Engineering and Physical Sciences Research Council

Science Foundation Ireland — For what's next

12th & 13th July 2021

International Student Conference in metallic materials

organised by the EPSRC & SFI Centre for Doctoral Training in Advanced Metallic Systems

Monday 12th July 2021

9:00 **Conference Opening & Keynotes** - Professor Russell Goodall, AMSCDT Director, University of Sheffield

(Chaired by Daniel Jensen & Elaine Livera)

Keynote 1 – Chris McDonald, Chief Executive, Materials Processing Institute

Keynote 2 – Dr Stella Pedrazzini, EPSRC Early Career Fellow, RAEng Associate Research Fellow, Imperial College London

Keynote Q&A – chairpersons will voice delegate questions from the Zoom chat thread to the keynotes

10:30 Presentations Session 1

	Session 1A Additive Manufacturing (Chaired by Kirstie Bruce and Yichao Yao)	Session 1B Microstructural Design (Chaired by Francesco Guarracino & James Pepper)	Session 1C Advanced Processing & Characterisation (Chaired by Elliot Cooksey-Nash & Ziyu Ma)
10:30	**Structural control of eddy currents in soft magnetic materials -** Alex Goodall, University of Sheffield	**From a Composite to a Blend: Exploiting Field Assisted Sintering Technology (FAST) to Engineer Fine-scale Alpha Morphologies in Novel Ti-64/Ti-5553 Synergistic Composites -** Samuel Lister, University of Sheffield	**Investigating ductility gains in automotive steels under non-linear strain paths -** Anastasia Vrettou, University of Birmingham
10:50	**Grain Refinement and Mechanical Properties for AISI304 Stainless Steel Single-tracks by Laser Melting Deposition: Mathematical Modelling versus Experimental Results** - Muhammad Arif Mahmood, National Institute for Laser, Plasma and Radiation Physics (INFLPR), Magurele, Romania	**Powder Hot Isostatic Pressing of Niobium: Influence of Powder Characteristics on the Microstructure and Mechanical Properties** - Alessandro Sergi, University of Birmingham	**Determining the Effects of Radiation Damage on Nuclear Grade Material-** Kavi Sharma, University of Sheffield

Time			
11:10	**Laser Powder Bed Fusion of a non-modulated NiMnSn Heusler alloy for magnetic refrigeration applications** - Kun Sun, University of Birmingham	**Development and characterization of Ti36Ni49-xZr15FeX=0-2 based high temperature shape memory alloys with enhanced cold workability –** Muhammad Tahir, Ghulam Ishaq Khan Institute of Engineering Sciences and Technology	**Hot Isostatic Pressing of Powder Blends for Alloy Development -** Daniel Porter, University of Birmingham
11:30	*Break*		
11:40	**Investigating the Effect of L-PBF Process Parameters on 3D Printed Nitinol Part Properties** - Josiah Cherian Chekotu, Dublin City University	**Eutectic High Entropy Alloys as Brazing Fillers Designed by Machine Learning -** Xavier Morell, University of Sheffield	**4D printing of Magnetic Shape Memory Alloys -** Anastassia Milleret, University of Birmingham
12:00	**Fabrication Of Flexible Sensors Based On Polymers And Nanomaterials Via Stereolithography, Laser Sintering, Drop Casting And Fused Filament Fabrication Techniques** - Anesu Nyabadza, , Dublin City University	**Study on the relationship between fatigue and microstructure of additively manufactured Ti64** - Bryan Naab, University College Dublin	**Investigation of the influence of the PBF-LB build plate part placement position on the microstructure and the mechanical properties of Ti-6Al-4V alloy components -** Axieh Joy Bagasol, University College Dublin
12:20	**Process Parameters Development of Aluminium-TiB2 Composite Alloy processed by L-PBF** - Francesco Careri, University of Birmingham	**Modelling the Microstructure Evolution During Hot Working of Titanium Alloys -** Guy Bowker, University of Manchester	**Microstructural Characterisation and High-Temperature Oxidation of Laser Powder Bed Fusion Processed Inconel 625 -** Emily Rose Lewis, University of Birmingham
13:00	**Prize Award for best oral presentation**	**Prize Award for best oral presentation**	**Prize Award for best oral presentation**

13:00 **Lunch & Poster Session 1**

Please review the posters in Acadiate and use the poster authors own online meeting link to chat with them about their poster.

- **An investigation into surface film properties and corrosion behaviour of gamma irradiated stainless steel** - Alex Hanson, University of Manchester
- **3D Printing of stainless steel fibre reinforced polymer composites** - Alison Clarke, University College Dublin
- **Ultrashort laser induced selective crystallization of gold thin films** - Ayesha Sharif, NUI Galway
- **Structural Optimization of Graded Lattice Structures for Metal Additive Manufacturing** - Brian McDonnell, NUI Galway
- **Investigating the Impact of Microstructure on Irradiation Damage in Zirconium Alloys Using Convolutional Multiple Whole Profile Analysis** - Callum Andrew, University of Manchester
- **Anomaly Detection during the printing of TiAl6V4 by Laser Powder Bed Fusion** - Conor Sheehan, University College Dublin
- **Neural Network Predictions of Charpy Toughness Based on Steel Composition, Including Chemical and Microstructural Analysis of C-Mn Steel Welds** - Enn Veikesaar, University of Manchester
- **Time evolved flow evolution in arc welding** - Fan Wu, University of Manchester
- **An investigation into X-ray CT Resolutions and Optimisation Methods for Titanium Samples Produced Through Additive Manufacturing** - Jamie McGregor, University of Manchester
- **The effect of texture on the stress and strain localisation during aluminium sheets bending** - Laura Gonzalez Duque, University of Manchester
- **Comparative Assessment of Nitronic 60 and Tristelle 5183 Hardfacing Alloys** - Linlin Cao, University of Manchester
- **Laser surface treatment of stainless steel for improvement in corrosion properties** - Mark Swayne, Dublin City University
- **Powder Metallurgical Processing for Graded Alloy Microstructures** - Natasha Sweeney Fort, University of Sheffield
- **Influence of processing parameters on the evolution of porosity, and microstructures in AISI 316L Steel Samples fabricated by selective laser melting** - Khaja Naib Rasool Shaik, National Center for Metallurgical Research (CENIM-CSIC), Spain

14:00 PGR Skills Workshops

- **Communicating your research** – with Chris Smith from The Naked Scientists
  Registration link: https://www.eventbrite.co.uk/e/conference-workshop-outreach-masterclass-tickets-158547934139
- **Coping with Covid-19 impact and personal resilience** – with Leni Robson
  Registration link: https://www.eventbrite.co.uk/e/conference-workshop-doctorate-resilience-tickets-158548495819
- **Accessible academic writing skills** - with Dr Claire O'Connell
  Registration link: https://www.eventbrite.co.uk/e/conference-workshop-academic-writing-tickets-158549912055
- **When EDI Goes Wrong** - with Barry Wall, Polkadot Consultants
  Registration link: https://www.eventbrite.co.uk/e/conference-workshop-when-edi-goes-wrong-tickets-158550335321
- **Manage your PhD as a project'**– with Dr Lisa Cox
  Registration link: https://www.eventbrite.co.uk/e/conference-workshop-phd-project-management-tickets-158550748557

