The Engineering Doctorate:
Technology Transfer and Impact on the Nuclear and Aerospace Sectors

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Delegate Booklet

Learning & Career Development Centre, Derby

Friday 7th November, 2014

Rolls-Royce Engineering Doctorate Network

Contents

Presentations List

Main Conference Room, LDC, Derby
Friday 7th November 2014

Agenda

Arrival and Coffee	09:00 – 09:30

The Engineering Doctorate at Rolls-Royce

'Welcome & Introductions' *Oliver Nowers* *Co-Founder – The Rolls-Royce Engineering Doctorate Network*	09:30 – 09:40
Plenary Talk *Henner Wapenhans* *Head of Technology Strategy, Rolls-Royce plc*	09:40 – 10:00

Session 1: Technology Transfer and Impact on the Nuclear Sector

'Mixed Mode Realities in Nuclear Manufacture' *Stephen Reddish* *Nuclear EngD Centre, University of Manchester*	10:00 – 10:20
'Advancing NDE for Nuclear Submarines: Numerical Modelling for Ultrasonic Inspections' *Richard Phillips* *Industrial Doctorate Centre in NDE, Imperial College London*	10:20 – 10:40
Coffee - (incl. Student Poster and DTC Exhibition)	10:40 – 11:20
'General Heat Flux Model for Arc and Beam Process Welding' *Tom Flint* *Nuclear EngD Centre, University of Manchester*	11:20 – 11:40
'A Participatory Design Framework: Incorporating Public Views into the Design of Nuclear Power Plants' *Martin Goodfellow* *Alumnus: Nuclear EngD Centre, University of Manchester*	11:40 – 12:00
Lunch - (incl. Student Poster and DTC Exhibition)	12:00 – 13:00

Session 2: Technology Transfer and Impact on the Aerospace Sector

Plenary Talk *Martine Gagne* *Head of the Rolls-Royce Strategic Research Centre, Rolls-Royce plc*	13:00 – 13:20
'Surface layer Phenomena in Single Crystal Castings' *Matthew Appleton* *University of Cambridge UTC, University of Cambridge*	13:20 – 13:40
'An Ultra-sound Choice' *Kit Lane* *Alumnus: Industrial Doctorate Centre in NDE, Bristol University*	13:40 – 14:00
'Rolls-Royce Research Activities in Singapore' & **'Overview of Rolls-Royce linked PhD's in Singapore'** *Charles Ng* *Nanyang Technological University, Singapore*	14:00 – 14:20
Coffee - (incl. Student Poster and DTC Exhibition)	14:20 – 15:00
'Effects of Loading Proportionality to Fatigue Life' *Matt Bees* *Swansea University Technology Centre, Swansea University*	15.00 – 15:20
'Value-driven Design for Aero-Engine Systems' *Julie Cheung* *Alumnus: Transport & the Environment, University of Southampton*	15:20 – 15:40
'Control of Ply Slippage during forming of Complex Shaped Prepreg Parts using Vacuum Bagging' *Saran Toure* *Manchester EngD Centre, University of Manchester*	15:40 – 16:00
'The Influence of High-Temperature Corrosion Fatigue on Nickel Disc Materials' *Grant Gibson* *Swansea University Technology Centre, Swansea University*	16:00 – 16:20
'Closing Remarks' *Mark Jefferies* *Chief of University Research Liaison, Rolls-Royce plc*	16:20 – 16:30
Close	

EngD Student Poster List

Heritage Museum, LDC

Session 1: 10:40 to 11:20
Session 2: 12:00 to 13:00
Session 3: 14:20 to 15:00

#1 Elizabeth Parker Quaife

University of Manchester - Nuclear EngD Centre
'Corrosion and CRUD: Understanding the Effects of Radiation'

#2 Jack Cooper

University of Sheffield, Nuclear EngD Centre
'Amorphous Carbon and Variant Vacuum Thin Film Coating Systems for PWR Tribological Applications'

#3 Riten Solanki

University of Birmingham - Formulation Engineering DTC
'Next generation Ceramic Shell Moulds for the Casting of Turbine Blades'

