivery and recycling, including all associated services. The framework is provided by networking all the elements involved in the value chain so that all relevant information is available in real time, and using the data to derive the optimum value adding stream at all times. Linking people, objects and systems produces dynamic, self-organizing and cross-company value adding networks that can be updated in real time and optimized on the basis of different criteria including costs, availability and consumption of resources.

The core feature of Industry 4.0 is the concept of smart factory. In a smart factory, products find their way independently through the production processes, machines and products communicate with each other, cooperatively driving the production processes. Industry 4.0 is characterized by the integration along three dimensions: vertical integration together with networked manufacturing systems, horizontal integration through value networks, and end-to-end digital integration of engineering across the value chain of a product's life cycle. Smart factories constitute the critical basis for the integration above.

The core technological concept of Industry 4.0 is Cyber-Physical Systems. In Industry 4.0, all production elements are enhanced to CPS, which consist of the physical part in the real world and the virtual part in the digital world. CPS enable the seamless integration and interaction of the virtual and physical worlds of the manufacturing systems both within a smart factory and across a value chain so as to achieve the accurate decision-making and global optimization. Other identified key technologies for Industry 4.0 include the industrial IoT, cybersecurity, cloud technology, big data analytics, simulation, additive manufacturing, augmented reality, and robots were identified as the possible underpinning technologies for Industry 4.0.

Vision
Industry 4.0 holds the promise of increased flexibility in manufacturing, better quality and improved productivity, which enables New Zealand companies to take on the challenges of producing more individualized products with a short lead-time to market. The resultant higher quality products and services ultimately enhance companies' competitiveness.

Mission
The LISMS is established to showcase some key technologies of Industry 4.0, as well as to demonstrate how New Zealand businesses benefit from implementing these technologies. The laboratory also facilitates interactions and collaborations between industry partners and researchers.

Objectives
• Assisting local industries in better understanding Industry 4.0
• Encouraging collaborations between industry and researchers
• Showcasing and implementing the research works at local industries

# Polymer Composite Manufacturing Technologies for the Future

Bickerton, Simon; Battley, Mark
Centre for Advanced Composite Materials,
The University of Auckland
s.bickerton@auckland.ac.nz, m.battley@auckland.ac.nz

Worldwide application of polymer composite materials continues to increase, with regard to type and volume of materials utilised, and the breadth of applications. Glass and carbon fibre reinforced thermoset polymers, initially developed for military applications, are now used widely in sectors including; transportation (automotive, marine, aerospace), infrastructure, sports and recreation, and industrial. The palette of available materials has broadened to include different fibres (aramid, natural (e.g. wood, sisal, flax, harakeke)) and polymer matrices (thermoplastics, biopolymers). The polymer matrices have been further enhanced through a wide range of micro and nano additives, while fibres are also being produced commercially at the nano scale. While polymer composites were originally developed for their excellent mechanical properties at low weight, materials are also developed for applications that utilise resulting thermal, electrical, and chemical properties. The breadth of material options allows development of a broad range of multi-functional polymer composites, while providing constant challenges for the development of cost-effective manufacturing processes. Polymer composites manufacturing has always been additive, and the physical processes of combining reinforcement and matrix constantly evolve with the development of material options.

As part of New Zealand's high value manufacturing economy, the manufacture and application of polymer composites is a recognised strength. Current research at the Centre for Advanced Materials will be summarised, providing examples of advancements in non-destructive evaluation through manufacture and on finished components, as well as developments on 3D printing of continuous fibre reinforced plastics. However, for New Zealand's industry to fully capitalise on advanced composite materials, our research community must be engaged on a broader range of technologies, including:

- Non-destructive evaluation of materials in the process chain, and of finished products
- Manufacturing process developments; Additive processes from automated layup to 3D printing
- Application of modern manufacturing systems; Automation, data analytics, industry 4.0
- Manufactured in functionality; Smart materials, sensors, actuators

This presentation will pose several questions and challenges to New Zealand's research community as to how we can build on our strengths, and further capitalise on the expanding pallet of advanced composite materials and processes.





# Industry 4.0 easily implemented with BECKHOFF

Sischy, Steven
Beckhoff Automation (Pty) Limited
s.sischy@beckhoff.com

The purpose of Industry 4.0 is to make manufacturing more flexible, efficient and sustainable through communication and intelligence, by networking Smart factories both vertically and horizontally. This networking concept within an 'internet of things, services, data and people' and has be potential transform the future of manufacturing.

Furthermore, it will open up new ways for companies to integrate their customers' needs and preferences into their development and production.

It will also  make it easier to analyse machine data, helping to enhance quality and avoid faults in the production process.

The fourth revolution with be the cyber connectivity of factories.

If the digital transformation to industry 4.0 is to be successful, it is essential that businesses invest in appropriate skills and IT infrastructure.

R&D, purchasing, production, warehousing and logistics are currently at the heart of the digital transformation to industry 4.0, while sales and services are the segments with the greatest potential to benefit.

Currently manufactures push into the market place what they believe their customers want, where as Industry 4.0 is a pull into the market place driven by the customers needs.

Beckhoff and EtherCAT, being PC-Based control have been ready for Industry 4.0 for the last 25 years. The convergence of IT and automation technologies will allow for better implementation of PC-Based control into the Smart factory concept. At the heart of this concept will be secure communication from the field devices all the way to cloud based computing.

An example of a success story for this concept already exists for a company named Catch of the Day; Australia's #1 eCommerce Group. Their rapid sales growth required that they challenge traditional thinking in order to meet increasing customer demands. With over 10,000 orders per day received, people and technology needed to work smarter together in order to achieve the fast delivery expectations that customers appreciate.

# Giving machines eyes: how cognitive computing can detect defects in real time

Swery, Elinor
IBM New Zealand
elinor.swery@nz.ibm.com

Fernando, Isuru
IBM New Zealand
fernando@nz.ibm.com

80% of the world's data is unstructured: it is not formatted in a way that is easy for a traditional computer to analyse and comprehend. This data includes natural language as found in technical documents, books, handwritten notes, images and videos. Computers can access this data, process it, store it, secure it and move it around, but our everyday traditional computing systems struggle at understanding this data.

Advances in Machine Learning algorithms and the application of these in an easily accessible system have resulted in the introduction of new cognitive computing systems such as IBM's Watson™. IBM Watson™ represents a set of cognitive capabilities that are easily accessible through APIs available on the cloud. These APIs enable a computer to teach itself, rather than relying on its programmers, by studying data, looking for patterns and drawing its own. These technologies are therefore well suited to recognising and interpreting patterns, and extracting meaning from them.

One of these technologies, The IBM Watson™ Visual Recognition service understands the content of images and then classify images into logical categories. The service uses deep learning algorithms to analyse images for scenes, objects, faces and other content. It allows user specific training of the service by creating a custom classifier to create a specialised class that is tailored for an application. This service enables unstructured data to be processed in a similar manner to how a person would; it enables objects and patterns to be detected in images rather than treating them as a set of pixel values. Undergoing a well-controlled training process allows the IBM Watson™ service to create a ground truth to benchmark against human classification. The benefit here is that the service is able to scale and continuously offer high levels of consistent accuracy that aren't subject to conditions, such as fatigue, of the human condition

This visual recognition service provides a gateway to gain insight from the large amount of unstructured data obtained from the manufacturing industry. One application, which will be discussed in detail, focuses on using the service to allow real time defect detection. A complete set of examples will be discussed, showing how it is possible to both detect and characterise defects in the manufacturing process of fibre reinforced composite materials. The advantages of using cognitive computing will also be highlighted, by comparing to traditional image analysis methodologies previously employed by the industry and research communities.





# Exploiting digital technologies to innovate in manufacturing

Shahbazpour, Mehdi
Fletcher Building
mehdi.shahbazpour@fbu.com

Information and communication technologies (ICT) are advancing at exponential rate driving disruptive changes in all industries. Digital Manufacturing is a term used to represent the collaborative transformation of manufacturing through the exploitation of these advances in ICT. In order for such transformation to take place in an organisation, a number of critical capabilities must first be developed or acquired. These include technical capabilities such as software development and management, big data management and analytics, internet of things, cloud computing as well as non-technical capabilities such as lean/agile manufacturing, innovation management and change management. Using a case study, I will present how Fletcher Building has accumulated these capabilities and used them to exploit digital technologies for implementing world class manufacturing across their business units.

# Internet of Things (IoT) Enabled Smart Manufacturing for SMEs

Ray Y. Zhong
Department of Mechanical Engineering, The University of Auckland, New Zealand

Internet of Things (IoT) enabled manufacturing is an advanced principle where typical production resources are converted into smart objects which are able to sense, interconnect, and interact with each other to automatically carry out the manufacturing activities. With the wide usage of IoT digital devices which are able to generate a vast amount of data, manufacturing companies are facing challenges for making full use of this collected data. This paper focuses on proposing various solutions for small and medium-sized enterprises (SMEs) in implementing IoT technologies and Big Data Analytics. SMEs are usually facing challenges when using data for decision making: 1) with the deployment of enormous IoT-enabled devices which may be different in functionalities, vast heterogeneous data will be captured and collected; 2) the collected data are linked to each other based on the manufacturing logics so that it is difficult to analyse the data using traditional approaches; and 3) the complex and bulky datasets are difficult to use in various applications, thus, innovative data presentation and interpretation approach are needed.

In order to address the challenges, this solution:

• uses Auto-ID like RFID or Barcode technology to convert various manufacturing resources into smart objects which are able to sense and interact with each other;
• adopts wireless and wired communication networks to collect the manufacturing data;
• establishes an innovative data model to visualize the captured and collected data in a graphical fashion;
• and uses the mined production information and knowledge to make advanced decisions and production automation.





# Manufacturing in a world of Disruptive Technologies

Marett, Kevin
LEAP Australia
kevin.marett@leapaust.com.au

The rise of the IoT has been driven by the convergence of market forces and parallel innovation of enabling technologies. Products have evolved from purely physical components to complex systems combining processors, sensors, software, and digital user interfaces that are now connected to the Internet and each other. As their definition has evolved, product capabilities have multiplied, creating new forms of value and even doing things well beyond their primary function.

The impact is a fundamental transformation of how manufacturers create and exchange value with customers. This transformation is shifting the sources of value and differentiation to software, the cloud, and service, and spawning entirely new business models.

To capture this great wave of value creation opportunity, manufacturers have an urgent need to rethink nearly everything — from how products are created, sold, operated, and serviced. Those who don't place their current competitive advantage at risk.

Manufacturers must begin to transform existing business processes and fundamentally rethink how they create, operate, and service smart, connected products in the IoT. For those that get it right, the future represents a huge opportunity to create product and service advantage:

• Transform How Products are Created.

- Manufacturers must plan and design flexible platforms that enable personalization, value added services, and product enhancements to be delivered remotely before and after the product is in the market.

- Manufacturers must design out the complexity created by combining processors, sensors, software, digital user interfaces and connectivity, and deliver a simple user experience.

- Manufacturers must incorporate product usage data into R&D processes and drive new functionality, define specifications, and increase customer intimacy.

• Transform How Products are Serviced.

- Manufacturers must plan and deliver remote software and service updates in real-time, with minimal customer disruption, and at minimal marginal cost.

- Manufacturers must plan and optimize product and service parts management and inventory control by tracking assets and analysing real-time product usage data to predict parts needs.

- Manufacturers must plan and optimize field service management processes by bundling proactive and reactive maintenance and providing technicians with information in advance to increase first time fix rate Tweet Post.

• Transform Business Models

-Manufacturers must rethink business processes and business models to maximize returns across the entire useful life of the product, and not just up to the point-of-sale

-Manufacturers must plan for increased complexity of expanded partner and supplier ecosystem, and consider the opportunities and threats they create.

-Manufacturers must capture and analyse product data to anticipate product service needs and user desires for additional services and capabilities.

ThingWorx is the first IoT software platform specifically designed to quickly build and run the connected applications required to make your products, operations, service, smart and connected. It makes your enterprise, your products, your plants, your systems and your people connected.

## The key role of traditional industries for creating high-tech growth

Husted, Kenneth
Faculty of Business and Economics, The University of Auckland
k.husted@auckland.ac.nz

Both in academic studies and in policy, low- and medium-technology (LMT) industries have often been side-lined, with the main focus being placed on the more fashionable high-tech industries. Yet LMT (or traditional) industries, such as primary, manufacturing, engineering, and service industries are widely recognised as the backbone of economies in developed countries. Across Europe almost two thirds of all employees in manufacturing are employed in the LMT sector.

When business research pays attention to traditional industries, it tends to focus on their shortcomings. Some key ones put forward in the literature include lack of resources to engage in sophisticated and costly R&D initiatives, high dependency on accessing innovation outside the firm, and lacking sufficient absorptive capacity. However, we see growing evidence for the fact that traditional industries often play an important role as users of high-tech solutions and so, they become an important factor in stimulating and commercialising high-tech innovation.

Our research investigates key features of the relationship between high-tech industries and LMT (traditional) industries. The paper is based on explorative work with primary and secondary information sources. These sources include interviews, archival evidence, and websites.

Key findings are:

• Firms in traditional industries often use extensively advanced knowledge and high-tech solutions developed elsewhere. They utilise them for commercial purposes such as increased productivity through automatisation of part of manufacturing processes and other process innovations.

• Well established infrastructure and market position results in lower uncertainty and more efficient recapture of the R&D spent.

• Traditional industries provide attractive (initially niche type) opportunities for firms in the high tech sector.

• LMT industries are under-reporting their R&D spent as the external R&D is often acquired in an embodied form e.g. in new technologies.

• In the absence of proximity between firms in traditional industries and technology providers, the former adopt alternative innovation strategies. In New Zealand, such strategies range from the in-house modification of existing technologies to the development of new products in collaboration with customers, and even science-led innovation.





## Interoperable Execution on Heterogeneous Platforms in Modern Industrial Environments

Zoran Salcic, Udayanto Dwi Atmojo, Heejong Park, Andrew Tzer-Yeu Chen, Kevin I-Kai Wang
Department of Electrical and Computer Engineering, The University of Auckland
z.salcic@auckland.ac.nz, kevin.wang@auckland.ac.nz

Manufacturers, particularly in the context of small and medium-sized businesses, face increasing demand for flexibility, whether that means supporting a wider variety of products, fulfilling small orders while minimising idle stock, or customising products for particular customers. This calls for the combination and coordination of different types of manufacturing equipment, including machines, robots, sensors, and actuators. This equipment may originate from different manufacturers, follow different communication protocols, and run on different execution platforms, yet the equipment all needs to work together to ensure that products are made efficiently and with minimal error. In this presentation, we will discuss the use of the SOSJ framework, which combines a service-oriented architecture approach with the system-level programming SystemJ, in order to show how it can be used to bridge between heterogeneous platforms, and allow for centralised control of manufacturing systems while meeting timing, safety, and static analysis requirements. This approach provides a simple service interface by abstracting the underlying hardware away, and will allow managers to program and control the devices more easily. This is demonstrated through a case study of an Automated Bottling Station which combines mechatronic actuators and sensors, embedded computers, and industrial robots.