Tuesday 13th July 2021

9:00 **Welcome & Keynotes**

(chaired by Niall Hughes & Wayne Heatman)

Keynote 3 - Professor Annika Borgenstam, Department of Materials, KTH Royal Institute of Technology

Keynote 4 – Aidan O Neill, Materials Engineer, Castolin Eutectic

Keynote Q&A

10:30 **Presentations Session 2**

	Session 2A Additive Manufacturing (chaired by Paul Stavroulakis & Tongyu Wang)	Session 2B Corrosion & Surface Engineering, Demanding Environments, Energy (Chaired by Mark Taylor & Omer Koc)	Session 2C Machine Learning, Modelling & Simulation (Chaired by Paul Twine& Ryan Euesden)
10:30	**Atomistic Simulations of Defect Driven Grain Structure Evolution** - Christina-Eleni Vlachou-Portari, University of Manchester	**Early stages of surface oxidations on Silicon and Boron containing steels** - David Stamper, University of Warwick	**Microstructural Fingerprinting -** Mike White, University of Manchester
10:50	**Additive Manufactured Metal-Based Microneedle as Minimally Invasive Drug Delivery System -** Nikoletta Sargioti , Dublin City University	**A thermodynamic and diffusion-based model to predict the extent of surface oxidation for AHSS-** Nicola Beech, University of Warwick	**Investigating and Modelling the Stress Relaxation Response of AA2139 during Creep Age Forming** Kevin Tanswell, University of Manchester
11:10	**Improving Complementarity Between Additive Manufacture and Brazing -** Frances Livera, University of Sheffield	**Modelling the Precipitation Kinetics in Ni-based Superalloys -** Sakina Rehman, University of Manchester	**A Comparison of Recrystallization Models for use in Through Process Modelling of Sustainable Aluminium** - Vincent Kan, University of Manchester

11:30 Break

11:40	**Development of novel High Entropy Alloys manufactured by selective laser melting for high temperature applications** - Lucy Farquhar, University of Sheffield	**Scale development and Inhibition on Sugar Cane Heat Exchangers -** Huda Al-Jurani, University of Manchester	**Modelling the Thermal Profile of Low Alloy Steels -** Ashley Scarlett, University of Sheffield
12:00	**Parametric Optimization of a Cold Spray Nozzle** - Florentina-Luiza Zavalan, University of Leicester	**Investigations into the effect of Ga- and Bi-dopant regimes of bulk τ-MnAl -** Elizabeth Davis-Fowell, University of Sheffield	**A Comparison of Steels for High-Intensity Bolting Applications -** Joshua Collins, University of Sheffield
12:20	Prize Award for best oral presentation	**Facile Synthesis of Visible Light Driven Sn3O4 Supported Bimetallic PdNi Co-Catalyst and its Photocatalytic Activity for Hydrogen Production -** R.Rahul, Arul Anadar College	**Novel Pre-age Deform and Re-age Processing Route for Tailoring Properties in Al-Mg-Si-(Cu) Alloy -** Hanwen Fu, University of Manchester
12:40		Prize Award for best oral presentation	**Global and local modelling for fretting in multi-wire copper conductors -** Chun Ting Poon, National University of Ireland, Galway
13:00			Prize Award for best oral presentation

13:00 Lunch & Poster Session 2

- **Additive manufacturing of 3D architectures using metallic inks** - Berk Emre Aydemir, University of Manchester
- **Integrated Computational-Experimental Study of Microstructurally Short Crack Propagation in AA7xxx alloys** - Cameron Grant, University of Manchester
- **Development of a Mid-Wave Infrared Thermometer for Metal Machining Operations** - Emilios Leonidas, University of Sheffield
- **1D and 2D Finite Volume solvers for solid mechanics** - Federico Mazzanti, University College Dublin
- **In situ characterisation of the thermomechanical deformation behaviour of powder processed Ni-based superalloys** - Frances Synnott, University of Sheffield
- **Investigating the Performance of New Cutting Tools for Machining Nickel-Based Superalloys** - Henry Boyle, University of Sheffield
- **Modelling Radiation-Induced Defects in Nuclear Zirconium** - Jake Larkin, University of Manchester

- **Material and Process Design for Additive Manufacture of Hard Metals** - Joshua Berry, University of Sheffield
- **Understanding microtexture effects on the properties of Ti forgings** - Patrick Curran, University of Manchester
- **Fabrication of Microalloyed Steel for Automotive Applications** - Sulayman Khan, University of Sheffield
- **Osteoinduction Augmented Magnesium Medical Implants for Skeletal Repair** - Tina Sadat Hashemi, Dublin City University
- **Methodology for Representative Microstructure Calculations** - Vasilis Loukadakis, National Technical University of Athens
- **Understanding the contribution of Intermetallic Compounds on crack propagation between automotive silver tracks and lead-free solders during pull testing** - Wunmi Olukoya, University of Sheffield
- **Predicting Porosity in L-PBF Manufactured Components Using a Process Variable Input Based Meta-Data Approach -** Christopher Packer, University of Edinburgh

14:00 **Sustainable Manufacture** **Student Sandpit, led by Dr Dan Cogswell, University of Sheffield**

16:00 **Industry Panel Discussion** **'Metals for a Better Tomorrow'**

Chaired by Kevin Parkin (Casting Technology International)

- **Kate Fox** Technical Capability Manager Light Alloys and Steels, Rolls Royce
- **Jaya Vaithilingam** Noble Metals Specialist - Johnson Matthey
- **James Ashby**, Technical Manager, Liberty Steel Powder Metals
- **Matthew Lunt** Senior Principal Scientist, Materials and Structures, DSTL

17:00 **Prize Awards for Best Posters & Conference Close**

Keynote Speakers

Dr Chris McDonald, Chief Executive, Materials Processing Institute

Chris McDonald has a background in industrial research and manufacturing, where he has worked internationally. A graduate of Cambridge University, Chris is a Fellow of the Institute of Chemical Engineers and of the Institute of Materials, Minerals and Mining. He sits on industrial advisory boards at a number of universities, including the University of Oxford and the University of Sheffield. Chris has an interest in innovation management and industry dynamics. In addition to leading the institute, he provides expert opinion and consultancy support to companies, institutes, governments and public bodies in innovation and technology strategy and management. He also advises on the technical due diligence aspects of mergers and acquisitions. Chris is prominent in the development of public policy, around innovation, steel, SMEs, where he works to support growth and inward investment. Chris is the policy chair for Innovation and Enterprise for the Federation of Small Businesses, a member of the CBI Regional Council and Shadow Monetary Policy Committee for the North East, the Innovation lead for the UK Metals Council and a member of the Steel Advisory Board for UK Steel (EEF).

Keynote Abstract: Going Smart and Going Green: Digitisation and Decarbonisation to Meet the Challenges of Industrial Strategy

Globalised modern economies, like the UK, face an unprecedented challenge as we emerge from the COVID-19 pandemic, in responding to shifting geopolitical power, racing to decarbonise and protecting our sovereign security. Digitisation is a major part of the solution to these challenges, but brings with it disruption to jobs and communities, as hard won skills are made redundant, and step changes in productivity that risk mass unemployment. The Green Industrial Revolution is also heavily reliant on critical materials, often sourced from unstable, undemocratic and unethical regimes. The response that is required is an optimistic, interventionist industrial strategy, that places a just transition at its heart. By targeting the required green investment in the places where skills are being released from digitisation, will ensure these new industries can be successful, as well as securing a just transition for communities. Nations that are successful in this transition will invest heavily in innovation and commercialisation of intellectual property and act to secure critical materials in their economy, protecting sovereign capability in defence, infrastructure and critical manufacturing.