#4 Chris Dodd

University of Southampton - Transport & the Environment DTC
'Optimal Mean Setting – Maximising Profit'

#5 John McGrady

University of Manchester – Materials Performance Centre
'Characterisation and Behaviour of Particulate Material in PWR Primary Coolant'

#6 Claire Jeavons

University of Sheffield - IDC in Machining Science
'Cost Modelling: Review and Application'

#7 Robert Hughes

Warwick University - Industrial Doctorate Centre in Non-Destructive Evaluation
'Eddy-Current Array Sensitivity Characterisation'

#8 Michael Watson

University of Sheffield – Leonardo Centre
'Image Based Finite Element Modelling of Thermally Sprayed Coatings'

#9 Gitanjali Nayar

University of Surrey – The Sustainability for Engineering & Energy Systems IDC

'An Integrated Chemicals Management Framework for the Sound Management of Chemicals'

#10 Prathiban Sureshkumar

University of Southampton, Transport & the Environment DTC

'Predicting Wind Tunnel Based Measurements of Open Rotor Noise'

#11 Amrith Surendra

University of Southampton - Computational Engineering Design

'Development of a Decision Support Framework for Aerospace Applications'

#12 Alex Owens

Imperial College London - Nuclear University Technology Centre

'The Application of Isogeometric Methods to the First Order Form of the Transport Equation'

#13 Jakub Gramatyka

University of Southampton - University of Southampton IDC

'Sensitivity, Accuracy and Risk Assessment of Aero-Engine Preliminary Design Process'

Doctoral Training Centre Exhibition List

Heritage Museum, LDC

Session 1: 10:40 to 11:20
Session 2: 12:00 to 13:00
Session 3: 14:20 to 15:00

A) **Industrial Doctorate Centre in Systems**

University of Bristol
Representatives: Chris McMahon, Oksana Kasyutich and Thomas Walworth

B) **Centre for Doctoral Training in Integrated Tribology**

University of Sheffield
Representatives: Giuseppe Tronci, Nicola Fois

C) **Nuclear EngD Centre**

University of Manchester
Representatives: David Stanley and Stephen Reddish

D) **Centres for Doctoral Training in –**
Next Generation Computational Modelling
Sustainable Infrastructure Systems
Energy Storage and its Applications

University of Southampton and University of Sheffield
Representatives: Phillippa Reed

E) **University Technology Centre in Materials**

Swansea University
Representatives: Rob Warren

F) **Industrial Doctorate Centre in Machining Science**

University of Sheffield
Representatives: Andrea Haworth

G) **Industrial Doctorate Centre in Non-Destructive Evaluation**

Imperial College London
Representatives: Roy Brown, Tom Barber and Cheng Huan Zhong

Presentation Abstracts

10:00am – Stephen Reddish

Mixed Mode Realities in Nuclear Manufacture

Manufacturing for the civil nuclear industry is both high value and low volume. To be competitive within the market companies will need to minimise cost in both the design and manufacture cycles.
This project looks at the use of Virtual & Augmented Realities, to bring disparate data and information sets together into single environments. It is hoped that this will reduce the design cycle times, and discover challenges before large expenditures have been made. The presentation will cover the early stages of the Research Engineers work, demonstrating the use of VR for assembly, Discrete Event Simulation, and education.

10:20am – Richard Phillips

Advancing NDE for Nuclear Submarines: Numerical Modelling for Ultrasonic Inspections

Ultrasonic Non-Destructive Evaluation (NDE) techniques provide a means to assess the integrity of a component without causing damage to its structure. This capability is paramount within the nuclear industry and enables structural analysis of safety critical components. Despite the success of this approach, defects with complex geometry, such as surface breaking defects, prove to be more challenging to reliably size and detect. As a result, industry practice takes a pessimistic approach whereby the through-wall extent of a surface breaking defect is severely overestimated to ensure all defects are found. However, this causes incorrect classification of insignificant indications as potentially hazardous, which ultimately increases overall costs. Providing a reliable and accurate means to model this ultrasonic interaction will lead to less conservative, yet safe, means to size surface breaking defects. This project aims to develop accurate Finite Element methods to model ultrasonic inspections of surface breaking defects and to facilitate the transfer of efficient techniques into an industrial environment.