# Additive Manufacturing and Internet of Things: Accelerating research and development through a Case Study approach

Wilson, Steve
Executive Director, Talbot Technologies Ltd.
steve@talbot.co.nz

Blache, Robert
Callaghan Innovation
robert.blache@callaghaninnovation.govt.nz

Taylor, Mark P
Director, NZ Product Accelerator
mark.taylor@auckland.ac.nz

Over the past 30 years manufacturing in New Zealand has largely been driven offshore due to both economics-of-scale effects and New Zealand's geographical isolation. However, Industry 4.0, alongside Additive Manufacturing, and the Internet of Things (IoT), now potentially provide mechanisms to counter the "Tyranny of Distance" that New Zealand has been facing for so long in being so distant from its key strategic market places. Instead of mass-produced "one-size-fits-all" products and solutions, niche applications, cleverly designed to adapt to their changing environment are like to become the new mainstream. This includes production facilities that can make "decisions" autonomously, based on data input gathered from a network of sensors. It also means products and solutions that are easily configurable depending on the changing environment they will "live" in. We expect this will lead to the disruption of existing supply chains and business models alike. A new collaborative effort between design, materials and manufacturing research, sensor technology, data and decision making science using cyber-physical systems will enable these new opportunities. New Zealand's relatively compact and cooperative research community and its heavily networked, and technologically capable, Industry groups together provide an ideal source of clever use of the Internet of Things. The relatively low capital costs associated with developing niche technology that can be "meshed" internationally makes IoT a perfect "playground" for New Zealand-based technology providers and manufacturers.

Immediate opportunities in the plastics and metal production spaces include the use of Additive Manufacturing to make spares, rapid tooling, and remote working prototypes for testing. They also include the manufacture of remote meshed sensor devices to capture big data, and the software to process it. Examples will be introduced that feature manufacture of aircraft spares, manufacture and remote testing of proposed aviation parts, and remote monitoring of meshed networks of road sensors

It is important that New Zealand focusses on "New Zealand Centric" "sticky" business that fits into areas where New Zealand has unique knowledge, unique recognized excellence, or unique natural resources. One such example is the concept of an "e Farm" where monitoring and close-loop delivery of operational and veterinary (or agri chemical) responses, can be generated from simple meshed networks that can be monitored and controlled from New Zealand no matter where the farm is.

The presentation will not only provide examples of real current collaborative projects, but also "imagineer" examples on New Zealand's potential commercialisation of the playground of the Internet of Things in the short to medium future.





# Freeform 3D printing: towards a new paradigm in manufacturing

Miller, Tim
Victoria University of Wellington
tim.miller@vuw.ac.nz

Ok, Jeongbin
Victoria University of Wellington
jeongbin.ok@vuw.ac.nz

Fraser, Simon
Victoria University of Wellington
simon.fraser@vuw.ac.nz

Molloy, Isabella
Victoria University of Wellington
molloy.isabella@gmail.com

Freeform 3D Printing is a recent innovation in Additive Manufacturing, which utilizes the freedom of simultaneous xyz axis movement and self-supporting extruded build material through digital control. Thus, after the initial deposit, material is extruded in space and does not require support material or rely on traditional Z axis layering techniques (2.5D printing). This spatial form of 3D printing produces less waste material with potential for material to be placed three dimensionally for structural optimization. The majority of Freeform research internationally is in the field of architecture using high end robotic arms to produce curvilinear spaceframe forms.

However, over the past few years, a research group at the School of Design at Victoria University of Wellington has been investigating the topic from an industrial design perspective in a number of unique directions. These include a Kiwi DIY large format 3D printer, blending of custom materials, a new aesthetic approach for Freeform printed products and more recently a partnership with Scion to explore Freeform printing with long-fibre bio-based composites.

The research commenced with the low tech version of a Freeform 3D printer by transforming a flatbed router into a 2.4m x 1.2m x 0.4m 3D printer with a commercially available handheld plastic welding extruder. The research test rig as driven by custom code produced through a Rhino/Grasshopper script.

In the second stage we are formulating and trialling filaments of thermoplastic polymer blends towards freeform 3D printing, which is aimed at achieving specific properties including structural strength, lightweight, heat dissipation, adhesion at intersection points and surface and tactile qualities.

The third stage is being undertaken by a Masters student who is exploring the design opportunities that Freeform printing affords in generating a new aesthetic for manufactured products. This includes possibilities for the consumer to engage in new levels of customization of the final built product through the use of fully parametric software.

The partnership with Scion will explore the use of long-fibre bio-based composites and employs an ABB industrial robotic arm, recently purchased by the VUW Faculty of Architecture and Design. We will be designing and building an extruder head to print larger scale structures.

# The use of computer aided engineering and 3D printing in the development of a robotic kiwifruit harvesting gripper.

Duke, Mike; Ross, Phillip; Downes, Catherine; Ting, Canaan
University of Waikato
dukemd@waikato.ac.nz

Scarfe, Alistair
Robotics Plus
alistair@roboticsplus.co.nz

This paper shows how a kiwifruit soft gripper was developed for robotic harvesting, using advanced design and rapid prototyping technologies.  Computer Aided Engineering was used for the gripper design and 3D printed Titanium and carbon-fibre, combined with Silicone over-moulding, were used to manufacture the gripper. Field tests showed that the soft gripper harvested kiwifruit fruit effectively and did not damage the fruit. The processes presented, demonstrate how low volume manufacture of high value, complex mechanisms, can be achieved.





# Massey University Centre for Additive Manufacturing: A Revolution in Design Engineering

Potgieter, Johan; Arif, Khalid
School of Engineering and Advanced Technology, Massey University, Auckland 0632, New Zealand
J.Potgieter@massey.ac.nz
K.Arif@massey.ac.nz

Design engineers are always challenged by the constraints of time and cost when designing new products or adding new functions and features into the existing products. Over the years this has led to development of many disruptive technologies that support design engineers with their design pursuits, like computer aided design and analysis tools, virtual reality, additive manufacturing (AM) or 3D printing. Out of these technologies the role of AM is revolutionary as the power of AM is the ability to dramatically reduce the cost and cycle time of prototypes, tooling and production systems

Envisioning the potential of AM in product development and to stay at the forefronts of design engineering education and research, Massey University has established an advanced and first of its kind centre for additive manufacturing (MUCAM). Our centre is equipped with a medley of technologies ranging from polymers to metals, and characterization gear to bolster research and development in the strategic areas of AM technologies. Research areas focus on innovative 3D printing technologies, biopolymer printing, robot-assisted printing, and characterization of mechanical properties. We aim to deliver meaningful solutions to end users and this has been a driving force behind our success in relatively a short period of time.

A core asset of MUCAM is strong industry collaboration, with research projects spanning over a wide range of partners: Scion, MBIE, Product Accelerator, FIET, and Precision 3D printing, to name a few. We are developing real-world material test facilities with partners for technology evaluation. The number of PhD students is also constantly rising due to our growing repute. Currently we are carving out an MOU with industry partners to serve as their research centre rather than working against them. This is expected to allow the involved parties to flourish in their areas of expertise and deliver strong collaborative solutions in the areas which are mostly out of bound for individual entities.

This presentation will highlight the salient features of MUCAM and the way it's bringing industry a step closer to university research. The role of AM technologies in engineering education at undergraduate and postgraduate level will be highlighted with some examples of projects and courses. Last but not least, the role of having all the necessary gear for AM research and education under one roof will also be presented.

# Effects of laser power on grain growth during selective laser melting of metallic alloys: direction and cell size

Chen, Zhan; Darvish, Kourosh; Phan, Minh and Pasang, Timotius
Department of Mechanical Engineering/AUT
zchen@aut.ac.nz, kdarvish@aut.ac.nz, mphan@aut.ac.nz, tpasang@aut.ac.nz

Metallic additive manufacturing (MAM) is increasingly being applied particularly in aerospace and biomedical industries. However, a major technological challenge for MAM to fulfil its huge potential, as explained by Roca et al. ["Policy needed for additive manufacturing", Nature Materials 15(8), 2016, 815-818], is the predictability of mechanical properties of MAM parts. Clearly, in Roca et al.'s view, fundamental understanding of MAM processing science is required to overcome the challenge. As will be briefly explained in this presentation, the referred predictability is highly dependent on: (1) how defects may form and how grains grow during MAM and (2) how MAM parameters affect defect formation and grain growth. Thus, an essential advance in MAM is to advance the understanding on how to minimise defects and to control grain growth during MAM. Powder bed fusion (PBF) processes, i.e., selective laser melting (SLM) and selective electron beam melting (SEBM), are the major forms of MAM. This presentation focuses on SLM.

Important features of PBF processes are small melt/track sizes and high beam scan speeds which result in both growth velocities and temperature gradients being considerably higher than those in other melting and solidification processes. In this presentation, that studies on defect formation mechanisms and solidification modes have been increasingly intensified will be briefly shown. Our recent contributions will also be briefly shown: (1) demonstrating how laser power affects the geometrical features of tracks and in turn affects the level of normal lack of fusion (LOF), (2) revealing for the first time how large spatters cause large LOF defects and how laser power dependent penetration may mitigate these large LOFs, (3) revealing how scan strategy related heat flux direction affects cell growth direction during epitaxial solidification, and (4) theoretically explaining why planar growth is absent in SLM. LOF and the uncertainty of its control and the insufficient certainty of solidification modes leading to the various forms of microstructures are important links to the difficulty to predict mechanical properties of SLM parts.

Following the background information above, the major part of this presentation will show our measurement and analytical work on how laser power affects cell size and degree of preferred growth (texture). Our measurement suggests that cell size relates to the angle between cell growth direction and heat flux direction. This relation may be explained by the well established relationship between cell size and local cooling rate, which is the product of growth velocity and temperature gradient, during solidification. An attempt is also made to separate the effect of increasing laser power, which also affects the thermal condition during SLM, on cell size. Increasing laser power appears to reduce the portion of grains needing the 90 change of <100> growth direction during epitaxial growth. Thus, texture along SLM build direction becomes stronger as laser power increases. Although our current study focuses on the understanding of solidification during SLM, the presentation will concluded by explaining how cell size and texture in SLM parts (affected by laser power during SLM) may affect mechanical properties of SLM parts.





# Hybrid Additive Manufacturing: Integration of Multiple Additive Manufacturing Techniques to Achieve High Value Multifunctional Objects

Jonathan Stringer
The University of Auckland
j.stringer@auckland.ac.nz

Additive manufacturing (commonly embodied as 3D printing) is of growing interest due to inherent advantages in achievable part complexity and consequent design freedom. While this has led to a wide variety of applications in fields as diverse as aerospace, medical prostheses and haute couture, the designer of an item is still confined to making the object from similar materials due to how the object is fabricated in the manufacturing process. To truly enable the manufacture of multifunctional parts in an additive fashion, it is necessary to fabricate not only the geometry of the final part, but also any functional components during the fabrication process.

Digital printing technologies, such as inkjet printing, are ubiquitous in the office environment, and can also be thought of as additive manufacturing technologies. In addition to graphical applications, they have also been researched extensively for use in 3D printing, bioprinting, and printed electronics. Hybrid additive manufacturing looks at combining 2 or more additive manufacturing techniques so that an object can possess both geometrical complexity and embedded functionality.

Work that has been carried out to achieve this goal will be presented, with discussion of the how the disparate workflows can be best integrated to obtain a multifunctional part. The fabrication of a demonstrator that uses prefabricated electronic components, printed conductive tracks and 3D printed geometry will be used as an initial case study.

## AUT process and material alternatives for Additive Manufacturing; The anomalies

Sarat Singamneni
Auckland University of Technology
sarat.singamnen@aut.ac.nz

Widespread research interest and developments around the world gradually led additive processes to be viable manufacturing options in specific applications. However, lack of understanding of the process-structure relations and fewer materials choices hampered the widespread use of the technology for true industrial applications. Consequently, process enhancements and alternative materials became the focus of Additive Manufacturing research across different research platforms in New Zealand and elsewhere. AM research at AUT played its role in this endeavour contributing towards both process evaluation, understanding and enhancement and experimental assessment and identification of alternative materials, as part of the activities of funded research programs such as the Product Accelerator. Mixed-mode slicing and optimised raster orientation approaches for extrusion printing, polymer nano- and bio- composites, metal ceramic material options have been developed. While establishing these new materials for AM has been the main objective, research results however pointed to certain anomalies arising out of the consolidation mechanics and possible bye-products.

Evaluation of the interactions between inter-strand coalescence and raster orientations led to the understanding that certain combinations of critical process and raster parameters result in negative Poisson's ratios in extrusion printed parts. This allows for developing auxetic materials through controlled extrusion 3D printing of selected polymer and polymer composite materials. Biopolymer options such as PMMA plus B-TCP composites were proved to be suitable for AM, but the process-structure relationships indicate the material consolidation mechanics to be amenable to the much adored stretch towards 4D printing. While experimentally establishing duplex stainless steels as viable alternatives for AM, extremely varying magnetic responses were noted together with abnormal machinability attributes. This presentation highlights these anomalies, elucidating the possible roles they may play in future research directions.





## Investigation of the temporal spacing effect on fused deposition modelled part properties

Ferreira, Arno; Arif, Khalid; Potgieter, Johan
School of Engineering and Advanced Technology, Massey University, Auckland 0632, New Zealand
A.Ferreira@massey.ac.nz
K.Arif@massey.ac.nz
J.Potgieter@massey.ac.nz

The quality and strength of all 3D printed parts is highly influenced by the build parameters such as raster orientation, layer thickness, road width, etc. The effect of these parameters is even more pronounced for processes like fused deposition modelling (FDM) where the parts are built by extrusion and disposition of material. Due to this reason, characterization of FDM for mechanical properties has been undertaken by many researchers using one or more parameters. Nevertheless, many unexplored influential factors still exist and are yet to be examined. For example, the printers used during characterisation studies normally limit full control over print parameters as well as the materials that can be used for building the test parts. Additionally, factors like the life of the printer also have the potential to affect the print quality but this has not been studied before and is the main focus of this research.

In order to investigate the effect of machine's life on the properties of printed parts, a longitudinal study was designed by setting up two groups (with 0° and 90° orientations) which were printed at different times with a temporal spacing of eighteen months. Samples were designed in accordance with the ASTM D638 Type I standard and manufactured on identical machines (Stratasys Fortus 450mc) and print parameters. The samples were characterized through tensile testing and with fracture and topological surface analysis using a scanning electron microscopy.

Tensile test results show a difference between the Young's moduli of the old and new sample groups. The diffusion levels between the chronological samples also exhibit a distinct difference with the original batch exhibiting greater diffusion. This diffusion results in almost indistinguishable layers with higher tensile strengths. The print layers are easily observed in the newer samples. Topographical analysis of the two sample groups exhibits a difference of up to 0.1 mm between the road widths with the older samples having narrower roads. Results from this research show that the age of a printer affects the mechanical properties of parts. Older parts exhibit greater strength compared to their new counterparts with the old parts being manufactured when the machine had fewer hours of use. Therefore, a significant difference exists between temporally spaced FDM parts.

In conclusion, a longitudinal study has been conducted studying the effects of machine age on the mechanical properties of printed parts. Findings show that as the printing machines get older their print quality deteriorates a factor that should be considered by designers and engineers when using FDM for functional as well as critical prototyping applications.