Dr Stella Pedrazzini, EPSRC Early Career Fellow, RAEng Associate Research Fellow, Imperial College London

Stella Pedrazzini works on the environmental degradation of engineering alloys. She has a particular interest in oxidation and hot corrosion of nickel and cobalt-based superalloys, aqueous corrosion of steel as well as advanced characterisation techniques such as transmission electron microscopy (TEM) and atom probe tomography (APT). She gained her DPhil in Materials Science from the University of Oxford in 2015, then spent three years as a post doc in the Oxford atom probe group. She then worked as a post-doc in the Rolls-Royce UTC at the University of Cambridge, before coming to Imperial College as a lecturer in October 2018. In 2019 she was awarded both an EPSRC Early Career Fellowship and an RAEng Associate Research Fellowship.

Keynote Abstract

Atom probe tomography (APT) is a high-resolution characterisation technique, which provides unparalleled spatial and chemical resolution on the nanoscale. It is a form of 3D quasi-atomic scale mass spectroscopy, which gives invaluable insight in the mechanisms of oxidation and corrosion of metals .Information on oxide scale formation and growth can be gained, including atomic segregation at grain boundaries and dislocations, which can then be used to inform oxide scale growth models and mechanisms. This type of analysis can be performed on corroded crack tips as well, allowing in-depth understanding of the failure mechanisms. This kind of information would normally require correlative microscopy using multiple high-resolution techniques, though it can be obtained through atom probe tomography. Understanding the corrosion mechanisms is key to predicting and extending component lifetime for specific applications.

Professor Annika Borgenstam, Head of department, Materials, KTH University

Annika Borgenstam is professor in Micro and Nano structures in Alloys. She is Head of the Department of Materials Science and Engineering at KTH Royal Institute of Technology in Stockholm, Sweden and Director for two research centres, the Competence Centre Hero-m 2 Innovation and Center for Mechanics and Materials Design. She is elected member of The Royal Swedish Academy of Engineering Sciences (IVA). She received her Master of Science in Engineering, Materials Technology, in 1990 and Doctoral degree in Materials science in 1997. Her work is on the structure of metallic materials from nano- to micro level, focusing on the understanding of how a particular structure is formed and how it can be modified. The emphasis is on the theoretical and experimental analysis of these structural transformations, with particular focus on the link between thermodynamic and kinetic properties and transformation mechanisms. The main objective is to develop models that describe how the structures are formed which can be used in the design of new materials or to improve already existing materials using an ICME approach.

Keynote Abstract: Materials of tomorrow - the design approach

To accelerate the design of new materials using an ICME approach theoretical as well as experimental tools are needed. In the research center Hero-m 2 Innovation, tools for the design of high strength steels, stainless steels, cemented carbides and powder based materials are being developed. Modelling achievements of phase transformation and mechanical properties as well as an improved understanding of the microstructural evolution will be highlighted.

Aidan O Neill, Materials Engineer, Castolin Eutectic

Aidan O Neill is a Materials Development Engineer at Castolin Eutectic Ireland where he works on the development and manufacture of atomised metal powders for surface protection of Industrial components. Aidan received his BEng in Mechanical Engineering from the University of Limerick in 2007, then specialised for a number of years in the area of super-hard cutting tool materials. In 2013, Aidan returned to education and graduated with a MEngSc in Material Science and Engineering from University College Dublin, completing a thesis in the characterisation of Zirconium based bulk metallic glasses (BMGs). Since 2014, he has been responsible for the development of metal powder alloys at Castolin

Eutectic Ireland. His particular interests are in the area of materials characterisation and the link between processing, microstructure and properties.

Keynote Abstract: Atomised Metal Powders for Surface Protection of Industrial Components

Atomisation is a process whereby a stream of liquid metal is transformed into millions of tiny droplets that are rapidly solidified to form powder particles. At Castolin Eutectic Ireland, Gas and Water atomisation are used to manufacture a range of metal powder alloys for surface protection of components in many Industrial sectors. In glass production, for example, moulds are subjected to repeated thermal cycling between about 500 and 800°C. Protective coatings produced from metal powders must therefore be thermally stable, and possess good hot hardness and oxidation resistance. Various techniques such as thermal spray and laser cladding are employed to convert the metal powder to a surface coating. In most cases, the powder must be once again heated above its solidus to achieve a well-bonded and dense coating. Many factors are at play here such as powder composition and particle size, base metal composition and preheating, equipment parameters, dilution, and solidification rates. The alloy composition gives the main properties required for the application. The challenge is to take the alloy through melting, atomisation, and surface coating processes while maintaining its compositional and structural integrity.

Oral Presentations

Session 1a – Additive Manufacturing

Structural control of eddy currents in soft magnetic materials

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Additive manufacturing is enabling the design of complex structural components, however it can also be used to manufacture functional components for electric machines such as a Stator. By utilising this freedom of design we are able to demonstrate a reduction in losses via structural control of eddy currents, to enable complex 3D flux pathways inspiring novel developments in electric machine architecture by removing the constraints of traditional 2D laminated structures.

Grain Refinement and Mechanical Properties for AISI304 Stainless Steel Single-tracks by Laser Melting Deposition: Mathematical Modelling versus Experimental Results

Muhammad Arif Mahmood [a,b], Andrei C. Popescu [c], Mihai Oane [d], Diana Chioibasu [c], Gianina Popescu-Pelin [a], Carmen Ristoscu [a], Ion N. Mihailescu[a]
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Many of the significant mechanical properties of stainless steel, including ultimate tensile strength, yield strength and hardness, the ductile-brittle transition temperature, and susceptibility to environmental embrittlement, can be improved by grain size refinement. Hall-Petch relation identifies that the improvement can be quantified in a constitutive relation. In this study, a new mathematical model to calculate the number of grains and their average size inside a single printed layer via the laser melting deposition (LMD) process is proposed. The printed layer's thermal history concerning the moving laser beam and co-axial addition of powder debits was analyzed and used to calculate the thermal stress and strain rate. The average grain size within the printed layer was calculated using the Johnson-Mehl-Avrami-Kolmogorov (JMAK) model. The mechanical properties, including ultimate tensile strength, yield strength, and hardness, were estimated using the average grain size. For single depositions of AISI 304 stainless steel powder debits on a steel substrate, dedicated experiments were performed to verify the model's trustworthiness. Scanning electron microscopy was used to quantify the number and size of grains. Vickers hardness tests were conducted to confirm the mechanical performances predicted by the developed model. It was found that the primary operating parameters strongly influence the grain type, resulting in three varieties of grains: (a) quasi-continuous circular, (b) long lath-shaped, and (c) a combination of the two mentioned above. The deposited layer's thermal history influences the thermal stresses and controls the growing grains' average size. A strong correlation between experimental and computational results, within the range of 10-15 %, and 8-10 %, was obtained for the average grain size and Vickers hardness

test. The laser scanning speed and laser power were in an inverse relation with the average grain size, while a direct relationship was noticed between the powder feed rate and average grain size. The mechanical computational and experimental results show that the highest yield strength (= 208 MPa), ultimate tensile strength (= 722 MPa), and hardness (= 278 HV) were obtained for the finest grain structure.