11:20am – Tom Flint

General Heat Flux Model for Arc and Beam Process Welding

Transient thermal fields, induced in a finite domain by the volumetric heat flux during welding, influence: the magnitude and distribution of residual stresses, the size of the fusion and heat affected zones, the evolution of the material micro-structures, material properties, and fracture toughness. The ability to predict these fields is crucial and depends on our understanding of the volumetric heat flux distribution. In my work the double ellipsoidal heat flux distribution commonly used in welding thermal analyses is extended to become the double-ellipsoidal conical heat flux model to accurately describe heat transfer in a variety of geometries and for various fusion welding techniques. Other heat flux models used in welding mechanics are special cases of this heat source model. In electron beam processes this heat flux model accurately describes the stopping of electrons in the domain.

11:40am – Martin Goodfellow

A Participatory Design Framework: Incorporating Public Views into the Design of Nuclear Power Plants

Public support for nuclear power is a key enabler for the deployment of new nuclear power stations. Historically, public attitudes to nuclear power have been influenced by a broad range of indirect interactions between the nuclear industry and the public, with a minimal amount of direct engagement (although this situation has improved in some countries in recent decades). The research undertaken in this EngD sought to establish whether the public could directly provide requirements input into the system level design of new nuclear plant concepts; thus allowing nuclear plants to be designed to be more socially sustainable. The presentation will outline how this was attempted and the outcome of a 'first of a kind' nuclear participatory system design framework. The broader implications for the future of nuclear new build will then be considered along with the current status of ongoing work in this area.

1:20pm – Matthew Appleton

Surface Layer Phenomena in Single Crystal Castings

Diffusion phenomena on the surface of nickel-based Superalloy single-crystal turbine components can be a cause for high levels of scrap so must be understood and mitigated where possible. One such instance is the carburisation of high-pressure turbine blades that occurs during coating processing. Unintended interaction between carbonaceous masking materials and the component's surface at 1000°C results in interstitial diffusion and then precipitation of small sub-surface carbides which can affect the local mechanical and environmental properties. This talk will outline the issue within manufacturing as well as the efforts during this EngD to better understand the sequence of events that leads to the defect. A range of analytical techniques are employed to determine the identity of the carbides and a series of experiments are planned to seek out a regime of coating or other approaches that will limit the incidence of such carbides forming all together.

1:40pm – Kit Lane

An Ultra-sound Choice

The ability to inspect Rolls-Royce jet engine components on-wing offers significant cost savings to the company and reduces disruption for our customers. This Engineering Doctorate project developed an ultrasonic system for the on-wing inspection of turbine blades for defects that may initiate in-service. Turbine blades are cast from single crystals of nickel-based superalloys because of the excellent mechanical properties that these materials exhibit at high temperatures. However, single crystals are highly anisotropic which causes major complications when inspecting these materials with ultrasound. Therefore, the main focus of this EngD was to compensate for the complex behaviour of single crystals to produce an inspection system with the highest sensitivity and reliability.
Upon completion of the EngD, the presenter has continued to develop advanced on-wing inspection methods, concentrating on reducing customer maintenance burden and improving the competiveness of Rolls-Royce products.

2:00pm – Charles Ng

Rolls-Royce Research Activities in Singapore

In order to continuously deliver innovation and value to customers, it is important to invest in future technologies for the next generation of environmentally-friendly engines. The Advanced Technology Centre (ATC) was established in 2009, as part of Rolls-Royce's strategy to pursue excellence and industry leadership through the identification and development of advanced technologies in the fields of manufacturing and repair technology, computational engineering and electrical power & control systems. The ATC also provides specialist materials assessment & Non-Destructive Testing support for in-service engines through the Materials Support Laboratory. The ATC has strong engagement with local research partners in Singapore, including research agreements with the Agency for Science, Technology and Research (A*STAR), Nanyang Technological University (NTU) and the National University of Singapore (NUS). This talk aims to give an overview of ATC's research programs with the various partners, their research focus and also introduce the new Rolls-Royce@NTU Corporate Lab.