## Characterisation of 3D printed, rubber-like material for product design and fabrication

Noble, Frazer K.
Massey University
f.k.noble@massey.ac.nz

Yuan, Xiowen
Massey University
xw.yuan@massey.ac.nz

Rubber and rubber-like materials are used widely in industry; they can support large strains without breaking (several hundred percent or more), have good mechanical strength (typically 10 – 21 MPa), and can, readily, be found in hardness ranging from 95 to 5 Shore A. Furthermore, a diverse range of products are manufactured using rubber, e.g. boots, shoes, balls, gloves, tyres, sealants, and seals, across a wide range of industries, using classical methods such as injection moulding, compression moulding, and extrusion.

With the development of new additive manufacturing technologies, 3D printing of rubber and rubber-like materials is now feasible. However, these materials' static and dynamic properties are not yet, fully, understood; impeding their use in the design and fabrication of new, additive manufactured products.

Massey University's Centre for Additive Manufacturing (CAM) is equipped with a range of 3D printers; in particular, a 3D System's Projet MJP 5500x multi-material machine, which can print parts with non-homogeneous stiffness, i.e. parts that are plastic-like in some regions and rubber-like in others. The purpose of this study is to characterize the Projet machine's 3D printed material to aid in the design and fabrication of new and novel products.

This paper describes the test standard used, the 3D printer's settings, our experimental set-up and procedure, and presents and discusses our results. We show that for an increasing proportion of rubber-like material, the 3D printed parts' stress-strain relationships change from being similar to rigid plastics, e.g. High Density Polyethylene (HDPE), to being dissimilar to rubber, e.g. Natural rubber (demonstrating a linear relationship between stress and strain).





## Developing the 3D Printing Ecosystem in New Zealand

Collins, Jim
Fuji Xerox New Zealand
jim.collins@nzl.fujixerox.com

Whilst the 3D printing industry in New Zealand has evolved and created many opportunities for local businesses and institutions to develop applications and new products from 3D printing technologies, organisations are also realising that the success of bringing a 3D printed product to market relies on a robust ecosystem of service and solutions providers. Since 2013, Fuji Xerox has been partnering with 3D Systems, the inventor of 3D printing to bring the best-in-market 3D printing technologies to the New Zealand marketplace. In this presentation, we will share our experience of what organisations should watch out for and consider when investing in the 3D printing technologies through case study sharing.

# Flux Pump Brushless Exciters for Superconducting Generators

Chris W. Bumby
Robinson Research Institute, Victoria University of Wellington,
chris.bumby@vuw.ac.nz

Andres E. Pantoja
Robinson Research Institute,
Victoria University of Wellington
olly.pantoja@vuw.ac.nz

Zhenan Jiang
Robinson Research Institute, Victoria University of Wellington
zhenan.jiang@vuw.ac.nz.

Rodney A. Badcock
Robinson Research Institute, Victoria University of Wellington
rod.badcock@vuw.ac.nz

Synchronous generators employing rotor coils wound from high-Tc superconducting (HTS) wire, are attractive for a range of applications requiring very high torque and power densities. However, the injection of large DC currents into rotating HTS coils presents a technical challenge. In this paper we discuss the development of a new type of brushless-exciter for HTS rotors, which is based on a dynamo-type HTS flux pump. This device applies a rotating magnetic field across the cryostat wall which leads to the injection of a DC superconducting current into the rotor coil circuit.

Our approach fundamentally reduces the thermal load upon the cryogenic system by removing the need for thermally inefficient normal-conducting current leads. It also obviates the need for high current slip-rings which can be subject to very high wear rates.

We report results from an experimental laboratory device and show that it behaves as a constant DC voltage source with an effective internal resistance. We then discuss the design of a prototype brushless exciter based on our experimental device, and describe its integration with a demonstration 10 kW HTS generator. We estimate the thermal load presented by our prototype exciter, and show that this can be further minimised by utilising duty cycle operation of the device. In this manner, the steady-state heat load is reduced by more than an order of magnitude below that of equivalently-rated metal current leads.

References:

1. Z. Jiang et al., Appl. Phys. Lett. 105, 112601 (2014)

2. Z. Jiang et al., Supercond. Sci. Technol. 28, 115008 (2015)

3. C.W. Bumby et al., Supercond. Sci. Technol. 29, 024008 (2016)

4. C.W. Bumby et al., Appl. Phys. Lett. 108, 122601 (2016).





# Enhanced laser ablation of bone tissue using ultrafast pulsed Bessel beams for applications in LASSOS

Ashforth, Simon A.; Aguergaray, Claude; Simpson, M. Cather
Department of Physics, The University of Auckland

School of Chemical Sciences, The University of Auckland

Photon Factory, MacDiarmid Institute for Advanced Materials and Nanotechnology
Dodd-Walls Centre for Photonics and Quantum Technologies
s.ashforth@auckland.ac.nz

Femtosecond laser pulses have shown the ability to perform extremely precise cutting of materials and tissues on a subcellular scale. Their extremely short pulse widths have the ability to cut and shape materials through a 'cold-cutting' mechanism [1,2]. Several studies have shown promising results with increased precision and accuracy over mechanical tools with limited heat affected zones (HAZ) in the form of thermal cracks, molten material deposition and carbonization [3-9]. Whilst these results show promise, the main criticism of the LASSOS tool is their limited cutting speeds compared to mechanical tools. Using a femtosecond pulsed laser system (pulse width = 100 fs, repetition rate = 500 Hz, λ=800 nm), a zero-order Bessel beam was generated using a LCOS-Spatial light modulator. The ablation threshold of bovine and ovine load bearing cortical bone was identified using the method of least damage and found to be irrespective of the target species at th = 0.15 ± 0.03 J.cm-2. The ablation threshold for a zero-order Bessel beam is significantly reduced compared to those determined for Gaussian beams in bovine and ovine cortical bone (Load Bearing: th = 0.91 ± 0.03 J.cm-2, Skull: th = 1.19 ± 0.06 J.cm-2). Furthermore, no incubation effects were found as shown by the calculated incubation coefficient ζ = 0.93 ± 0.06.

The relationship between tissue removal and number of pulses applied was also examined by altering the translation rate of the sample under the incident laser effectively changing the number of pulses applied at each point along the linear ablation features. Cross sections of the ablation features were imaged and depths measured using scanning electron microscopy (SEM). At similar fluences and pulse numbers, the ablation depth achieved with zero-order Bessel beams were greater than those created with Gaussian beams, as shown in Fig. 1 in bovine cortical bone. Ablation rates were also significantly higher for Bessel beams compared to Gaussians beams with rates ranging from 2.69 – 13.21 ± 0.05 µm pulse-1 (bovine) and 2.49 – 12.79 ± 0.03 µm pulse-1 (ovine) for fluence between 2.5 and 25 Jcm-2. All ablation features were inspected using SEM and optical microscopy for signs of a HAZ in the form of thermal shockwave cracking, molten debris deposition and charring of the tissue but none were found even at highest fluences and pulse numbers.

REFERENCES
[1] C. RULLIÈRE, [FEMTOSECOND LASER PULSES : PRINCIPLES AND EXPERIMENTS] SPRINGER, NEW YORK(2005).

[2] K. SUGIOKA ET AL., "ULTRAFAST LASERS-RELIABLE TOOLS FOR ADVANCED MATERIALS PROCESSING," LIGHT-SCIENCE & APPLICATIONS, 3, (2014).

[3] B. GIRARD, ET AL., "EFFECTS OF FEMTOSECOND LASER IRRADIATION ON OSSEOUS TISSUES," LASERS IN SURGERY AND MEDICINE, 39(3), 273 (2007).

[4] B. EMIGH, ET AL., "PORCINE CORTICAL BONE ABLATION BY ULTRASHORT PULSED LASER IRRADIATION," J BIOMED OPT, 17(2), 028001 (2012).

[5] G. NICOLODELLI, ET AL., "INFLUENCE OF EFFECTIVE NUMBER OF PULSES ON THE MORPHOLOGICAL STRUCTURE OF TEETH AND BOVINE FEMUR AFTER FEMTOSECOND LASER ABLATION (VOL 17, 048001, 2012)," JOURNAL OF BIOMEDICAL OPTICS, 17(4), (2012).

[6] L. T. CANGUEIRO, ET AL., "FEMTOSECOND LASER ABLATION OF BOVINE CORTICAL BONE," JOURNAL OF BIOMEDICAL OPTICS, 17(12), (2012).

[7] Y. C. LIM, ET AL., "MICROPILLAR FABRICATION ON BOVINE CORTICAL BONE BY DIRECT-WRITE FEMTOSECOND LASER ABLATION," JOURNAL OF BIOMEDICAL OPTICS, 14(6), 064021-064021-10 (2009).

[8] V. WIEGER, S. ZOPPEL, AND E. WINTNER, "ULTRASHORT PULSE LASER OSTEOTOMY," LASER PHYSICS, 17(4), 438-442 (2007).

[9] S. ASHFORTH, ET AL., "INVESTIGATING ULTRASHORT LASER PULSES AS A LASER SCALPEL FOR ORTHOPEDIC SURGERY," OSA TECHNICAL DIGEST. AW40.1.

# Development of continuous reel-reel pilot manufacturing processes for production of superconducting Roebel cable

Rodney A. Badcock
Robinson Research Institute, Victoria University of Wellington
rod.badcock@vuw.ac.nz
Chris W. Bumby
Robinson Research Institute, Victoria University of Wellington,
chris.bumby@vuw.ac.nz
Nicholas J Long
Robinson Research Institute, Victoria University of Wellington
nick.long@vuw.ac.nz.
Kent Hamilton
Robinson Research Institute, Victoria University of Wellington,
kent.hamilton@vuw.ac.nz

HTS coated conductor wires comprise a thin (~ 1 µm) quasi-epitaxial ceramic film which is deposited upon a metal substrate and produced in continuous long lengths up to 1 km. The very high engineering current densities achievable (up to 200 A/mm2), make this a highly promising material for next generation high field magnets and machines. In power applications employing HTS wires, it is necessary to have high current, low ac-loss, cables of several kilo amps capacity. In conventional copper conductors this is accomplished by the formation of Roebel bar or continuously transposed cable We have applied these same principles to high temperature superconducting (HTS) coated conductor wires to produce HTS Roebel cables that are manufactured using reel-reel processes in long lengths and deliver several thousand amps capacity .

A pilot manufacturing plant has been developed. A key process is the shaping of coated conductor wire into the required "serpentine" strands required for the production of HTS Roebel cable. We have shown that this can be achieved by blanking-die punching within a reel-to-reel process, where in-plane shear is minimised to prevent crack propagation within the ceramic thin film, and accurate position feedback control achieved using feedthrough encoders and incremental error correction. We have also developed a new process to automatically wind up to 15 serpentine strands into a continuously transposed cable, using a non-centro-symmetric winding approach which prevents the fragile ceramic film being subjected to large out-of-plane bending stresses.

This manufacturing process technology has been transferred to GCS Ltd who are the only commercial manufacturer of HTS Roebel cable worldwide. Long cable lengths have been supplied commercially to many high technology applications including superconducting generator development at Siemens AG , beam line coil research at CERN , State Grid (China) and many others.

In this presentation we discuss the manufacturing and QA processes implemented for producing long length Roebel cables using coated conductors, and show that cables up to 100 m in length can be produced with current capacities of > 1500 A @ 77 K, and > 20 kA at liquid helium temperatures. We also discuss the reel-reel insulation and cable reinforcement processes required to produce viable high field magnets using this cable. Finally we conclude by presenting examples of some large-scale applications of our HTS Roebel, including an 1 MW HTS transformer.

Badcock, R. A., Long, N. J., Mulholland, M., Hellmann, S., Wright, A., & Hamilton, K. A. (2009). Progress in the manufacture of long length YBCO Roebel cables. IEEE Transactions on Applied Superconductivity, 19(3), 3244-3247.

Long, N. J., Badcock, R. A., Hamilton, K., Wright, A., Jiang, Z., & Lakshmi, L. S. (2010). Development of YBCO Roebel cables for high current transport and low AC loss applications. In Journal of Physics: Conference Series (Vol. 234, No. 2, p. 022021). IOP Publishing.

Kummeth, P., Nick, W., Van Hasselt, P., Frank, M., Kuhnert, A., Oomen, M., & Arndt, T. (2015). Design and development of a test rig for HTS generator components. IEEE Transactions on Applied Superconductivity, 25(3), 1-4.

Lorin, C., Segreti, M., Ballarino, A., Bottura, L., Durante, M., Fazilleau, P., ... & Rifflet, J. M. (2015). Cos-$\ theta $ design of dipole inserts made of REBCO-Roebel or BSCCO-Rutherford cables. IEEE Transactions on Applied Superconductivity, 25(3), 1-5.



ORAL ABSTRACT - PARALLEL SESSION 2c *RANGITOTO 3*

# Natural fibre and natural fibre composites: surface modification, processing and functionalization

Yuan, Xiaowen; Wu Heng Cheng, Laifei; Cao, Peng
Centre for Additive Manufacturing, School of Engineering and Advanced Technology, Massey University, Auckland 0632, New Zealand
Science and Technology on Thermostructural Composite Materials Laboratory, Northwestern Polytechnical University, China
Department of Chemical and Materials Engineering, The University of Auckland
Auckland, New Zealand
xw.yuan@massey.ac.nz

Researchers worldwide have been engaged in developing materials utilizing natural resources instead of petroleum-based products. Natural fibre and natural fibre composites have attracted great attention in the last ten years due to their cost effectiveness, low density, high specific strength and stiffness, nature, and environmental friendliness. The high cost of carbon fibres, and their composites have limited their wider application due to the high cost and the use of unsustainable raw materials in manufacturing. Therefore, it is desirable to prepare carbon fibres or activated carbon fibres from biomass-based natural fibres, and to fabricate composites incorporating carbonised fibres. This research is to investigate the potential of fabricating carbon fibres composites using natural cellulosic materials, such as natural fibres. Surface modification and processing will be discussed. The composite performance is evaluated by analysing the tensile strength, flexural strength and thermal insulation properties. The morphologies of the fibre surface and composites interface, mechanical and thermal properties, structure-processing-performance relationship are investigated and correlated. In particular, the fracture and deformation mechanisms of the composites are studied.

# Functionalised polymers for more efficient nanosecond UV laser micromachining

W. J. Brodie, Graham; Kang, Hong; Ward, Thomas; MacMillan, Fraser; Jin, Jianyong; Simpson, M. Cather

Photon Factory, MacDiarmid Institute for Advanced materials and Nanotechnology, and Dodd-Walls Centre for Photonics and Quantum
School of Chemical Sciences, The University of Auckland, Auckland, New Zealand
Department of Physics, The University of Auckland, New Zealand
t.ward@auckland.ac.nz
all authors contributed to this work equally

Pulsed laser ablation is a valuable tool which offers much cleaner and more flexible etching process than conventional lithographic techniques. Although much research has been undertaken on commercially available polymers, many challenges still remain, such as contamination by debris on the surface, a rough etched appearance and high ablation thresholds1,2.