Laser Powder Bed Fusion of a non-modulated NiMnSn Heusler alloy for magnetic refrigeration applications

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This work aims to develop a manufacturing route for a low-cost magnetocaloric NiMnSn alloy using laser powder bed fusion (LPBF). LPBF can enable the production of high surface-area-to-volume components in order to increase the efficiency of heat transfer in magnetic refrigeration. Here, a series of LPBF experiments were performed to study the influence of the process parameters on the build density, structural defects (cracks and pores), and microstructural development on the builds. Generally, the density increased with the increase in the volume energy density (VED). The relative density was above 100% of the theoretical density when the VED was higher than 100 J/mm3, suggesting the occurrence of Mn evaporation. Through optimising the parameters to avoid lack of fusion and keyhole porosity, samples with lower density of defects were achieved, although it was difficult to fully eliminate the defects, especially cracking. Different heat treatments were applied to homogenize the chemical composition and increase the magnetocaloric properties, resulting in lower segregations of Ni, Mn, and Sn within the microstructure. By performing X-ray diffraction, it was found that the build is predominatly made of a highly ordered cubic L21 Heusler structure.

Investigating the Effect of L-PBF Process Parameters on 3D Printed Nitinol Part Properties

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Nitinol (nickel-titanium) is the most utilized shape memory alloy due to its superelasticity, low stiffness, damping, biocompatibility, and corrosion resistance. Selective laser melting (SLM) is emerging as an effective method to fabricate Nitinol with desirable functional and mechanical properties; as the composition, microstructure, thermal gradients and density can be varied. The process parameters and thermal cooling gradient are highly critical for obtaining the correct phase structure for shape memory capabilities. Various parameters in L-PBF can be categorised as laser, scan, powder, and environment (temperature and oxygen concentration) related factors. In the current work, multiple Nitinol samples were 3D printed in horizontal and vertical build orientations with varying laser power, scan speed, hatch spacing and layer thickness. The resulting energy densities and thermal gradients, were found to influence the density of the printed samples. The mechanical characteristics of the printed samples were investigated through cyclic compression and impact testing. The strain recoveries and latent heat regenerations were monitored using Digital Image Correlation and IR thermal imaging techniques. The effect of laser parameters on thermal expansion, hardness and stiffness of the samples were also investigated via dilatometry, Vickers microhardness, and impulse excitation techniques. The microstructure, phase properties, and phase transformation behaviour were explored through SEM/EDX, nanoindentation, XRD, Differential Scanning Calorimetry (DSC), AFM and EBSD. This detailed study

provides a more detailed understanding of the relationship between the L-PBF process parameters for fabricating Nitinol parts with tailored mechanical and functional properties.

Fabrication Of Flexible Sensors Based On Polymers And Nanomaterials Via Stereolithography, Laser Sintering, Drop Casting And Fused Filament Fabrication Techniques

Anesu Nyabadza[1-3], Mercedes Vázquez[1-3], Brian Fitzpatrick[4], Dermot Brabazon[1-3]
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The use of flexible sensors has tripled over the last decade due to the increased demand in various fields including biomedical, food industry, and wearables. Flexible sensors have the ability to be bent and stretched during use and can still retain their electrical and mechanical properties. This gives them an advantage over rigid sensors that lose their sensitivity when subject to bending. Advancements in additive manufacturing and nanotechnology have enabled the development of tailored flexible sensors. In this project, various additive manufacturing methods are used to develop nanocomposite-based flexible sensors including stereolithography, laser sintering, fused deposition modelling and drop casting. The two key materials in the fabrication of these sensors are a flexible polymer and conductive metal nanoparticles. Shape memory polymers have gained much attention in the literature due to their shape memory, softness and self-healing properties. In this project, various polymers are used as substrates on/in which the sensing conductive material is placed including parafilm, POLY(N-ISOPROPYLACRYLAMIDE) and gelatin. Conductive particles including silver, copper and carbon nanoparticles are used to induce sensing properties to the sensor. A flexible temperature and a humidity sensor are developed in this project.

Process Parameters Development of Aluminium-TiB2 Composite Alloy processed by L-PBF

Francesco Careri [a,b], Stano Imbrogno [a], Raja H. U. Khan [c], Moataz M. Attallah [a].
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This work aims to develop a process map for Laser-Powder Bed Fusion (L-PBF) of defect-free components of a novel Al-TiB2 reinforced composite alloy. The influence of the process parameters (laser power, scan speed, hatch spacing) on the general final quality of the produced specimens have been investigated. The optimisation and the analysis of the process parameters was performed at different stages. The porosity and the surface roughness were evaluated using optical microscopy analysis and the profilometer. Electron microscopy was used to analyse both single laser tracks and the bulk specimens. Moreover, the material properties in terms of hardness, related with the microstructure, were evaluated and linked to the process parameters investigated. The obtained results indicate that different L-PBF process parameters lead to a variation of the material integrity as well as the microstructure and mechanical properties. In addition, a suitable energy density allows to reduce the porosity together with surface roughness and lead to superior mechanical properties.

Session 1b – Microstructural Design

From a Composite to a Blend: Exploiting Field Assisted Sintering Technology (FAST) to Engineer Fine-scale Alpha Morphologies in Novel Ti-64/Ti-5553 Synergistic Composites

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Field Assisted Sintering Technology (FAST) has been the focus of increasing research in recent years as a near-net shape manufacturing process for titanium alloys. The solid-state sintering and joining (FAST-DB) abilities offer many advantages over both conventional melt-wrought routes and other emerging routes such as additive manufacturing (AM). In this study, two aerospace grade titanium alloys in size distributions surplus to AM requirements, have been recycled and blended to produce titanium-titanium composites via FAST with a range of processing parameters. Optical and scanning electron microscopy inspection has revealed regions of fine-scale alpha laths, despite the relatively slow cooling, where the two alloys have diffusion bonded locally. Such fine-scale laths are typically produced via substantial heat treatment and aging processes in beta alloys to achieve exceptional high strengths. Vickers hardness testing has provided initial results that mark a hardness increase of up to 18% for the composites compared to the stronger of the parent alloys. Further testing and characterisation is now under way to assess the strength-ductility behaviour and understand the chemistry of these composites. The utilisation of waste and surplus material to hit a compositional sweet spot which enables enhanced mechanical properties could be potentially game-changing for titanium use in many industries.

Powder Hot Isostatic Pressing of Niobium: Influence of Powder Characteristics on the Microstructure and Mechanical Properties

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In this work, the powder hot isostatic pressing (P-HIP) response of niobium was investigated for the near-net-shape manufacture of space components. Particularly, the influence of the powder characteristics on the as-HIPed microstructure and mechanical properties was investigated. The first part of the study focuses on the characterisation of three different Nb powders (fine, mid-range and coarse) to understand the differences in terms of powder morphology, particle size distribution (PSD) and oxygen content. The three powders were successfully consolidated using HIP to create dense microstructure. The microstructural analyses performed using electron backscatter diffraction (EBSD) technique showed fully recrystallised microstructures with a correlation between the particle size and the average grain size. To understand the influence of interstitial levels on the strength of as-HIPed Nb, microhardness tests were performed on the three powders. The results clearly show that the interstitial content has an important effect on increasing Nb strength by solid solution strengthening. Tensile tests performed on mid-range Nb showed superior levels of strength and elongation if compared to wrought Nb. To further emphasise the role of interstitial content in the mechanical properties of pure Nb, mid-range powders were subjected to sieving operations to increase the interstitial levels and then tensile tested. The results clearly show an increase in yield strength and ultimate tensile strength, retaining excellent levels of elongation. The final part of the work focused on the development of a simple structure-property relation model to understand

and predict the yield strength of pure Nb based on Interstitial levels and grain size in the as-HIPed microstructure.