Overview of Rolls-Royce linked PhDs in Singapore

The Industrial Postgraduate Programme (IPP) is an initiative by the Singapore Economic Development Board (EDB) to develop a pool of postgraduate manpower with the essential and critical R&D skill-sets for roles in the industry. There are currently seven Rolls-Royce IPP trainees in the Advanced Technology Centre (ATC) spread over the three core areas of research; manufacturing technology, computational engineering and electrical power & control systems. In addition, the Rolls-Royce@NTU Corporate Lab, a joint investment of S$75 million by National Research Foundation, Rolls-Royce and NTU will also host 40 PhD students working on projects across ATC's three core areas of research. This talk will introduce the PhD projects managed under the Rolls-Royce IPP and R-R@NTU Corporate Lab.

3:00pm – Matt Bees

Effects of Loading Proportionality to Fatigue Life

In contrast to most specimen fatigue data generated in the laboratory, the loading experienced by gas turbine discs is usually multi-axial, driven by rotational and thermal loading. Furthermore, the transient nature of the thermal stresses can mean that the magnitudes of the different principal stresses at a component feature change non-proportionally during a typical flight cycle. This causes two challenges for stress analysts, firstly to understand how to extend uniaxial fatigue life prediction models to multiaxial conditions and then to include the effects of non-proportional loading. The current programme seeks to investigate these complex stress effects and build/extend upon models which allow for fatigue life predictions under such conditions. An improved understanding of the field should allow for reduced safety margins developed by confidence gained from multi-axial laboratory tests, followed by component modelling.

3:20pm – Julie Cheung

Value-driven Design for Aero-Engine Systems

This EngD project was performed within the Computational Engineering and Design research group at Southampton University, and the Product Cost Engineering (PCE) group at Rolls-Royce. The objective of the project was to develop a framework for applying Value-Driven Design. To provide some context, within the early stages of traditional engineering design, performance attributes such as specific fuel consumption and weight typically takes precedence over product cost.

The challenge faced by PCE was how to integrate the cost attribute into the design process, such that the whole engine design is the optimal business solution. The project outcome was a Value-Driven Design modelling framework developed to analyse product value to the customer and enabling engineering and business trades. Today, Value-Driven Design is continuing to gain interest within Rolls-Royce through community of practices and further research programmes; and more importantly embedding the concept into Design and Management Systems.

3:40pm – Saran Toure

Control of Ply Slippage During Forming of Complex Shaped Prepreg Parts Using Vacuum Bagging

Complex shaped parts manufactured using out of autoclave prepreg vacuum bagging have a high quality finish. This is not only due to in the control of resin to fiber ratio in prepregs, but also to a reduction in fiber misalignment, slippage and stresses occurring within plies during compaction. In a bid to further reduce deformation modes and control failure modes, we carried experiments where, we introduced wetted fabrics within a prepreg plybook during compaction. Here are presented the results obtained from the vacuum bagging of two angle curved shapes. The first shape is that of a turbine fan blade with smooth curves all throughout whilst the second is a cone shaped both with smooth and sharp edged angles. The quality of the final parts made from each of these two shapes is compared to that of parts made from the standard vacuum bagging process of prepregs, without introducing wetted fabrics.

4:00pm – Grant Gibson

The Influence of High Temperature Corrosion-Fatigue on Nickel Disc Materials

In order to meet the increasing demands of the aviation industry and emissions targets set by governing bodies, turbine entry temperatures have increased. This has led to a rise in the associated firtree temperatures in discs, such that the material now operates in a temperature regime suitable to promote hot corrosion attack. Historically literature studies tested material for pitting resistance, however this work negated the important role of stress. This EngD study aimed to replicate the corrosion attack seen in service components and understand the fundamental controlling parameters of the mechanism. This allowed a mechanistic understanding to be developed, informing engine lifing and future designs. Furthermore work was undertaken to provide a viable mitigation through existing technology, in the form of an improved shot peening method.