Functionalizing polymers with a photosensitive group is a novel and effective way to improve the efficiency of laser micromachining3. The Polymers in this study (PMMA and polyurethane) have been grafted with different concentrations of anthracene, a chromophore which has a high absorption at 248 nm. A series of lines etched with a changing number of pulses and fluences by a nanosecond laser were applied to each polymer film. The resultant ablation behaviours were studied through optical interference tomography and Scanning Electron Microscopy. The anthracene grafted polyurethanes showed a vast improvement in both edge quality and presence of debris compared to the unmodified counterpart. Under the same laser fluence and number of pulses the spots etched in the anthracene contained polyurethane show sharp depth profiles and smooth surfaces, whereas rough cavities with numerous debris can be observed for the case of standard polyurethane

We find that even at low etching fluence (0.12 J cm-2), the anthracene contained polyurethanes can still be etched efficiently at low pulse numbers. Threshold fluences of each sample show a general decreasing trend with the increasing of chromophore monomer concentration although there is not a significant decrease beyond 5.89% anthracene. We note that the addition of a small amount of anthracene (1.47%) shows a reduction in ablation threshold showing that the desired effect can be achieved with minimal alteration of the polymer. These types of anthracene grafted samples designed for 248 nm laser ablation can greatly improve machining without significantly altering the mechanical integrity of the polyurethane which is, for example, very attractive for their use with medical devices4.

References:

(1) M. Damaceanu, et al. "Laser Ablation of Polyimide Thin Films." In CAS 2010 Proceedings (International Semiconductor Conference); IEEE, 2010; pp 231–234.

(2) K. Suzuki, et al. "Polymer Resist Materials for Excimer Ablation Lithography." Appl. Surf. Sci. 1998, 127–129, 905–910.

(3) E. Biver, et al. "Influence of Pyrene Grafting on PMMA Nanosecond Laser Ablation at 248 Nm." ACS Appl. Mater. Interfaces 2014, 6 (1), 41–48.

(4) R. Estevam-Alves, et al. "UV Direct Laser Interference Patterning of Polyurethane Substrates as Tool for Tuning Its Surface Wettability." Appl. Surf. Sci. 2016, 374, 222–228.





# High accuracy personalised manufacturing to assess ballistic damage to the human cranium

Kwon, Eryn; Fernandez, Justin; Taylor, Michael; Bickerton, Simon
Centre for Advanced Composite Materials, The University of Auckland, New Zealand
Auckland Bioengineering Institute, The University of Auckland, New Zealand
Institute of Environmental Science and Research, Christchurch, New Zealand
eryn.kwon@auckland.ac.nz

Biological structures such as the human head are complex in geometry, with high variability between individuals. This poses a challenge when manufacturing a model for crime scene investigation. After a crime occurs, a personalised model of the victim may be required in order to test the hypothesis and aid crime scene reconstruction for a court presentation. For crimes of a large gravity such as ballistic homicide, high accuracy of such a model is essential for a fair trial. Conventionally, animals have been used to conduct forensic experiments. But the disparity from human geometry and material properties (as well as ethical concerns) have driven a need for a physical replica of a human cranium model.

The two major factors affecting the accuracy of a physical model are the material reaction and the geometry. The simulant materials must replicate the response of the biological structures, while the geometry of the model must match with the victim as closely as possible to reduce the uncertainties associated with the experimentation. A correct model will absorb similar kinetic energy from the bullet, retarding the bullet speed at a similar rate, while replicating all characteristics of a typical cranial gunshot wounding such as bevelling, temporary cavitation, amount and position of the crack propagation and blood spatter generation in a similar way to that of the victim's head would have produced.

In this study, a physical model based on a live human MRI scans were constructed and tested. The cranial MRI images (0.9 mm voxel resolution) are first digitized into three separate layers; Skin-Skull-Brain. The digitised geometry was checked for manifold edges and continuity using computer aided design software. The finalised geometry was made into a model geometry using a 3D printer. Multiple samples of the model were produced using silicone moulds with a positioning box for a ballistic testing with a 9 mm calibre bullet. The simulant materials were selected based on ballistic testing results to possess similar ballistic response to that of human materials. Once the personalised virtual geometry is established, the manufacturing time required for sample generation is around 5 hours per sample, limited by the curing time of the simulant materials used.

Upon ballistic testing, the physical model samples exhibited many characteristics similar to human cranial wounding as reported in the literature. The physical model is faster to prepare and easier to store than compared to animal samples. The multiple identical replicate samples allow repeated testing, a scenario which is impossible when using only animal samples.

In summary, this work provides a promising platform for highly personalised rapid prototyping of a complex biological structure such as human craniums, which is a valuable tool in the forensic industry. Additionally, these same technology could be applied to create a highly accurate and personalised model for use in the medical fields, such as surgical training or implant design.

# Prestress and Pretorsion of Elastomer Composites for Self-morphing Soft Robotic Structures

Dirven, Steven
School of Engineering and Advanced Technology, Massey University
s.dirven@massey.ac.nz

Soft robotics is a rapidly-expanding biomimetic engineering field which is yet to make the transition from fun, to functional. In science, it has diverse biomimetic applications ranging from emulating the physical functions of bodily organs (e.g. Esophagus, Heart, Stomach), to exploring the structure, and motion, of invertebrate organisms such as octopuses, squid, worms and caterpillars.

In order to apply soft robots to useful tasks, both forward and inverse modelling are required to describe their pose, and how they move, in 3D space. However, by design, their structures no longer embody the constraints of links and joints, which were requisite in rigid robotics and form the basis of traditional forward and inverse spatial-modelling techniques. In order to describe the continuum deformation exhibited by soft robotic structures a paradigm shift in modelling approaches is required for the field to flourish. Thus, soft robotic design, actuation, and modelling are closely linked.

The challenge for any self-morphing structure, is to store or harness energy in a form that can be released in an organized manner. In this paper, this is achieved by embedding prestressed and pretorsioned elastomer fibre into an elastomer matrix. Fiber diameter (bond surface), stress (energy source), hysteresis behaviour (energy source) and matrix volume (sink) each contribute to the structure's final equilibrium state. The current work demonstrates preliminary modelling and experiments aimed towards developing more complex self-morphing soft-robotic structures.

The techniques are being applied to facilitate design of mechanically-programmed structures for gripping and grasping of delicate, perishable, horticultural goods during-, and immediately post-, harvest. During manufacture, the actuators begin almost flat, and are created with embedded flexible sensors. When they are to be deployed they will passively rise, and step free, from their shallow moulds, self-morphing via mechanical programming to form larger, 3 Dimensional, functional, gripper structures.

This paper presents a radically novel approach to soft robotic design, conceptualisation, and modelling. By design, the techniques cater for the exploitation of self-morphing soft robotic structures that can change behaviour in response to environmental stimuli, an area of research which is under-developed. The outcomes of this project will fundamentally change how the discipline of soft-robotics is approached, reducing the mystery in an otherwise grey art.

References:

(1) M. Damaceanu, et al. "Laser Ablation of Polyimide Thin Films." In CAS 2010 Proceedings (International Semiconductor Conference); IEEE, 2010; pp 231–234.

(2) K. Suzuki, et al. "Polymer Resist Materials for Excimer Ablation Lithography." Appl. Surf. Sci. 1998, 127–129, 905–910.

(3) E. Biver, et al. "Influence of Pyrene Grafting on PMMA Nanosecond Laser Ablation at 248 Nm." ACS Appl. Mater. Interfaces 2014, 6 (1), 41–48.

(4) R. Estevam-Alves, et al. "UV Direct Laser Interference Patterning of Polyurethane Substrates as Tool for Tuning Its Surface Wettability." Appl. Surf. Sci. 2016, 374, 222–228.





# Developing a 3D printer for the manufacture of cellulose hydrogels

Huber, Tim
Biomolecular Interaction Centre
University of Canterbury
Department of Chemical and Process Engineering
University of Canterbury
tim.huber@canterbury.ac.nz

Clucas, Don
Department of Mechanical Engineering
University of Canterbury don.clucas@canterbury.ac.nz

Vilmay, Mathieu
mathieu.vilmay@canterbury.ac.nz

Pupkes, Birte
birte.pupkes@canterbury.ac.nz

Stuart, James
Department of Physics
University of Canterbury
jss84@uclive.ac.nz

Dimartino, Simone
simone.dimartino@ed.ac.uk

Fee, Conan
School of Product Design
University of Canterbury
conan.fee@canterbury.ac.nz

Cellulose is a biopolymer that has successfully been used in its hydrogel form for many applications ranging from contact lenses, purification and filtration systems and tissue engineering. However, processability, shapeability and especially "3D printability" are strongly limited by the necessity of using an appropriate solvent because cellulose is neither melt-processable nor curable. Thus, making complex, 3D dimensional structures from unmodified cellulose has remained extremely challenging. As a result, despite its enormous potential, 3D printing of cellulose is mostly unexplored.

Aqueous solutions of sodium hydroxide and urea are low-cost solvents for cellulose, working at sub-ambient temperatures. These cellulose solutions can be gelled rapidly and effectively irreversibly by increasing the solution temperature to 50 °C and above, making it an attractive system for 3D printing processes.

The required thermal energy can be transmitted by Laser light. Laser guiding optics require beam collimation and focussing to achieve a beam with a narrow profile, resulting in a minimum beam width of approximately 50 µm. In our work, by focussing the beam onto the surface of the cellulose solution and controlling the 2-dimensional movement of the beam, paths of gelled material with a width of 100—150 µm have been created. Thus, in analogy with UV-based 3D printing, we will describe herein the use of thermal energy in the form of light as a mechanism to gel cellulose locally and layer-by-layer to create a three-dimensional structure for the first time. A detailed description of the iterative printer design process will be presented.

Three processing parameters, namely speed of x-y movement, applied laser power and layer thickness, all factors directly effecting the volume of solution gelled per time unit, were found to be crucial variables for producing printed objects of high quality. Additionally, because of the thermo-sensitive nature of the cellulose solution, careful temperature control was required to prevent undesired solidification of the solution. We will describe the printer design and development from preliminary first trials to its current state.

# Minimising Defects and Improving Manufacturing Processes of Composite Structures Produced via Liquid Moulding

van Oosterom, Sam; Bickerton, Simon
Centre for Advanced Composite Materials,
The University of Auckland
svan556@aucklanduni.ac.nz, s.bickerton@auckland.ac.nz

Fibre reinforced plastics (FRPs) are complex materials that utilise an array of constituents, creating materials with highly anisotropic properties. Their favourable strength and stiffness is leading to increasing application in high performance applications. Utilisation of FRPs in parts of increasing complexity leads to increases in the risk of defects being introduced during manufacturing processes.

The presence of defects in high cost, high performance parts can be detrimental to both structural integrity and aesthetic appeal. With their continued integration into large scale manufacturing processes, questions arise concerning:

- What is classed as a defect?
- At what stages of the process chain are they introduced?
- How were they formed?
- What methods can be utilized to detect them?
- What is their influence on the part and process?
- How can they be prevented or their effects mitigated?

By answering these questions there is the potential for both the material and manufacturing costs of FRPs to be significantly reduced.

Understanding defects requires a clear definition of the types of defect of concern, and how to distinguish between acceptable variation and an unacceptable defect. The points at which these defects are introduced to the manufacturing process must be determined, as locating this is the first step in understanding and ultimately removing that defect from the production process. A complete understanding of the defect formation mechanism and key process parameters that influence its inception must be established, and a variety of techniques and technologies exist that can be implemented to locate and designate these. Once the processes through which a defect is introduced and formed in a product have been determined, the effects of the defect must be investigated and quantified.

The focus of this research is refinement of manufacturing processes to produce high quality parts at the lowest cost. Manufacturing processes that involve infusion of an epoxy resin through reinforcements of carbon or glass fibre are the target, with fibre wrinkles and folds being common defects. Through the use of non-destructive measurements on fibre reinforcing materials in the process chain, process feedback loops will be established to determine what variations in material and process parameters have on the final product. This feedback can be utilized to determine the key parameters/properties that affect part quality, and the acceptable level of variability of these in the manufacturing process.

Once the key parameters in the manufacturing process have been identified, processes can be modified to maximise the acceptable level of variability. The acceptable level of variability in the manufacturing process can then be determined, and used to minimise the number of defective parts while maintaining wide enough parameters to keep costs low.

By implementing non-destructive testing, process data recording, and final part analysis, a historic manufacturing database can be developed. This can be utilised to clearly define the acceptable range of parameters at each stage of production, allowing parts with a high likelihood of developing unacceptable defects to be removed before further cost is incurred.

# PC-based automation provides a solid technological foundation for Industry 4.0 architectures

Pearce, Neil
Beckhoff Automation Limited
n.pearce@beckhoff.co.nz

Industry 4.0 or Industrial IoT is a hot topic in the world of smart / high-tech manufacturing at present and there are different perceptions out there as to what it is, what the benefits are, how it needs to be implemented as well as potential risks and associated costs.

The focal point of Industry 4.0 is commonly identified as the convergence of IT (Information Technology) and AT (Automation Technology); the resulting technology is PC-based Control; an automation solution that German based BECKHOFF Automation has pioneered for over 30 years.

BECKHOFF Automation is one of the driving forces among the 24 core companies of "it's OWL" which is considered to be the largest and most concrete projects in the context of Industry 4.0 and has delivered two projects for Scientific Automation and eXtreme Fast Automation applications.

BECKHOFF Automation's control platform is known as TwinCAT 3. The TwinCAT software transforms almost any PC-based system into a real-time control with multiple PLC, NC, CNC and/or robotics runtime systems. The TwinCAT engineering and control software, integrated into the Microsoft® Visual packages are available for the creation of applications such as Big Data, pattern recognition as well as condition or power monitoring, in addition to traditional control tasks – which can sustainably increase production and engineering efficiency as a result. New software libraries are now available for advanced analytics and communication between controllers and cloud-based services.

With PC Control as a globally accepted platform that supports the ADS, EAP and OPC UA protocols, the prerequisites for the universal vertical and horizontal integration demanded by Industry 4.0 are already fulfilled.





# Augmented Reality-assisted intelligent window for Cyber-Physical Machine Tools

Liu, Chao
Department of Mechanical Engineering, The University of Auckland
cliu810@aucklanduni.ac.nz

Xu, Xun
Department of Mechanical Engineering, The University of Auckland
xun.xu@auckland.ac.nz

Machine tools have always been a main component in any manufacturing system. As we step into the era of Industry 4.0, an urgent need to advance current CNC machine tools to a higher level of connectivity, intelligence and autonomy, has also been raised. This project proposes a new generation of machine tools, i.e. Cyber-Physical Machine Tool (CPMT), inspired by recent advances in ICT such as Cyber-Physical Systems (CPS) and Internet of Things (IoT). CPMT is the integration of machine tool, machining processes, computation and networking, where embedded computers and networks can monitor and control the machining processes, with feedback loops in which machining processes can affect computations and vice versa. CPMT is an application of CPS in the manufacturing environment. Real-time data generated by machine tools and machining processes are captured using various sensors, data acquisition devices and cameras. Together with the feedback from the CNC controller, these real-time data from the physical world are transferred into the cyber space through various networks to build a Cyber Twin of the machine tool. The Cyber Twin, as a digital abstraction of the machine tool, has built-in computations that monitor and control the physical processes and provide the data to the cloud for further analysis. With extensive real-time data and computations deeply integrated with machining processes, CPMT requires advanced HMIs which allow users to intuitively interact with the system and make efficient decisions. Augmented Reality (AR) is a novel human-computer interaction technology that overlays computer-generated virtual information on the real world environment. AR enables intuitive and effective interactions between humans and CPS. Recent advances in AR technology have indicated great benefits and potential for implementing AR in manufacturing environment.