Development and characterization of Ti36Ni49-xZr15FeX=0-2 based high temperature shape memory alloys with enhanced cold workability.

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Shape memory alloys have the unique characteristic of remembering their parent shape. TiNiZr based high temperature shape memory alloys (HTSMAs) have limited cold workability rendering their limited engineering applications. Ti36Ni49-xZr15FeX=0-2 based HTSMAs were successfully developed by arc melting followed by homogenization at 950℃ for 2 hours in an argon atmosphere. Solution treatment was done at 850℃ for 1 hour followed by water quenching. Gradual increase of Fe (0-2 at. %) tends to enhance the cold workability significantly (6-13%) thereby increasing the ability of the material for being plastically deformed when subjected to cold rolling. Microstructural evaluation, topographical analysis, shape memory behavior, mechanical properties and corrosion properties determination were done. Completely martensitic structure was visible by optical microscopy and there is a relative coarsening of the martensitic structure with increased iron content. Scanning Electron Microscopy (SEM) indicated the presence of parent phase and (Ti, Zr)2NiFe precipitates. Atomic Force Microscopy (AFM) indicated the gradual increase in surface roughness with respective iron addition. Transformation temperatures declined with increasing Fe content due to relative stability of parent (B2) phase for a wider temperature range. Micro-hardness results indicated that there is a relative softening of the matrix with respective iron addition due to relaxation of the distorted lattices. Nano-Indentation results also indicated the softening of the matrix for localized regions. Corrosion resistance decreased with increased iron content due to enhanced Ni ions release rates.

Eutectic High Entropy Alloys as Brazing Fillers Designed by Machine Learning

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With the objective to reduce the carbon emissions, more efficient and hence higher temperature processes will be required. This is driving the next generation of materials, and among them, brazing fillers with better mechanical properties, performance at high temperatures and the capability to easily braze materials with different chemical natures (e.g., metal to ceramics). Recently Eutectic High Entropy Alloys (EHEAs) have attracted a lot of interest due to their dual phase microstructure, which provides better control of the final mechanical properties at high temperatures. EHEAs should also possess good castability and avoid segregation and large thermal expansions as a consequence of the isothermal eutectic transformation. However, the traditional trial and error design methodology cannot be applied for those alloys due to the large number of possible alloys, as a result of combining element and stoichiometry. In order to be able to make reliable predictions, this work attempts to show a new design methodology based on machine learning by the preparation of two novel EHEAs. In the methodology, a dataset based on the thermodynamic, electronic and atomic size features of 300 high entropy alloys has been used to train a random forest, a machine learning predictive model, to be able to classify an alloy as an EHEA or not. The process and examples of alloys thus designed will be shown.

Study on the relationship between fatigue and microstructure of additively manufactured Ti64

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The advent of additive manufacturing (AM) technologies such as electron beam melting (EBM) is creating a demand for new research into how AM processing influences the material properties and failure mechanisms of Ti-6Al-4V (Ti64). The present study examines the relationships between microstructure, processing, static mechanical properties and fatigue behavior of Ti64 alloy produced by EBM. Furthermore, the effects of hot isostatic pressing (HIP) and heat treatment on microstructural evolution, static mechanical performance and on the fatigue behavior are presented. The as-built material exhibited a fine lamellar microstructure with high strength and low ductility when compared to the coarser $\alpha + \beta$ transformed microstructure of the heat treated and HIP'ed material, which had comparatively low strength and high ductility. The impact toughness of these materials was found to be more sensitive to the porosity content rather than the microstructure. Porosity content and microstructure are both identified as contributing factors to the fatigue behavior of the examined materials.

Modelling the Microstructure Evolution During Hot Working of Titanium Alloys

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The texture evolution during hot rolling of individual Ti-6Al-4V α and β phases was predicted using a crystal plasticity model. Model parameters were varied to investigate the effect of morphology and strain rate on the resulting deformation textures of the individual phases during hot rolling. The α phase formed a 0002||ND component characteristic of warm rolling CP-Ti, rather than 0002||TD components that appear for experimental rolling in the dual phase region. The β phase formed characteristic α and γ fibres but did not form rotated cube components comparable in mrd to that of experiment in literature. Both observations support the hypothesis that dynamic transformation could be the cause of these distinct texture components.

Session 1c - Advanced Processing & Characterisation

Investigating ductility gains in automotive steels under non-linear strain paths

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The structural integrity of automotive chassis components is constrained by the geometry of the part and the mechanical performance of the selected material, with ductility being a key property. This study explores step-change ductility improvements that can be attained by subjecting the material to a non-proportional strain-path; improvements here could revolutionise both the achievable component complexity and offer a method for fabricating alloys that are presently unfeasible using existing methods. Whilst ductility gains are evident via non-proportional loading, the mechanisms that govern the material response are not well understood, for example, any deformation history can result in very different, often undesirable mechanical responses. A two-step deformation procedure was applied to a single phase ferritic steel, consisting of a cold rolling (pre-straining) step followed by a uniaxial tension step. The magnitude and direction of the rolling pre-strain was varied, aiming to understand the subsequent response, as was the direction of the uniaxial tension. Texture, microstructure and grain-orientation specific behaviour was examined using a combination of Electron Backscatter Diffraction (EBSD) and in-situ via Synchrotron X-Ray Diffraction (SXRD). Results indicated that the direction of deformation, especially for the pre-straining step, plays a salient role in the imposed texture and as a result, in the macroscopic mechanical response. Texture configuration showed a remarkable change for perpendicularly rolled specimens, even for very low rolling induced strains. Increasing the rolling strain significantly decreased the specimen ductility, particularly when abrupt strain path changes were applied. This result was also reflected in the lattice strain and work hardening behaviour of the individual grain families, with the latter showing an abrupt decrease in early stages of plastic deformation, for the specimens subjected to the highest rolling strains.

Hot Isostatic Pressing of Powder Blends for Alloy Development

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This study focuses on the development and metallurgical characterisation of metal powder blends and for the development of novel alloy compositions by powder metallurgy, as well as the assessment of their additive manufacturability and weldability. Two different metal alloys were chosen; a metallurgically compatible couple (Ti-Zr), which may form a stable solid solution, and an incompatible couple (Al-W). The metal powders were mechanically blended and the solid parts were produced by Hot Isostatic Pressing (HIP). The materials were characterised using optical microscopy, scanning electron microscopy (SEM), X-ray diffraction analysis (XRD) and hardness measurements. The Al-W material was represented by an uneven distribution of W particles within the Al-solid region. The Ti-Zr in contrast showed fully consolidated and diffused microstructure characterised by lamellar grains. The materials reactivity was then tested using a novel laser shock-plume analysis setup using a high speed camera and an infrared camera.

4D printing of Magnetic Shape Memory Alloys

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Magnetic shape memory alloys (MSMA) are ferromagnetic materials exhibiting a plastic reversible transformation when subjected to a magnetic field. This unique property makes them good candidates for actuators. Previous studies have reported an increase of the shape memory effect in bamboo-like Ni-Mn-Ga structures. Thus, 3D Printing, using Laser Powder Bed Fusion (l-PBF), is a potential manufacturing approach to fabricate near-net-shape textured MSMAs structures. This study investigates the influence of l-PBF process parameters (laser power, scan speed, hatch spacing and scanning strategy) on the relative density and the microstructure of bulk and lattice specimens made from a gas atomised Ni-Mn-Ga powder doped with excess Mn. The as-built bulk samples showed a high relative density, up to 98% with a homogenous 14M structure and a ferromagnetic behaviour. The residual porosity in the build is mainly due to gas voids, lack of fusion and cracking. Fabrication of lattice structures at a low laser power (70W) and scan speed (450 mm/s) resulted in a significant decrease in cracking. The effect of process parameters on the strut's geometry was also investigated, in addition the influence of the lattice geometries on the magnetic properties. Microstructural analysis revealed a layered microstructure with a stripe-like surface relief that originated from the presence of martensitic twins within the sample. Further work will focus on developing a new design to enhance the magnetic properties.

Investigation of the influence of the PBF-LB build plate part placement position on the microstructure and the mechanical properties of Ti-6Al-4V alloy components

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This study investigates the x-y-z build plane print homogeneity obtained using selective laser melting (SLM), over a build area of (250 x 250 x 170) mm, with respect to both the printed part material and mechanical properties. To date, this type of investigation has been focused on x-y build planes and this study extends the homogeneity investigation to the z direction. The printing was carried out on Ti-6Al-4V ELI alloy, using a Renishaw production scale SLM system. Printed test parts were located at z heights of 20, 90 and 160 mm, positioned at 9 locations across the 250 x 250 mm, x-y build area. Parts at each location were examined using XRD to determine their phase structure, along with SEM and OM for the analysis of the grain and phase morphology. Microstructural examination demonstrated the presence of a mixture of equilibrium α+β phases and very course α^'martensite needles, for all test samples. Relatively small differences in part microstructure were observed across the build area. The mean hardness of the sample in the z-plane ranges from 342 ± 4, at the bottom (20 mm) of the test samples, to 344 ± 4 HV0.5 at the top (160 mm). Samples from across the build volume were HIP treated and tensile test results will be presented, both before and after this treatment. Only minor variations in Ti-6Al-4V part properties were obtained over the (250 x 250 x 170) mm x, y and z build directions, demonstrating the homogeneity of the printing process.

Microstructural Characterisation and High-Temperature Oxidation of Laser Powder Bed Fusion Processed Inconel 625

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The aim of this study is to identify the impact of post-process heat treatment and surface modifications on the oxidation behaviour of IN625 Ni-superalloy fabricated using Laser Powder Bed Fusion (L-PBF). The isothermal oxidation behaviour of L-PBF IN625 was studied and compared to wrought material at 950°C for times up to 500 hours in laboratory air and pressure. L-PBF introduces unique metallurgical features, including surface texture, morphology, anisotropic microstructures and mechanical properties, and the microsegregation of alloying elements. Heat treatments were applied to remove inhomogeneity, resulting in microstructures similar to those achieved with traditional routes. These unique features were studied to determine their influence upon the oxidation and corrosion properties of the alloy.

Determining the Effects of Radiation Damage on Nuclear Grade Material

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In the UK, Advanced Gas-Cooled Reactors (AGRs) use a variation of 316 stainless steel as the fuel cladding due to its high temperature and corrosion resistance. There is an economical drive to use UO_2 fuel with higher enrichment and burn-up which will produce substantially harsher nuclear core environments, impacting the cladding's end of life performance during post-discharge and storage. Therefore, it is paramount to investigate the physical and mechanical properties changes brought on by the increased nuclear activity in order to mitigate any potential future hazard. The aim of this PhD project is to gain a fundamental understanding of the effects of radiation damage on AGR fuel cladding material, stainless steel, by extrapolating data to predict the damage for high enrichment and high burn-up nuclear fuel. Originally the project's main analytical technique was Transmission Electron Microscope (TEM) but due to COVID this has changed to a novel X-Ray Diffraction (XRD) technique called Convolutional Multiple Whole Profile (CMWP) analysis. This uses diffractograms to determine dislocation density via peak broadening and other factors. In this contribution, two projects will be presented. Firstly, the effects of gamma radiation on the corrosion layer in stainless steel and the correlation to its distance to the radiation source; this will be explored via Scanning Electron Microscope (SEM) analysis. Secondly, an overview of the novel XRD technique, with its limitations, will be explained, in combination with a proposal for future work packages.

Session 2a – Additive Manufacturing (chaired by Paul Stavroulakis & Tongyu Wang)

Atomistic Simulations of Defect Driven Grain Structure Evolution

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Grain boundary migration is the key process that happens during recrystallization in metals. An aluminium fcc crystal containing a pristine part (-19.1°) and a deformed part, made of two different blocks (14.1° and 24.1°), was constructed. After minimization, two high-angle $\Sigma 7$ [111] boundaries, separating the pristine and the deformed parts, and two low-angle boundaries, separating the two blocks of deformed material, were formed. The grain boundaries migrated from the pristine to the deformed part thanks to the extra energy provided by the absorption of the dislocations, contained in the low-angle boundaries. The boundary migration, which was driven by the difference in potential energy between the pristine and the deformed parts, left only pristine material behind. The simulations were performed at a range or temperatures (600K to 900K), using LAMMPS. The position of each boundary was found by detecting the peaks in the potential energy plots. The mobility values for each temperature were calculated using the velocity and the driving force data. The activation energy was then calculated by fitting Arrhenius plots at the mobility data. The trends in the calculated values in combination with the form of the boundary will unveil the mechanism of grain boundary migration during recrystallization.

Additive Manufactured Metal-Based Microneedle as Minimally Invasive Drug Delivery System

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Various traditional methods are used as drug delivery systems that usually result in pain and poor administration of nucleic acid and drug molecules. A painless micro-sized device capable of delivering drugs easily and efficiently, with no side effects, would present an attractive solution. Additive manufactured microneedle (MN) arrays have been considered as an innovative platform for an optimal and cost-effective design and manufacture, eliminating the traditional system's disadvantages. In this project microneedle arrays have been explored as an alternative drug delivery system. Specifically, the research aims to develop 3D-printed 316L stainless steel MN array with optimal mechanical/biological properties for disease management and treatment. A computational modelling approach using explicit dynamic analysis (ANSYS, Inc., USA) was employed to determine the optimal geometrical features of the MN arrays (i.e. height and aspect ratio) when under compressive loading. Experimental investigations (of mechanical properties) were also conducted to validate the computational data. Comparison of simulation and experimental data led showed similar results with a difference less than 2%. A Design of Experiment (DoE) approach was used to determine the influence of printing parameters on the geometric features (i.e. needle height, aspect ratio, surface area, and tip diameter) and mechanical properties (compressive strength, and Young’s modulus) of MN arrays. In particular, the influence of changing the laser speed (500–700 mm/s), power (35–70 W), and trace width (0.09–0.12 mm) was investigated. Process optimization based on these results concluded that MN arrays with 1,000 µm height, 4:1 aspect ratio, printed using a laser power of 70 W, speed of 600 mm/s and trace width 0.12 mm could lead to MN arrays with optimal dimensions and mechanical properties. Overall, these findings provided a better understanding the 3D printing process parameters required to achieve MN arrays with the optimal properties for clinical use as drug delivery systems. Future work will focus on the optimisation of the drug delivery from the MN arrays.