This poster presents an AR-assisted intelligent window for CPMT. The intelligent window is essentially an advanced Human-Machine Interface (HMI) which provides users with intuitive interactions with CPMT. The proposed intelligent window consists of four main functional modules, i.e. Real-time Control, AR-assisted Process Monitoring, AR-assisted Machining Simulation, and Process Optimization. An AR-assisted intelligent window for an EMCO Concept 105 milling machine is developed using a touch-screen computer. A Graphical User Interface which integrates the aforementioned functional modules is developed as the intelligent window. Real-time CNC feedback-based tracking method was applied for AR implementation to enable faster, more accurate and more reliable augmented graphics rendering. Experiments have been conducted to show the advantages of the AR-assisted intelligent window in comparison with traditional control panels. The experimental results have shown that the developed intelligent window can provide users with intuitive and comprehensive perception of the machining environment, allowing them to control, monitor and optimize the machining process in real time, as well as conduct high-fidelity machining simulation in real machining environment with real machining parameters

The experiments conducted in this research have shown great potential as well as various possibilities for implementing CPS and AR technology in the manufacturing environment. While CPS is able to endow manufacturing systems with advanced intelligence and autonomy, AR enables intuitive and efficient human-machine interactions between humans and CPS.

# Cloud-based Manufacturing Services for Smart Factories

Mubarok, Khamdi
Xu, Xun
The University of Auckland, New Zealand
kmub677@aucklanduni.ac.nz

xun.xu@auckland .ac.nz

Developments in Information and Communication Technology (ICT) have helped factory floors to become smarter and more autonomous. Industry 4.0 is an initiative of creating the smart factory of the future by integrating technologies such as Internet of Things, Cyber-physical Systems, and Internet of Services (Smart Services). At the same time, Cloud Manufacturing, a paradigm symbolizing the shift of manufacturing businesses from production-oriented to service-oriented, is gaining traction. Although Industry 4.0 and cloud manufacturing both focus on service-oriented architecture, the two concepts deliver services in different ways. In this paper, we propose a platform that unifies the services in cloud manufacturing and the ones in Industry 4.0 to provide embedded smart manufacturing services for smart factories. The characteristics of the smart factory in the context of Industry 4.0 and the current status of cloud manufacturing are discussed. It is believed that the advanced use of intelligent devices, easy access to virtual production facilities, and the high value of complex manufacturing data in a factory will influence the way how services are composed and delivered in the cloud. As these new features are made available to the manufacturing industry, there is a demand for various manufacturing services from initial product design to after-sales services. The technologies that can be used to support these services include Industrial Internet of Things, Cyber-physical Production Systems, Semantic Web, and Big Data analytics are discussed. A comprehensive approach to manufacturing services for smart factories is proposed. The initial requirements, system architecture and implementation procedure of the proposed platform are described. The future directions in this area are also discussed.





# Cyber-Physical 3D Printing System

Wang, Yuanbin
The University of Auckland
ywan821@aucklanduni.ac.nz

Xu, Xun
The University of Auckland
xun.xu@auckland.ac.nz

Currently additive manufacturing is not vastly used in industry as the process is slow, unreliable and susceptible to failure. The technological basis of cyber-physical systems can vastly improve different aspects of the operation and greatly increasing its ability to meet various, industry, manufacturing requirements. Therefore, improving its viability as an underutilised manufacturing method.

A cyber-physical system comprises of a physical system that is closely integrated with computational elements to improve adaptability, efficiency, reliability, and usability. The integration of cyber-physical elements with 3D printing and additive manufacturing is a relatively unexplored field, with limited development and technology. A Cyber-Physical 3D printer with remote control and monitoring capabilities saves both time and material in the printing process. It turns a printing system into a smart printer. The increased efficiency and quality through effective intercommunication between machines enables additive manufacturing to go beyond small batched and high complexity component production to a mainstream manufacturing process.

An essential aspect of this system is a strong information model. Utilising a reliable and efficient method of data collection, conversion of the raw data into useful information for physical application, central storage of global information where computational elements form decisions which are then carried our through actuators. Through the use of AstroPrint software and MT Connect information modeling protocols a foundation has been formed. Creating a 3D printer with wireless accessibility, remote monitoring capabilities and core pillars of an information model.

Further development and improvements to this system with the addition various functionality and feature in both physical and computation aspects to improve adaptability and autonomy will see the full realisation the Cyber-Physical 3D Printer.

# Improving the rate of crystallization of Polylactic acid (PLA) on open source 3D printers

Harris, Muhammad; Arif, Khalid; Archer, Richard; Potgieter, Johan
School of Engineering and Advanced Technology, Massey University
J.Potgieter@massey.ac.nz

Polylactic acid (PLA) is one of the most common types of 3D printing material, known for its renewability and biodegradability. PLA is extensively researched to improve its parameters like tensile, flexural, and impact strength and elastic modulus through investigation of control variables like layer thickness, layer width, speed of printing, feed rate, extruder temperature and bed temperature.

PLA is made from dimers of D-Lactide or L-Lactide obtained through the fermentation of starch from natural plant sources like wheat or corn. The quantity of D-Lactide directly influences the degradation and crystalline structure, the low values of which are credited to more crystallinity. However, despite the lowest optimal amount of D-Lactide, the problem faced by PLA is the low rate of crystallization. This hinders the growth of crystal structure inside the amorphous material and causes the lowering of tensile strength and other mechanical properties. The literature lacks the idea of improving the rate of crystallization without addition of nucleating agents through the introduction of ambient temperature near Tg (temperature of crystallinity). It is also noticed that the commercial 3D printers do not print PLA as it is mostly printed with open source small 3D printers, which lack the ambient heating mechanism.

This research introduces a technique of improving the rate of crystallization of PLA through heating the samples with surrounded heating elements while being fabricated on small 3D printers. This heating prolongs the time of distribution of temperature from bed to the top of the FDM part. Tensile test according to ASTM standard are performed and the resulting data is analyzed using ANOVA to find the significant factor on the ultimate tensile strength. The microstructure of the fractured tensile test parts is also analyzed through SEM imaging.





# Ablation Rate Dependence on Material Bandgap and Pulsed Time Delay for Ultrashort Pulsed Dual Wavelength machining

Ward, Thomas; Aguergaray, Claude; Sorrenson, Peter; Simpson, M. Cather
The Photon Factory, The University of Auckland
The MacDiarmid Institute for Advanced Materials and Nanotechnology and The Dodd Walls Centre for Quantum and Photonic Technologies
School of Chemical Sciences, The University of Auckland
Department of Physics, The University of Auckland,
t.ward.@auckland.ac.nz

Ultrashort pulsed ablation is a processing technique that allows almost any material to be "cold cut". It allows precise microfabrication, while avoiding the associated heat effects of longer pulsed lasers. This is a promising processing technique in a variety of fields such as surgery, dentistry and microfabrication of electronics [1]. The key challenge with this method is the slow processing rate compared to other methods, hence lowering its economic feasibility.

In this study we used a dual wavelength approach using 400nm and 800nm pulses while varying the time delay between these two pulses to ablate our samples. It has been found that a dual wavelength approach ablates a greater volume compared to a single wavelength, and that there is an optimum time delay between the two pulses [2, 3]. The exact mechanism of this is still under investigation and we aim to shed further light on this through investigation of the dependence of the optimal time delay on the bandgap of the ablated material. We expect this to have affect due to the dependence of ablation type on both the incident light and the material bandgap.

Laser Ablation was carried out using an amplified Ti:Sapphire laser (Mantis (oscillator) and Legend Elite (amplifier), Coherent Inc., USA), which supplied 110fs pulses at a repetition rate of 1kHz, with a maximum pulse energy of approximately 3mJ. This was frequency doubled using a BBO Type 1 crystal (Altechna 0.5mm thickness) and the pulse delay was applied using a retro reflecting prism on a micrometre linear translation stage. The zero position was obtained implementing a second BBO crystal after the pulses are re-joined to produce 266nm light. To confirm the zero point we found the stage position at which 266nm light is output from the second crystal as it is only produced at the zero time delay point. This was observed using a UV passing filter to separate this from the other wavelengths.

To examine the effect of the bandgap on the optimal time delay five materials were selected. The incident light of 400 and 800nm correspond to energy values of 3.10eV and 1.55eV respectively. The chosen materials were silicon (1.03-1.13eV), kapton (2.04eV), alumina (6.07eV), quartz (9eV) and stainless steel. These materials cover a range of bandgaps both between and bridging that of the incident pulses, as well as investigating a metal. Preliminary results show that dual wavelength ablation significantly improves ablation rate. We see an improvement by over a factor of two compared to that of a single pulse.

References

1. Krüger, Jörg, and Wolfgang Kautek. "Ultrashort pulse laser interaction with dielectrics and polymers." polymers and light. Springer Berlin Heidelberg, 247-290, (2004)

2. Lin, Chih-Hsuan, et al. "Ablation of polymethylmethacrylate by two-color femtosecond synthesized waveform." CLEO: Science and Innovations. Optical Society of America, (2014).

3. Kamata, Masanao, et al. "Dual wavelength femtosecond laser materials processing." Lasers and Electro-Optics, 2007. CLEO 2007. Conference on. IEEE, (2007).

# Support Structures for 3D Printing

Jingchao Jiang; Xun Xu; Jonathan Stringer
The University of Auckland
jjia547@aucklanduni.ac.nz
xun.xu@auckland.ac.nz
j.stringer@auckland.ac.nz

The use of 3D printing and additive manufacturing technology has grown rapidly in recent years; with applications in areas such as aerospace, automotive and medical, as well as more traditional prototpying applications. One of the reasons for this rapid growth is the ease with which complex objects can be fabricated when compared to traditional subtractive methods. As the desired objects become ever more complex, it is inevitable that there are overhangs within the structure that require additional support material. This is to prevent collapse and reduce warping of the part, as necessitated by the additive manufacturing method used. This support material has to subsequently be removed, adding additional build time and cost to production of the part. By optimising the support structure and associated manufacturing parameters, it is therefore possible to significantly reduce the time and cost of parts fabricated by 3D printing. This work looks at how the support structures can be optimised, with particular focus on topological optimisation of the support structure to minimise resource utilisation in the printing process. Use of different support strategies will be discussed. It will also look at how different support structure optimisation techniques can be compared, and suggest suitable geometries to help standardise measurement of their relative effectiveness.





# Development of a Low Cost Inkjet 3D Printer

Dixon, Blair; Potgieter, Johan
School of Engineering and Advanced Technology, Albany, Massey University
B.J.Dixon@massey.ac.nz
J.Potgieter@massey.ac.nz

Existing commercial 3D printers that use inkjet technology are large and expensive. They do not allow much control to adjust printing parameters, meaning it is difficult to conduct research with different materials and binders. Due to these factors it is not viable to use one for research purposes. Therefore the aim of this project is to develop a low cost, powder based 3D printer that utilises inkjet printing technology. The 3D printer uses a standard drop-on-demand inkjet print head to deposit a binder onto the powder bed one layer at a time to build the desired object.

Based off of an open source design, the printer developed in this project has been customised to allow full control over printing parameters. The body of the printer is laser cut from acrylic. All mechanical components are off the shelf items wherever possible to keep costs down and allow the print area to be easily scaled. Custom made parts manufactured in house allow for the print head to be easily changed to whatever is needed. The print head used is refillable and can therefore be filled with custom binders.

For the purpose of this project the binder is deposited with an HP C6602A print head which is filled with regular black printer ink. The ink is deposited onto a bed of 3D Systems Visijet PXL core powder.

With the 3D printer developed in house, all aspects can easily be adjusted. Having full control over printing parameters will allow research to be conducted to develop new 3D printable powders and binders, or to improve the printing quality of existing powders and binders.

The 3D printer has also been developed so that it is easy to adapt to other features to increase its capabilities. With the addition of a UV light source, UV curable binders could be researched; or with the addition of a laser, powder sintering could be researched.

# Large scale printing in the dairy industry

Silver, Kevin; Arif, Khalid; Archer, Richard; Potgieter, Johan
School of Engineering and Advanced Technology, Massey University
J.Potgieter@massey.ac.nz

Additive manufacturing (AM) allows designers to build 3D parts of almost any geometry and streamline the process of getting from initial design to prototype in short times. However the existing processes/technologies are limited to small size parts only due to high resolution of the generally produced designs. If a very large part with typical layer resolutions of 0.025mm to approximately 0.2mm is produced, the time required for making such a part will be prohibitive. In addition the material costs (ranging from tens to thousands of dollars per kilogram) will be tremendously high and the machine size will need to be gigantic. An example of a large scale AM is printing of milk storage vat insulation and support structure.

As per dairy industry regulations, milk must be stored at a low temperature in a vat after collection from cows. Currently the milk vats are thick walled stainless steel tanks which are expensive to purchase and require a lot of insulation and constant cooling to keep the milk at the required temperature. The requirements for thermal insulation and mechanical strength are not easily achievable for passive cooling through conventional manufacturing technologies and therefore AM offer a great opportunity to achieve mechanical and thermal properties as and where needed.

This research aims at producing a milk vat insulation using an appropriate large scale AM technology. The main focus is on optimization of the structure of the vat insulation and support and selection/preparation of a lightweight low-cost material. The structures that have been considered are based on the structural and thermal requirements. Among many possibilities, fractal tree-like structure presents an encouraging option for its thermal resistance. This structure shows minimal to no heat loss at thicknesses of around 100mm. However it fails under the loads produced by the buckling of stainless steel tank. An alternative structure being studied is the honeycomb structure for its strength which is strong enough to overcome the buckling of the tank. The thermal resistance of the honeycomb however is poor. By combining the benefits of various structures together an ideal structure can be produced that will have necessary thermal resistance and mechanical strength.

An ideal structure requiring minimum material and printable from existing materials is a long way from reality however this research is continuously exploring the possibilities through simulations and experimental testing. It is expected that an optimum solution for the current problem will be produced in due course which will be universally applicable to other large scale printing problems.





# Retrofitment and optimization of a legacy FDM system for biopolymer 3D printing

Wilson, Hayden; Arif, Khalid; Potgieter, Johan
School of Engineering and Advanced Technology, Massey University
H.Wilson@massey.ac.nz
K.Arif@massey.ac.nz
J.Potgieter@massey.ac.nz

This paper presents retrofitment and open sourcing of a legacy fused deposition modelling system (Stratasys FDM Vantage X), which then facilitates research into extrusion of new materials. The open source solution enables the control of a wide range of variables within the printer which can allow the motors and temperatures within the machine to be manipulated to alter the output. As a result, the properties and look of the extruded material, dependent on these factors, can be adjusted. The system also achieves z-axis resolution beyond manufacturer's specifications and this enhanced z-axis resolution can enable smaller layer heights for finer quality prints but larger heights for thicker materials. Open source software also provides a range of alternatives for slicing the parts. These open source alternative software solutions allow g-code to be generated which is used for controlling all aspects of the printer. Using g-code also allows manual manipulation after the slicing so that any other required alternations can be made.

The retrofitment of the system is not enough on its own and therefore optimisation of the machine is necessary so that different materials for the machine can produce parts which not only look aesthetically pleasing but also contain appropriate strength that commercial 3D printers offer. Being able to set the chamber and extruder temperature as well as altering the speed of material extrusion through the extrusion "hot-ends" allows different materials to be calibrated and optimised. This in turn enables each layer prints correctly and the layers bind together properly by ensuring the material reaches its glass transition temperature to let it flow normally. Optimisation is also necessary to see which orientation(s) affects the material strength when the layers bind as certain orientations work for some materials but not bind the same way for other materials.