Improving Complementarity Between Additive Manufacture and Brazing

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Additive manufacture (AM) and brazing are two areas that have seen a significant quantity of research individually, but their combination has not been widely investigated. AM is a layer-upon-layer building technique that can produce complex, three-dimensional parts in shorter timeframes than traditional manufacturing, but is limited in build size for metal part production. Brazing uses a molten filler metal to create a joint between two parent materials. Combining the geometrical freedom of AM with a joining process could reduce the lead-time of component manufacture and enable complex part geometries to be realised. The disparity between the typical surface finish of AM and the surface roughness requirements for a brazed joint is the main challenge in combining the techniques. Currently, AM parts are machined down to decrease their rough surface to allow the filler metal to adequately wet and spread to form a strong joint. This adds time and cost to the manufacturing processes, which the use of a native AM surface could minimise. There is scope to tailor an AM surface, by implementing a topographical structure, which may aid braze alloy wettability and even control flow direction to produce complex joint geometries. The applications of this research are considerable due to the freedom of AM and its increasing popularity as a manufacturing technique in aerospace, medicine and the nuclear industry.

Development of novel High Entropy Alloys manufactured by selective laser melting for high temperature applications

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High-entropy alloys (HEAs) represent a large potential research area for high strength alloys which are mostly stable at elevated temperatures. Many HEAs shown enhanced strength and hardness when made by additive manufacturing (AM) due to microstructural refinement. The CoCrFeNi HEA system, in particular, has been shown to have a stable single phase microstructure and is suitable for AM. The effectiveness of in-situ alloying of elemental Cu and Ti powders to pre-alloyed CoCrFeNi powder during the AM process is investigated. The CoCrFeNiX (where X = Ti, Cu) samples were manufactured using selective laser melting (SLM) by varying parameters such as laser power, hatch spacing and scanning velocity. Samples were then analysed by microstructural characterisation and comparison with arc-melted samples and alloys from the literature. Novel HEAs have also been designed predicted to have solid solution phases, specifically for the application. This design process was done by the calculation of empirical parameters such as mixing enthalpy (ΔH_{mix}), valence electron concentration (VEC) and atomic size mis-match factor (δ). The values for those alloys were then compared to those calculated for alloys with a known solid solution microstructure. 9 of the suggested alloys were made using arc-melting and analysed using scanning electron microscopy (SEM) and X-ray diffraction, to assess the success of the design procedure.

Parametric Optimization of a Cold Spray Nozzle

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Cold spraying is increasingly attractive as an additive manufacturing technique as it retains the original properties of the feedstock and it can produce oxide-free deposits. This technique consists in accelerating metal powder particles to a high velocity by a high-speed flow and spraying them onto a substrate, where they plastically deform at impact and form a coating. A uniform particle distribution of uniform velocity is desirable to achieve a good quality metal deposition. Two aerospace design codes based on the Method of Characteristics (MOC) are used to define axisymmetric convergent-divergent cold spray nozzle shapes of smooth, S-type profile. The profile is parametric and allows a multi-objective optimization. The goal is to improve on the metal particle delivery of the Impact Innovations GmbH 5/11 Out4 commercial nozzle, which has conical walls. The nozzle inner wall is varied by changing the nozzle inlet convergent angle, the throat radius of curvature, and the peak slope in the divergent part. The effectiveness of the redesigned nozzles is tested numerically by Computational Fluid Dynamics (CFD), using a coupled Eulerian-Lagrangian formulation, in which the steady gas expansion is computed by a Reynolds-Averaged Navier-Stokes (RANS) Shear Stress Transport (SST) k-ω model and the particle motion is determined by the Discrete Phase Model (DPM). Then, the design performance is assessed by evaluating a penalty function for the different nozzle shapes. The penalty function combines some of the most desirable characteristics in cold spraying, namely: a high particle impact velocity, a good spatial uniformity in this velocity, and a good uniformity of the radial distribution of the particles.nFinally, the performance of the best performing cold spray nozzle shape within the parameter space investigated is compared with that of the commercial conical convergent-divergent nozzle. This study has shown the potential of this integrated, multi-objective, parametric design approach that can be built up in complexity to further improve the deposition performance of cold spray nozzles.

Session 2b - Corrosion & Surface Engineering / Demanding Environments & Energy

Early stages of surface oxidations on Silicon and Boron containing steels

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An investigation into the early stages of oxidation on silicon and boron containing steel samples, these early reactions were modelled using MICRESS, to determine how the oxides nucleate and grow across the surface of the sample. Different modelling strategies were implemented such as the seed density model, seed undercooling model etc. in order to see the most logical oxide growth, as well as which outcome mirrored industrial oxidation most accurately. Boron is commonly added to improve hardness and strength in extremely small amounts (10-50ppm), but with these additions, problems arise with oxidation during manufacturing annealing lines. The output of the model shows the growth of silicon and boron oxides as they cover the surface in up to 5 minutes of oxidation, the reactions were modelled in annealing atmospheres (low oxygen) in order to suppress the formation of iron oxides and concentrate on the growth of silicon and boron oxides.

A thermodynamic and diffusion-based model to predict the extent of surface oxidation for AHSS

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Advanced High Strength Steels (AHSS) are widely used in car structures to reduce vehicle weight, thus lowering fuel consumption and CO_2 emissions. While these steels possess excellent mechanical properties such as yield strength and elongation, their corrosion resistance is poor. AHSS therefore require the application of a zinc coating, which corrodes preferentially and protects the base material. Prior to galvanising, these steel grades are annealed at temperatures of around 800°C in atmospheres containing up to 100% hydrogen. Under these conditions, the metallic alloy constituents of AHSS (e.g. Mn Si, Al and Cr) can oxidise and form an external oxide layer that liquid zinc may fail to adhere to. Consequently, surface quality issues such as bare spots can arise. If the critical conditions leading to external oxide formation were known, manufacturers could strategically avoid their occurrence by instead encouraging the formation of internal oxides. An informative thermodynamic and diffusion-based model has been developed to visualise and identify the critical concentrations of AHSS alloying elements as well as the stable oxide phases which form. The model, its development and results, are discussed.