Various preliminary tests have so far been conducted to validate the printing results. In the beginning, single fibres were extruded and examined under an optical microscope to see consistency of the extrusion. The extrusion temperature for a variety of materials (ABS, PLA, etc.) has been conducted and optimal values found, e.g. an extrusion temperature of 266 oC for ABS is considered optimal. Further, ASTM D638 has been used to determine tensile properties of the printed materials however it has been found that inter-layer bonding, and bonding between roads, has not been sufficient and only individual fibres supported the load. This anomaly has led to further optimization of inter layer gaps which is a topic of current research. More work on analysis of build accuracy and developing a geometric description of the interlayer gaps and actual welds achieved is also underway.

# Development of 3D Printing Technology for Flexible Supercapacitors

Wilson, Hayden; Yuan, Xiaowen; Potgieter, Johan
School of Engineering and Advanced Technology, Massey University
Cao, Peng
Department of Chemical and Materials Engineering, The University of Auckland

h.wilson@massey.ac.nz
xw.yuan@massey.ac.nz
j.potgieter@massey.ac.nz
p.cao@auckland.ac.nz

This paper presents the development of a 3D printer to produce flexible supercapacitors formed using a graphene solution combined with a composite paste. This project uses a dual extrusion system which will be capable of finely distributing and plotting the two compounds separately. 3D printing these microstructures in different shapes is currently possible but using the different composites of powder would allow the mechanical properties of the structure to change, leading to the ability to create these flexible super capacitors which can be utilized in a wide range of applications. Building this into existing flexible carbon-based materials can allow electrical energy to be stored and utilized

The 3D printer will be able to automatically print these microstructures and control the rate of the extrusion from the syringe as currently this is done manually. As the graphene powder and secondary structure solution should be extruded separately, a dual extrusion system is necessary where each syringe can be activated manually and the exact amount of paste passing through the micronozzle (needle) can be controlled precisely using a fluid control pump. This would automate the process and allow a single platform to control the printing and extrusion of the paste without a secondary control mechanism or person needing to perform any tasks manually which is currently required for the development of these in the university.

The 3D printer developed for this project is based on a conventional FDM 3D printer which uses an overhead extrusion unit, mounted to a gantry, to deliver molten/liquid material onto a heated base platform which will hold the finished product. This printer however uses a modified dual extrusion system consisting of two syringes, each loaded with the composite solution and the graphene solution which can be replaced to quickly trial new compositions without needing to replace and purge multiple components. The syringes are driven by stepper motors which will slowly increase pressure on the compound forcing it to extrude at a constant rate. This printer then has the ability to take the research from flexible super-capacitors and use it with flexible batteries. Therefore there is potential to develop batteries which could be used in transport and medical applications specifically where it is no longer required to create large battery packs in machines but instead these could be wrapped around surfaces or used in areas where motion would be exhibited.





# Characterization of SLS composite powder properties

Mearns, Cameron; Potgieter, Johan; Dirven, Steven
School of Engineering and Advanced Technology, Massey University, Auckland 0632, New Zealand
C.Mearns@massey.ac.nz
J.Potgieter@massey.ac.nz
S.Dirven@massey.ac.nz

Additive manufacturing has rapidly grown in the last few decades, with new areas of research and development opening in multiple disciplines. As well as the evolving technologies and techniques, the use of additive manufacturing has evolved as well. Techniques such as selective laser sintering (SLS) have become more common place, not just in traditional fields, such as rapid prototyping, but also in emerging uses, such as low-volume, high-value production.

One of the advantages of using SLS is that it can quickly produce polymer parts of high detail and complexity, without the need for much post-processing after printing, and without the need for additional support material. It can achieve this because of the manner of bonding achieved between powder particles during sintering, which leaves nearby particles unaffected. This means that excess powder not sintered during the process can support the part without bonding to it. A key opportunity for growth of SLS based systems is the identification and use of new printing materials. These present new opportunities for both new material properties, as well as reducing material costs. Historically SLS technologies have focused on printing single materials. Lately there has been research conducted into printing composite materials, such as polymer-coated aluminium, as well as plant-based composites. This also matches recent efforts to develop materials from existing resources, such as waste materials from forestry and farming processes.

Due to the nature of the printing process it is very difficult for operators to easily test the feasibility of new materials. Incorrect heating and laser parameters are capable of not just causing damage to the printed part, but to the machine itself. This is one of the most influential factors that has limited the development of new powders, as operators are often hesitant to risk their machines. Characterising how different properties link to print settings and enabling parameter selection based off material specifications rather than experience will reduce the risks during testing.

The objectives of this research include the identification of the effects of: the filler material/binder ratio, the effects of humidity, and the effects of colour. Being able to classify and account for the effect of these parameters will allow for the identification and assessment of a wider range of potential SLS powders. We will also be testing the use of a low-cost desktop SLS machine for materials testing. The machine, a Sintratec Kit, uses a 2.3W 450nm Diode Laser to sinter. Together with using a lower power laser, the Sintratec has a smaller build chamber, allowing for testing to occur with smaller amounts of powder.

# Marker-less registration in mixed prototyping process

Lin, Yuan
The University of Auckland
ylin797@aucklanduni.ac.nz
Xu, Xun
The University of Auckland
r.zhong@auckland.ac.nz

Physical Prototyping (PP) is an important process for design verification, which not only provides valuable suggestions for design modification, but also affects manufacture and marketing plans. Since production of physical prototype is costly and time consuming, PP significantly constraints the efficiency of product development, which usually requires iterative conduction of design and evaluation tasks. Virtual Prototyping (VP) is a typical solution to this problem. By presenting a virtual prototype to engineers and end users, the designer could identify some design flaws in an early stage of design phase without using any physical prototype. However, virtual prototypes can only reveal limited aspects of a product design. Thus, it is difficult to realize some ergonomic issues and unachievable machining features. 3D Printing, or also known as fast prototyping, is an effective approach to reproduce the details that cannot be represented by Virtual Prototyping. Although not being so expensive and slow as physical prototyping, its cost and efficiency is still far from adequate. Besides, the appearance and mechanical properties of 3D printed parts are often inconsistent with final products. These differences may be misleading in product evaluations.

As admitted by many scholars, a promising alternative is to utilize a combination of virtual and physical parts in prototyping process. This method is called Mixed Prototyping (MP), which has already been implemented in several research projects. The main research issue in this method is to display virtual parts in proper position with respect to physical parts. In most MP systems, fiducial markers have been adopted for registration because they are easy to identify and localize. However, there are several disadvantages of marker-based registration. First, it is difficult to attach markers on some physical parts that come with small size or uneven surfaces. Second, the system is not aware of misplacement of markers since no spatial information is retrieved from physical parts. Third, although the occlusion or out-of-sight problem could be solved by motion tracking, the accumulated error cannot be eliminated until entire marker is fully visible again. Therefore, it is imperative to introduce marker-less registration methods in this area.

In this article, authors described a procedure of achieving real-time marker-less registration. During pre-processing, an optical flow based image segmentation algorithm would be implemented to subtract the image of physical parts from video sequence. Afterwards, the pose of these parts is determined by 3D reconstruction and reverse engineering. In spite of prototyping, this registration method also could be applied in many other industrial applications including collaborative design, machining simulation, assembly training and monitoring.





# Stress reduction through digital technology in manufacturing

Mahesh Babu, Purushothaman
Auckland University of Technology 1mahesh.babu@aut.ac.nz
Seadon, Jeff
Auckland University of Technology
jeff.seadon@aut.ac.nz
Moore, Dave
Auckland University of Technology
dave.moore@aut.ac.nz

The case study focuses on stress reduction by using digital processing in material receiving at a manufacturing facility. The implementation aided the organisations to reduce costs, energy, resources, process time, and wastage while reducing stress on employees. Previously, the process was manually operated due to the fear that items missing during transit or mistrust in supplier-customer relationship. The study focused on the issues encountered, problems employees faced and roadblocks for improving the process.

Stress on procurement, warehouse, production, quality, and management teams was evident. The defects and delays in the receiving process resulted in frequent supply delays, cost overshoots, delayed payments to suppliers and inventory write-offs. Internally, any error or defect not captured in the receiving area was viewed as an integrity issue. The manual process used increased stress when trucks arrived close to closing hours, which resulted in the workers doing overtime to complete the work. In addition, the fear of missing items kept the employees constantly stressed, affecting their work-life balance, and leading to health issues.

The company made a decision to implement a digital process for receiving goods, which reduced employee stress and improved data quality. The problem was defined from a management perspective where the 'as-Is' process flow was mapped, followed by a gap analysis. The project team confirmed the issues, associated stresses, and identified cause and effect relationships. Stress elimination using digital architecture was devised in consultation with the allied department and suppliers. The method adopted a sales-based multi-bin ordering system, electronic kan-ban, and quality control at source.

The manufacturer used the internet to interact with the suppliers and a mobile network and the RFID cards to communicate back to the plant as well as visual identification by digital image capture. The process required the manufacturer to send a request to supply materials electronically. The supplier entered details of its readiness to supply in custom RFID-binned containers and the delivery vehicle was alerted through a handheld device connected to mobile networks. The driver visually verified the component and scanned the RFID tag, which is electronically transmitted to get acceptance, thus eliminating part and quantity disputes. At the manufacturing plant, the material is unloaded onto a conveyor, photographed and tags were scanned. The server verified the scanned data with the collection list and the material was moved to storage. This eliminated missing parts, checking and counting, apart from images being stored for future dispute handling. Since the process relies on digital information, which is easily retrieved, the number of errors declined, reducing stress. Additionally, the accuracy and speed of digital processing reduced work hours.

Data quality also improved since manual interchange and repeat counting were eliminated. The process reduced counting and identification errors by 97.6%, gaining an average of 3 hours per day. Other benefits included a 100% reduction in accounting time and advanced supplier payments by one week. Further, seven employees were moved to new areas, and delivery time commitment to customers was reduced by 7 days to 14 days.

# Fabrication Process of Carbon Fibre Composite Materials for Additive Manufacturing

Kvalsvig, Andrew; Yuan, Xiaowen; Potgieter, Johan; Cao, Peng
Centre for Additive Manufacturing, School of Engineering and Advanced Technology, Massey University,
Department of Chemical and Materials Engineering, The University of Auckland
a.kvalsvig@massey.ac.nz

The topic of this research is the design and implementation of a process for creating a new carbon fibre composite material designed specifically for additive manufacturing (AM). Currently, manufacturing carbon fibre parts is an expensive, arduous and time-consuming process, especially for intricate parts. AM is better equipped for manufacturing low volume and intricate parts when compared to traditional manufacturing processes. Utilising AM for carbon fibre part manufacturing of intricate parts will allow parts to be made cheaper and quicker.

There are several carbon fibre AM 3D printers that utilise fused deposition modelling (FDM) technology and thermoplastic resins. The key difference in the new composite material is the use of a thermoset resin. The main reasons behind using a thermoset resin are that this technology is not commercially available and that parts made using this material will exhibit superior mechanical properties compared to thermoplastic parts. Another key characteristic of this composite material is that continuous/long fibres must be used to reinforce the thermoset matrix.

An overall system has been devised that outlines the structure of the processes required to make the new composite material and is based on the material used in FDM 3D printers. The system is designed to use carbon fibre yarn and a thermoset resin to continuously create a composite material that has a uniform cross-sectional shape and area. Two prototypes have been devised to complete the process of impregnating carbon fibre yarn inside a two-part epoxy resin. Overall, each prototype was capable of creating the composite material with the second prototype developing better specimens. The main problems exhibited by both prototypes is the inability to impregnate the centre of the carbon fibre yarn. This problem will lead to deficiencies in parts made using this material and must be overcome.

The next stage of the research is to analyse the quality of specimens to ensure the specimens have been impregnated properly and to determine the mechanical properties of the specimens. This will involve conducting tensile test using an Instron universal testing machine and using a scanning electron microscope (SEM) to analyse the specimen's surface and cross-section.

Overall, the process of creating the new carbon fibre composite material for AM has been achieved. The prototypes have been able to create this material but need to be optimised. The next stage of the system to be developed is the process of controlling the curing of the thermoset resin to be better suited to the AM process. The state of the composite material will be determined by the design of the system that will be utilising the composite material to create three-dimensional parts.





# Extrusion system for 3D printing from biopolymer pellets

Whyman, Sean; Arif, Khalid; Potgieter, Johan
School of Engineering and Advanced Technology, Massey University
S.Whyman@massey.ac.nz
K.Arif@massey.ac.nz
J.Potgieter@massey.ac.nz

This project is aimed at accurately and consistently 3D printing pellet based materials through a pellet extrusion system. Issues seen among common 3D printing systems using a pre-formulated filament are the lack of mixing capability and a restriction around the types of materials that are capable of extrusion. Therefore, a system has been designed and built to test and develop an extruder that can overcome these issues and explore materials such as biopolymers infused with Harakeke flax fibres. The platform supporting the extruder is based off currently available consumer Fused Deposition Modelling (FDM) printers. It uses a simple Cartesian coordinate system to deposit material around a single x/y plane and increases the z axis to create a layered or stepped 3D object.

The polymer extruder is largely based off standard single screw extruder designs, but because of the nature of this system, the extruder must also consider both filament and common screw extruder characteristics. For this to be practical, the extruder needs to be compact enough for it to be usable on a small platform, but also powerful enough as to perform like an extruder. The extruder is comprised of several parts; the screw at the heart of the extruder, the barrel and cooling system, the hopper and the die head. The development focus of the extruder is to not only extrude the intended polymer, but to do it more consistently and reliably over longer periods of time. The extruder was designed with a short barrel and heating band to restrict the melt zone of the polymer. An auger drill bit is used with a rubber extrusion process in mind where it is acting more as a guide for the polymer with minimal shear. Alongside the heating, water cooling is applied as an effective method of preventing heat traveling up towards the hopper and adding to the extruders compact form factor.

The control software being used to slice 3D parts, export g-code, send data and monitor the print is currently all open source. There are three pieces of software in use; Slic3r for slicing 3D objects and g-code generation, Pronterface as the interface and transmitter, and Marlin for receiving and interpreting g-code. The board used to control the printer is an open source Ramps v1.4 Arduino Mega shield. This software layout is chosen because it provides many options to customise and tweak our platform.

The polymer used in the initial testing and development phase is polylactic acid (PLA). This platform is designed to accept a wide range of pelletised polymers including some experimental ones. Test prints have been carried out successfully and tested to determine the tensile strength of the welded layers of the samples. Further changes will be added to the system to improve the cooling, feeding and control characteristics to further improve the quality and consistency of the output.

# Super-hydrophobicity of casted PDMS surfaces

Jose, Ellen; Ashforth, Simon; Aguergaray, Claude; Simpson, M. Cather

Photon Factory, The University of Auckland
The MacDiarmid Institute for Advanced Materials and Nanotechnology

The Dodd Walls Centre for Quantum
School of Chemical Sciences, The University of Auckland
Department of Physics, The University of Auckland

c.aguergaray@auckland.ac.nz

The expansion over the last decade of super-hydrophobic surfaces (surfaces having a water droplet contact angle greater than 150° and a sliding angle less than 10°) has been motivated by a number of industrial applications ranging from anti-icing/clogging surfaces for power transmission, radars and telecommunication antennas, to self-cleaning windows, clothing, or micro-fluidic. This behaviour is typically achieved through the control of surface roughness with well-designed microstructures. Artificial super-hydrophobic surfaces can be fabricated by a number of techniques figuring photolithography, plasma treatment, wet chemical reactions, or electrospinning and so on [1-3]. While sometimes efficient, these techniques do not allow for the wide scale manufacturing required for these surfaces to spread into the market.
The method we explore herein relies on laser micro-machining. Patterning can be obtained either through direct laser irradiation [4] or via transfer of the laser-engraved pattern through casting [5]. In the present study we use a casting method to improve the hydrophobic properties of a section of polydimethylsiloxane (PDMS). PDMS was used as the substrate and casted using a machined stainless steel as a mould. We chose polymer casting with PDMS as this technique is fast, cost effective and suitable for large scale operation and because PDMS features excellent mechanical and chemical properties for such application (intrinsic deformability, hydrophobic properties, softness and low surface energy). PDMS already found multiple applications in micro-fluidic, lithography and medicine for example.

In this study we aim at improving the efficiency, the reliability and the processing time to obtain uniform treated surfaces through precise evaluation of the different parameters accessible. A Ti:Sa amplified femtosecond laser (110 fs, 800 nm, 1 kHz) was used to create a 2D matrix of uniform holes in 316 stainless steel. We investigated the laser parameters through the power of the beam and the number of shots per hole to study their effect on the size of the features. We also looked into various patterning designs by changing the distance between the centre of each peak thus alter their distribution and ultimately the hydrophobicity of the surface (cf. Fig. 1 (a)).

Measurements of the contact angles of water droplets on each area showed a strong correlation between the spacing of each feature and the hydrophobicity of the substrate. Larger contact angles were found for lower peak-to-peak distances (100 µm). A contact angle of 156˚ was found with peak height of 26 µm and a peak base width of 39.2µm (cf. Fig. 1). SEM measurements also confirmed that the number of shots was the predominant parameter to control the holes features and thus the shape of the casted peaks. We will present at the conference a complete analysis of the parameter space and of the associated hydrophicity behaviour of the treated samples.

REFERENCES
[1] Y. Yan, et al., "Mimicking natural superhydrophobic surfaces and grasping the wetting process: A review on recent progress in preparing superhydrophobic surfaces," Advances Colloid and Interface Science, vol. 169, p.80 (2011).
[2] V. Ganesh, et al., "A review on self-cleaning coatings," Journal of Material Chemistry, vol. 21, no. 41, p. 16304 (2011).
[3] S. Lee, et al., "Continuous fabrication of bio-inspired water collecting surface via roll-type photolithography," Int. J. Precis. Eng. Manuf.-Green Tech, vol. 1, no. 2, p. 119 (2014).
[4] S. Van Pelt, "Local wettability tuning with laser ablation redeposits on PDMS," Applied Surface Science, p. 456 (2014).
[5] C. Ngo, et al., "Transparency and superhydrophobicity of cone-shaped micropillar array textured polydimethylsiloxane," International Journal of Precision Engineering and Manufacturing, vol. 16, p. 1347 (2015).





# Enhancing the Quality of Carbon Fibre Reinforced Plastics with Novel Non-destructive Testing

Hermann, Tino
Centre for Advanced Composite Materials, The University of Auckland
t.hermann@auckland.ac.nz

Henke, Thomas
BMW Group
thomas.henke@bmw.de

Bickerton, Simon
Centre for Advanced Composite Materials, The University of Auckland
s.bickerton@auckland.ac.nz

Production methods for medium and high volume manufacturing applications are developed with a strong focus on costs, this being particularly true for the manufacturing of carbon fibre reinforced plastics (CFRP). The BMW Group has successfully implemented CFRP mass production through project i (i3 and i8 models), and most recently the new BMW 7 Series. Both the i3 and i8 have a structural CFRP part count in excess of 50, which are produced either by preforming and high pressure RTM, or by wet-pressing.

Simple and easy to interpret measures are vital requirements for the acceptance of a measurement method within an industrial production environment. A non-destructive quality monitoring system to assess the quality of semi-finished textiles as an intermediate product for CFRP parts is currently under development. In the proposed method, compaction response and the resistance to fluid flow, the so called injectability, are used as a dedicated measure for the quality of the semi-finished product.

Advancing techniques for material characterisation and material failure detection is the main goal of this research. Folds, wrinkles or a change in area weight will all have a different influence on the subsequent mould filling process and therefor on the final part's quality. On this basis, a simple, mobile device is envisaged to support BMW Technology and Production staff to evaluate the injectability and compressibility properties of stacks and preforms. Such a device gives instant feedback, to identify changes in properties from batch to batch. The method presented provides a highly effective and reliable non-destructive characterization of semi-finished textiles applicable within an industrial production environment. The non-destructive quality measurement method will significantly decrease the personal and material costs by reducing the time consumed for the assessment of injectability and compressibility. In the same manner, the reliability of the preform process will be increased by reducing the intervention time by providing immediate feedback on the part's quality.

# Additive manufacturing using sugar in caramel form

Najaf zadeh, Hossein
Department of Mechanical Engineering University of Canterbury
hossein.najafzadeh@pg.canterbury.ac.nz
Clucas, Don
Department of Mechanical Engineering University of Canterbury
don.clucas@canterbury.ac.nz
Huber, Tim
Department of Chemical and process Engineering / University of Canterbury
tm.huber@canterbury.ac.nz
Conan, Fee
Department of Chemical and Process Engineering / University of Canterbury
conan.fee@canterbury.ac.nz

Since the past 30 years, Additive Manufacturing (AM) technologies have developed rapidly, that are capable to 3D-print a wide range of materials often difficult to manufacture. However, in the biomedical, drug delivery, tissue engineering and food industry applications a need for a safe and non-toxic, biocompatible, biodegradable and water soluble material is forecasted. White sugar (sucrose) is a potential material that addresses these requirements, and moreover, it is environmentally friendly, widely available and is inexpensive, thus making it favourable for further investigations.

Sucrose is a disaccharide consisting of two monosaccharide components, "Glucose and Fructose". The chemical synthesis of the monosaccharides can be done by polymerization of aldehydes or oxyketones or by oxidation of polyalcohols. By caramelisation of sugar, its mechanical properties and also thermal properties would change which makes it a suitable candidate for 3D printing.

Sucrose does not have a true melting point. Thus, in the process of changing from solid phase to liquid, the sugar molecules break apart and shake loose from their neighbours and form a caramel. Moreover, the molecules break down even before it liquefies and as a result, the more breaking down sucrose molecules before malting, the lower melting temperature is needed to achieve liquefaction. Therefore, sucrose caramelised when the enthalpy related to its caramelisation is lower than melting enthalpy

Sugar caramel needs to be prepared prior to the 3D-printing a part. In order to prepare appropriate 3D printable caramel, initially, thermal properties of sucrose were studied. Thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC) were used to find the melting point of sucrose. Various heating rates from 1ºC min-1 to 10 ºC min-1 were utilised. Results indicate that sucrose melting temperature is ranged from 184.2 ºC to 188.4 ºC, which is due to the presence of water within the samples as well as the crystallinity of sucrose molecules. In addition to the above tests, water was added to the sucrose in the process of caramelisation and heated to a temperature range from 180 ºC to 220 ºC with a specified heating rate and finally cooled down to form a solid caramel. TGA/DSC tests of samples show that melting temperature of caramels, range from 135 ºC to 148 ºC. Results demonstrate that changing in the amount of water in preparation of caramel has a significant effect on caramelisation of sucrose.

The prepared caramel was 3D printed using a modified fused deposition modelling 3D-printing method to evaluate the mechanical properties of a 3D printed caramel, including strength, toughness molecular structure, and contact angle of caramel as a supporting material with other printable objects like hydrogels. Finally, applications of printing sugar caramel e.g. as a support material along with a different model material, caramel printing for the food industry, and printing caramel for applications in drug delivery will be discussed.





# Textile Simulations for Virtual Composite Materials Manufacturing

Wijaya, Willsen; Bickerton, Simon; Kelly, Piaras; Allen, Tom
Centre for Advanced Composite Materials,
The University of Auckland
wwij336@aucklanduni.ac.nz, s.bickerton@auckland.ac.nz, pa.kelly@auckland.ac.nz, tom.allen@auckland.ac.nz

Fibre reinforced polymer composites (FRPC) are becoming of greater importance in the engineering world. The ability to tailor the material properties to suit particular applications, has led to their use in many applications where high stiffness and strength, at low weight, are desirable. This research is focussed on simulation of textile reinforcement behaviour through manufacturing of FRPC, as part of multi-physics simulation of virtual manufacturing processes.

Resin transfer moulding (RTM) is one of the most popular techniques to produce FRPC components. This manufacturing method is adopted for medium to high volume production, for parts with a wide range of product complexity. Prior to production of a component using RTM, it is important to have estimates of required compaction forces and resin injection pressures, in order to make appropriate choices of manufacturing equipment. These parameters can be estimated from time-consuming, labour-intensive, and operator-sensitive experiments. Furthermore, these experimental characterisations are typically completed on the textile preforms used in the actual products, which are generally expensive and no longer usable after sampling for experiments. Due to the nature of these experiments, there is a strong drive towards reasonably accurate numerical predictions that cover the entire aspects of RTM process. Such numerical predictions can be referred to as a virtual manufacturing process chains, possibly covering:

1.The weaving of the textile preforms to capture the inherent randomness within a given preform. Through this numerical weaving, averaged dimensions can be extracted at several representative regions within the preform.

2.Creation of textile unit cells from the averaged dimensions.

3.Perform numerical compaction on the textile unit cells to obtain estimates of the required compaction forces as well as the deformed shapes of the textile unit cells.

4.Perform flow simulations on the deformed textile unit cells to obtain estimates of the preform permeability (meso-scale permeability).

5.Perform macro-scale flow simulation based on the predicted meso-scale permeability distributions, to simulate filling of the preform in the RTM mould cavity.

The focus of this research covers the second to the fourth point of the virtual manufacturing process chain above. Textile unit cells are generated using TexGen, a CAD software developed for the creation of textile unit cells. TexGen models the fibrous tows as continuum solids; the individual fibre filaments that comprise the tows are not concerned. The created textile unit cells are then exported from TexGen to Abaqus for textile compaction simulation. Abaqus is a powerful numerical tool which is commonly used for structural analysis. Advanced contact algorithms are employed to model the interaction between the tows, and between the tows and the compaction plates. Following the compaction simulation, the deformed textile geometry is then voxalised for flow simulation in ANSYS CFX. Both the inter-tow flow and the intra-tow flow have been simulated. Periodic boundary conditions are applied to simulate the repeating nature of the textile unit cell. By applying a pressure difference along the direction of interest, the meso-scale permeability along that direction can be back calculated using Darcy's law.

# Stirling engine design and empirical optimisation

Egas, Jose; Clucas, Don
University of Canterbury
jose.egasortuno@pg.canterbury.ac.nz
don.clucas@canterbury.ac.nz

Environmental impact derived from fuel's combustion is a global concern. Stirling engines are an attractive technology as they offer a way of reducing this impact through their ability to use different heat sources and their theoretically high efficiency. A Stirling engine's heat source may include: geothermal, solar, nuclear and waste heat recovery. High and low temperature energy sources, and co-generation systems are attractive.

Despite Stirling engines have simple thermodynamic models, inside a real machine complex interactions between the working fluid and the different engine's components result in difficult to model heat transfer processes, as consequence, there is a lack of verified accurate mathematical models. Implications are the impossibility of predicting a specific design performance and uncertainty when using a theoretical model to optimise the new design, that is, to find the combination of design variables that maximizes the objective variables. The current project poses a new approach for solving this optimisation problem: an empirical approach. If it were possible to automatically control the main design variables while reading the objective variables, a search algorithm could be performed to map different variable combinations and find the one that maximizes the engine's performance. The number of design variables related to the Stirling engine, and especially the possible number of combinations such variables can take, can be huge, making it necessary to develop an automated machine capable of performing the search matrix over long periods of time and processing the information acquired in a procedure that can be described as a "multi variable empirical optimisation". Due to the nature of such a system, additive manufacturing and computer aided design (CAD) are of special interest. A CAD modelled and a mainly additive manufactured automated Stirling engine has been developed as a way of testing the proposed optimisation method. The engine developed consists of a low temperature Stirling machine in which stepper motors have been added to control four design variables: dead volume, phase angle, compression ratio, and frequency. The engine's hot heat exchanger is attached to an electric heater providing energy and the cold heat exchanger is air cooled. A pressure sensor attached to the engine's working volume is used to obtain pressure data and create pressure-volume (P-V) diagrams while the engine is running, thus, power and efficiency (the objective variables) can be derived. A first search algorithm was performed to optimise the phase angle, and a direct linear relation between optimum phase angle and frequency has been observed. Future work involves the application of new search algorithms in an attempt of optimising other main design variables for our specific Stirling engine's application, which focusses on a micro co-generation system based on the remaining heat of a solid fuel cook stove, to be used mainly in developing regions to mitigate energy poverty and reduce digital divide with development and educational purposes.





# Exploring the Capability Building for doing Frugal Innovation within developed market firms

Subhan, Fasiha
The University of Auckland
f.subhan@auckland.ac.nz
Husted, Kenneth
The University of Auckland
k.husted@auckland.ac.nz

Frugal innovation has proven to be a powerful approach of innovating using fewer resources. It is a particular type of innovation which can be identified by the following three criteria all at the same time; 1) Substantial cost reduction from consumer perspective such as purchasing price and maintenance cost; 2) Focuses on core functionalities and benefits so that it is fit for the purpose and environment; 3) Optimised performance level so that it meets the existing need of the consumers and gives high value to them. This approach of innovating has been picked up by some researchers and practitioners as potentially relevant alternative model for organising innovation within developed markets. There are some anecdotal examples of developed market firms that are trying to introduce the idea of frugal innovation into their normal innovation activities. However, no systematic attention has so far been allocated to understand how do firms within developed markets build capabilities for doing frugal innovation? Therefore, this proposed research will attempt to answer this question. Such exploration is important because activities of firms within emerging markets are radically different from firms within developed markets and result in different capabilities (Subramaniam et al., 2015; Williamson & Zeng, 2007, 2009). Also, firms within developed markets have limited or no experience of frugal innovation (Lim et al., 2013; Subramaniam et al., 2015), and therefore, such an exploration will unveil fruitful insights.

The conceptual framework is developed by first drawing upon the literature of frugal innovation in emerging markets which highlights two important activities within new product development projects that contribute to building capabilities for frugal innovation. These activities are; cost minimization from a consumer perspective and value maximisation for customers (Radjou & Prabhu, 2015). Building on these activities and drawing on dynamic capability perspective, this framework suggests two capabilities and explores their building process. These capabilities are strategic decision-making at the firm level and integrating knowledge resources at the project level. By adopting qualitative case study approach, four cases will be selected as a sample, which would be the established firms within developed markets involved in doing frugal innovation product activities. Theoretically, this research will contribute to the literature of frugal innovation by developing an in-depth understanding of capability building for frugal innovation within developed market firms. From a practical perspective, this research will imply managerial recommendations for firms within developed markets for incorporating frugal innovation activities in their normal innovation activities.

# Parametrically Designed, 3D Printed Surfaces towards Emotional Qualities

Ok, Jeongbin
School of Design, Victoria University of Wellington
jeongbin.ok@vuw.ac.nz
Scudder, Daniel
dan.scudder@gmail.com

Within the context of design, a surface constitutes a physical and visual interface of an object, and more importantly, one does not only reveal the identity of the entity it encloses but also determines impressions and expectations of the object. Despite their significance, surfaces have long been considered to be a subordinate part of form rather than an independent design element, especially under the reign of mass production. Being against the conventional hierarchy, this paper discusses a systematic and customisable process of preparing purpose-specific, context-oriented functional surfaces.

Digital technologies including parametric modelling and 3D printing were utilised across creation, modification and fabrication of surfaces. Through experimentation with software and mechanical configurations, a series of surfaces with different parameters were produced. Additionally, the potential for direct digital manufacturing (DDM) and its practical penetration was investigated by producing all surfaces directly from a 3D printer without the use of post-production processes.

In user testing participants observed and physically interacted with surfaces, followed by populating a questionnaire that askes their interpretation across inquiry geometry, physical properties and emotive responses. The results were then analysed using Design of Experiments (DOE) in order to identify parameters more or less responsible for evoking specific visual, tactile, and emotional qualities and explore how these surfaces can be interpreted emotively, physiologically and aesthetically by the user.





# Product Configuration for the Personalization of Smart Products

Yu, Shiqiang
Department of Mechanical Engineering, The University of Auckland
syu431@aucklanduni.ac.nz
Lin, Yuan
Dpartment of Mechanical Engineering, The University of Auckland
ylin797@aucklanduni.ac.nz
Zheng, Pai
Department of Mechanical Engineering, The University of Auckland
pzhe539@aucklanduni.ac.nz
Qiu, Liming
Department of Electrical and Computer Engineering, The University of Auckland
lqiu368@aucklanduni.ac.nz
Wang, Yuanbin
Department of Mechanical Engineering, The University of Auckland
ywan821@aucklanduni.ac.nz
Xu, Xun
Department of Mechanical Engineering, The University of Auckland
xun.xu@auckland.ac.nz

Through the synergies of advanced IT technologies in sensor network and hardware infrastructure, both industrial and consumer products are evolving rapidly to carry more smart features. Apart from expecting feature laden products, customers also demand products tailored to their specific function, size and shape, which are associated user experience (UX). Configure-to-order (CTO) business model can enable rapid responsiveness to diverse customer needs and enhance manufacturers' competitive edge. Typically, manufacturing firms operating in CTO manner would adopt mass customization strategy and implement it with a product configuration system (also known as product configurator). Although product configuration technologies have been matured for decades, even state-of-the-art product configuration system (e.g. Autodesk Configure One) cannot provide a good UX. Moreover, there are still gaps in the research on product configurator design for smart product. To achieve a customer-centric smart-product development process, both information technologies (e.g. Virtual Reality (VR), Internet of Things, and Web 2.0) and manufacturing techniques (e.g. adaptable design, reconfigurable production system, and additive manufacturing) are deemed to be the enabling tools. This project studied the product personalization process for smart products by observing a group of customers conducting a series of product configuration tasks in several types of product configurators (including web-based and VR-based version). At last, a methodology on developing product configuration system for smart product is proposed and validated by a case study.

# Smart Wearables with Cloud-based Automated Monitoring

Zheng, Pai
The University of Auckland

One of the biggest recent trends in the mobile devices market is the introduction of smart wearable devices, with the industry expected to triple in size to be worth a total of $25 Billion USD by 2019. Devices for a variety of purposes designed to be worn on different parts of the body are steadily seeping out into the market, with major players such as Google (Google Glass), Apple (Apple Watch), Fitbit (Fitness Band) along with smaller startups developing platforms such as Mbientlabs' MetaWear or Adafruit industries' FLORA for the DIY/Maker market. Continued reduction in unit costs for these devices greatly increases the accessibility of these devices for many groups of people in different markets. The availability of the cloud creates a relatively effortless way to achieve large scale data-mining and analytics, generating opportunities for many fields such as user experience improvement and/or research trials. The current implementation of wearable platforms appear to be limited to a local scope, with no cloud-connected options. In addition to this, the presence of wearables in the field of research appears to be anemic at best, leaving this potentially powerful method of data acquisition untapped.

It is identified that one of the biggest issues pertaining to the lackluster presence of wearable devices is the absence of a robust, cloud-based data acquisition method. With this in mind, this project provides an exemplar to which real-time acquisition occurs in conjunction with data processing in a completely seamless manner. As part of the exemplar of a functional data acquisition framework, a newly developed product named i-BRE was used as a companion product, at the core of which is a Mbientlabs MetaWear MetaEnv sensor, communicating via Bluetooth 4.0 Low Energy to an Android smartphone running a custom Android app. The acquired breathing data is then sent and logged onto a remote cloud-based server hosting the companion Web application.

This demonstrates three important aspects of data acquisition using cloud-based wearables: (1) Real-time feedback such that acquired data is almost instantly stored for post processing; (2) Distributed usage with support for large numbers of concurrent users and (3) Inclusion of relevant post-processing seamlessly into the process. With these three aspects fulfilled and the assumption that it is possible to measure the results of a trial with little to no supervision, a large number of research participants can be studied in parallel. In addition, data-driven analysis can be performed on captured data in order to study user behavior, allowing for user experience improvements in product design. The result allowing for large scale, simultaneous experimental data acquisition in tandem with user behavior feedback.





# Factors Affecting Knowledge Sharing Behaviour in Collaborative Innovation

Cumin, Dana
The University of Auckland
dana.cumin@auckland.ac.nz

Callagher, Lisa
l.callagher@auckland.ac.nz

Husted, Kenneth
k.husted@auckland.ac.nz

The study sets out to examine factors that affect knowledge sharing behaviour (KSB) in the context of collaborative innovation (CI). Specifically, the relationship between individual factors (commitment), organisational factors (top management support and knowledge protection mechanisms) and KSB.

KSB is recognised as an important condition for organisations engaged in CI, which I define as a contractual inter-firm project. CI has increased to the point where it now accounts for approximately 90% of all strategic technology alliances. KSB in the context of CI is important to investigate as one of the risks is loss of knowledge as firms need to share their know-how. The most common risks when engaging in collaboration showed 48% of firms risked loss of knowledge and higher coordination costs. However, the majority of studies on KSB have been conducted within a firm. Given the decision about what knowledge to share lies within the individual, it is important to understand both the individual and organisational factors that affect individuals' KSB in CI for better management.

As CI presents a unique psychological challenge for individuals, the factor that captures this complexity is dual commitment. Individuals who are involved in projects with two different organisations experience conflicting allegiances since they need to reconcile the demands and goals of the two competing entities. Top management can covey organisational goals through support to share knowledge as this can facilitate a knowledge sharing culture in the organisation. Though knowledge sharing is essential for innovation, firms also wrestle with knowledge leakage that can strategically affect their performance. To minimise harm, firms use various mechanisms to protect their know-how: these can be formal (contracts) or informal (complexity of product). When a firm has put effort into getting strong protection, sharing knowledge with varying partners is more likely, which, in turn, improves innovation performance of the firm ).

In order to capture both individual-level and organisational-level factors to understand their relationship to KSB, a multi-level study will be conducted. Knowledge protection mechanisms will be tested at the organisational level and commitment, top management support, and knowledge sharing behaviour will be examined on the individual level. A cluster sampling will be employed. According to Statistics NZ there are 1,549 R&D intensive firms in NZ with 30,000 full-time personnel as of 2014. The aim of this study is to have a sample size of 3-5 employees per organisation to allow analysis, hence, 50-100 firms will be needed for a sample size of 200-300 employees. A pilot study has been launched in February 2017 and data will be analysed using a multilevel structural equation modelling to examine the relationship between commitment, top management support, and knowledge protection mechanisms to KSB.

# Decentralised or Centralised; what's better in managing change in PD?

Rajapaksha, Janaka
Design and Development Research Group, The University of Auckland
jraj081@aucklanduni.ac.nz
Wynn, David C.
Department of Mechanical Engineering, The University of Auckland
d.wynn@auckland.ac.nz

Coordination within product development processes (PDPs) has long been recognised as of paramount importance to improve efficiency and efficacy of such processes. Therefore there has been much research focusing on proving the importance of coordination. A comparatively small portion of it focuses on analysing coordination methodologies or improving coordination. Furthermore research that considers design changes or variations that arise within PD processes while analysing coordination is almost non-existent.

In the literature, coordination has been defined as the timely exchange of information and resources, division of and allocation of tasks, and synchronisation of actions. The importance of coordination in achieving expected successful project outcomes through carrying out a review of existing literature has also been identified.

Changes in PDPs, on the other hand, have the potential of causing minor to major problems to the progression of development processes. A research showed that how uncertainty in projects can develop into problems, through presenting changes to the original scope that can affect performances (effectiveness, efficiency), sometime to a point of projects being a complete failure. Then, complexity of a project has been described being proportional to the level of difficulty in coordination. Another research discussed the importance of coordinating information flow, especially within a complex product development process, in achieving desirable outcomes.

In order to analyse complex PD processes and develop insights from an information flow coordination perspective, the focus of research presented here lies on simulating a model representative of a PD process. The objective is to model the interaction between performance of the PD process and coordination models and to analyse the effect of an exogenously instigated engineering change on performance under different coordination mechanisms. To achieve this, a computer model has been developed to capture important elements of a generic PD process such as tasks, task dependencies, task durations, and supplier and integrator attributes while accounting for the inherent uncertainty of a PD process.

Building on this model, simulation is employed to compute performance data for representative cases and seek general insights. Two coordination models are considered. We aim to study simulated project performance data under the two different information coordination models in absence of any changes. Then, the same process model is used to consider the situation in which an instigated change interferes with the project's progress. The effects of the coordination models on the performance of the PD process are qualitatively compared while highlighting the underlying parameters used in setting up each model.

Initial experiment results support the hypothesis of the existence of a strong relationship between coordinator effectiveness and project performance. Results also align with previous research observations on the importance of facilitating adequate levels of communication within project models and effective coordination of communication, in ensuring efficient project performance. Future research work will focus on simulating a variety of process models to achieve more observations with simulating multiple changes within PD processes.





# Revealing revealed – How innovative firms openly share knowledge

Amarasinghe, Saumya
The University of Auckland
s.amarasinghe@auckland.ac.nz
Husted, Kenneth
The University of Auckland
k.husted@auckland.ac.nz
Siedlok, Frank
The University of Auckland
f.siedlok@auckland.ac.nz

Open Innovation (OI) is often credited as being the driving force behind the emerging shift in the strategic management of innovation and knowledge within organisations. OI suggests that innovative firms should use external knowledge to accelerate internal innovation and let internal knowledge flow out to be exploited externally (Chesbrough, 2003). The popularity of OI, both in academia and in practice, leads many firms to reconsider the openness of their innovation process, which in some instances involves voluntary knowledge outflows that do not generate immediate financial revenues to the firm – a phenomenon termed 'revealing' (Dahlander & Gann, 2010). Sharing knowledge freely across porous firm boundaries bears the high risk of leaking valuable knowledge and the uncertainty of beneficial outcomes. Therefore, it is paramount that firms understand the key elements and their interplay in the knowledge sharing process to manage and perform effective revealing activities.

Existing studies on revealing are insufficient to develop a coherent model that could capture the key elements and guide firms to implement and evaluate revealing transcending the open source software (OSS) context. Therefore this study address the question of 'how do innovative firms reveal?' focusing on a broader context beyond OSS.

Review of existing scholarly work shows that revealing has three dimensions – content (from selective knowledge to revealing all), access (from restrictive to open-to-all) and timing policy (continuously revealing throughout the innovation to revealing only at the end); and six broadly categorised organisational factors – 1) knowledge type, 2) firm capabilities, 3) modularity, 4) open strategy, 5) perceived reciprocation and reuse, and 6) competitive environment – influence the three dimensions into forming different revealing profiles. However, we are yet to understand 'how' these factors influence the dimensions and thereby the way revealing is practised and its potential outcomes.

Open source innovation, publications, patenting and various forms of collaborative innovation are practices widely used by firms that has revealing embedded in them. Therefore, the study employs a multiple case study approach to explore further into identifying the components of each category of factors that influence revealing in each case and how they affect the choice of revealing profile, the choice of revealing practice/s and the outcomes.

Our intended contribution supports the MaD Network's vision to create active and collaborative research networks by adopting OI principles. Collaborations require careful assessment of mutual benefits as well as potential risks to the firms. The resultant conceptual model of this study is a guiding framework for firms to evaluate the organisational factors identified by the study and make a strategic choice on the mix of the dimensions and appropriate practice/s. This enables the firms to minimise the adverse effects of revealing and make an informed choice of the revealing profile that is optimum to reach the required outcomes.

## PRESENTERS INDEX



THE UNIVERSITY OF AUCKLAND NEW ZEALAND

i4.0 Laboratory for Industry 4.0 Smart Manufacturing Systems

FACULTY OF ENGINEERING

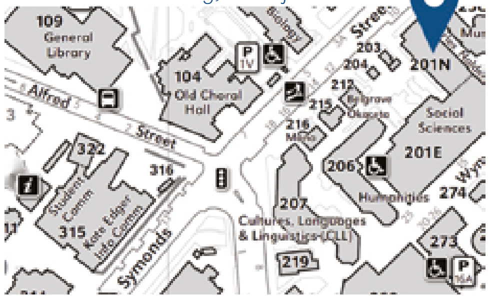
# Industry 4.0 Laboratory Open Day

## -MAY 12 2017-

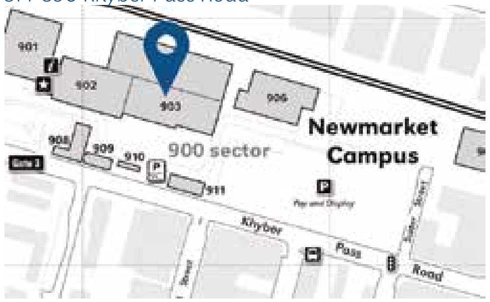
Join us at two of our laboratries located at the University of Auckland's City and Newmarket campuses. We will be demonstrating some key Industry 4.0 technologies, including:

- IoT-enabled AGV for Smart Factory
- Intelligent Windows for machine tools
- Augmented Reality applications in industry
- Intelligent Control of Distributed Automation Systems

**CITY CAMPUS** *Parking is at the Owen G Glenn Building, 12 Grafton Road*




**NEWMARKET CAMPUS** *Parking is via Gate 3, 314-390 Khyber Pass Road*




## -EVENT SCHEDULE-

NEWMARKET CAMPUS (903.322)

10.00 Arrival and morning tea

10.30 Industry 4.0 Laboratory tour

11.15 Travel from Newmarket to City Campus

CITY CAMPUS (301N.439)

11.45 Industry 4.0 Laboratory tour

1.00 Lunch and mingling

**REGISTER HERE**

https://goo.gl/8bdiue

**LEARN MORE**

https://goo.gl/noeiu1


**CONTACT**

Professor Xun Xu

xun.xu@auckland.ac.nz

**engineering.auckland.ac.nz**

Manufacturing and Design **NZ**