Modelling the Precipitation Kinetics in Ni-based Superalloys

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In turbine-disc applications, Ni-based superalloys are precipitate strengthened by the dispersion of coherent ’ (L12) precipitates in an FCC-disordered solid solution matrix of . When these Ni-based superalloys oxidise, protective oxide layers are formed along the surface of the superalloy. Beyond these layers is a weaker region depleted in ’ particles, due to the diffusion of species from the ’ precipitates to the surface oxide, leading to a detrimental effect on the mechanical properties of the superalloy. The first year of this PhD is dedicated to developing a mean field model, which simulates the precipitation kinetics of a Ni-based superalloy in the presence of oxygen. Two mean-field models, the Kampmann Wagner Numerical (KWN) model and the mean radius model, are compared and are combined to develop a higher fidelity precipitate size distribution model. The particle distribution is divided into a series of discrete size classes, each represented by a control volume. The model consists of a rate law, which calculates the growth or dissolution rate of each discrete particle size class, and a continuity equation, which keeps a record of the amount of solute being tied up in the precipitates. The nucleation of precipitates is omitted from the model as the evolution of existing precipitates is of interest only. To include the effect of oxygen, accurate thermodynamic data is obtained to represent equilibrium compositions, diffusivities and Gibbs energies using the CALPHAD databases present in ThermoCalc. Further work would involve combining this model with crystal plasticity, oxide kinetics and phase transformations, and the diffusion of species e.g. Al, Cr, O. This combined model is working towards the main aim of the PhD project which is modelling environmentally assisted cracking (EAC) in Ni-based superalloys.

Scale development and Inhibition on Sugar Cane Heat Exchangers

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Brazil is one of the top producers of sugar for the global sugar production. Recently, Brazil has increased its production of ethanol from sugar cane and BP-Bunge Brazil contributes by producing over 1.5 billion litres of ethanol. The process to produce ethanol and sugar is to first break down the sugar cane which is then clarified using addition of lime. The addition of lime increases the concentration of calcium ions that are present in the sugar juice produced. When the juice is heated in the evaporator system the calcium ions form scales on the surfaces. This reduces the heat transfer coefficient of the steel walls, efficiency of the evaporator system and the rate of ethanol and sugar production. A scale inhibitor applied to the surface of the steel to reduce or prevent scaling is envisioned for this project. The preliminary study is to develop a film of calcium phosphate scaling on stainless steel 304L in order to develop coatings to prevent this film from being developed.

Investigations into the effect of Ga- and Bi-dopant regimes of bulk τ-MnAl

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Rare-Earth Free Permanent Magnets have been subject to renewed academic and industrial interest over the past decade due to increasing concerns about rare-earth availability and the environmental impact associated with their refinement. One candidate material is τ-MnAl though much work is needed to improve its magnetic and metastable properties. Motivated by this, bulk MnAl has been synthesised annealing in both an undoped state and doped with Ga and Bi. The systems were annealed following published procedures to form the τ-MnAl ferromagnetic state within a Quantum Design MPMS3 SQUID to observe the change in magnetic properties as the transformation to τ-MnAl like states took place. All dopant regimes saw a formation of a ferromagnetic phase but with changes in transformation temperatures, behaviours and resulting magnetic properties, showing an appreciable increase in system coercivity and Curie Temperatures but decreases in remanence and saturation magnetisation.

Facile Synthesis of Visible Light Driven Sn3O4 Supported Bimetallic PdNi Co-Catalyst and its Photocatalytic Activity for Hydrogen Production

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Air pollution and climate change are closely related. As well as driving climate change, the main cause of CO2 emissions – the extraction and burning of fossil fuels – is also a major source of air pollutants. What's more, many air pollutants contribute to climate change by affecting the amount of incoming sunlight that is reflected or absorbed by the atmosphere, with some pollutants warming and others cooling the Earth. These short-lived climate-forcing pollutants (SLCPs) include methane, black carbon, ground-level ozone, and sulfate aerosols. They have significant impacts on the climate: black carbon and methane in particular are among the top contributors to global warming after CO2. When we burn fossil fuels, such as coal and gas, we release carbon dioxide (CO2). CO2 builds up in the atmosphere and causes Earth's temperature to rise, much like a blanket traps in heat. This extra trapped heat disrupts many of the interconnected systems in our environment. Climate change might also affect human health by making our air less healthy to breathe. Higher temperatures lead to an increase in allergens and harmful air pollutants. For instance, longer warm seasons can mean longer pollen seasons – which can increase allergic sensitizations and asthma episodes and diminish productive work and school days. Higher temperatures associated with climate change can also lead to an increase in ozone, a harmful air pollutant. The remediation of environmental pollution and generation of hydrogen using photocatalysts shows potential solution to the increasing demand for energy and the associated environmental concerns. TiO2 acts as a significant photocatalyst and has been widely investigated in energy and environmental fields. However, its poor quantum efficiency, which is due to the rapid recombination rate of photogenerated electron-hole pairs, still limits the widespread use of TiO2 in practical applications. In recent times, semiconductor with cocatalyst composite materials are used to modify band gap position, improve carrier separation and facilitate charge recombination for photocatalytic generation of hydrogen. In support of this reason, construction of photocatalysts with some metal sulfides, metal oxides, and noble metals were useful to enhance the hydrogen generation. Furthermore, it has been reported that the structure and morphology of the photoactive sites of semiconductor to improve the light harvesting and photocatalytic activity. However, the efficiency, expensive and toxic nature of materials would also be calculated for practical applications. Recently, non-toxic tin oxide (Sn3O4) photocatalysts shows enhanced activity for hydrogen evolution. Based on these concepts, we attempted to synthesis Sn3O4 supported Pd-Ni alloy nanoparticles prepared through two-step hydrothermal process and the photocatalytic activity was examined by the generation of hydrogen. The synthesized Sn3O4 supported photocatalyst has been characterized by XRD, TEM, EDX and XPS.

Session 2c - Machine Learning / Modelling & Simulation

Microstructural Fingerprinting

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Quality control of materials often involves image analysis, performed by an experienced Materials Scientist, by eye. This can be a time-consuming process and is subject to bias. The rise in machine learning for image recognition has provided a new toolkit for image analysis, which is yet to be fully exploited within the field of Materials Informatics. This project explores the use of machine learning techniques to generate compressed representations (fingerprints) of micrographs, which allow for quantitative comparison between microstructures. Potential applications include quantification of the disparity between microstructures for quality control, classifying microstructures, predicting materials properties from image data and identifying potential processing routes to engineer new materials with specific properties. Two main approaches are considered. First, the classical "bag of words" (BoW) approach is implemented with both scale-invariant feature transform (SIFT) and speeded-up robust features (SURF) for keypoint feature generation. Second, convolutional neural networks (CNNs) are explored and comparisons between the two approaches made using several classifiers The Carnegie Mellon University Ultrahigh Carbon Steel (CMU-UHCS) dataset is utilised to test the above methods and all CNNs discussed are pre-trained on the ImageNet dataset. CNNs outperform BoW across the board, however, there is a saturation in classification accuracy at around 97%.

Investigating and Modelling the Stress Relaxation Response of AA2139 during Creep Age Forming

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Creep Age Forming (CAF) has been successfully used to manufacture thin wing skins. Now the technology is being developed to fine-tune the shape of thick, geometrically complex, single-piece cockpit fuselage sections. This application involves forming a new advanced aluminium alloy previously deformed by High Energy Hydro Forming (HEHF).

CAF applies heat and mechanical pressures to refine the aerodynamic profile of a component, whilst age hardening the material to the final temper condition. Significant cost and weight savings have been demonstrated with this technology as it allows for the production of large, complex, integral components, thereby reducing assembly and joining operations. The accumulation of dislocation creep results in a permanent change of shape and stress relaxation response, occurring alongside the precipitation hardening that strengthens the alloy. A complex interplay exists between these two effects, as ageing inhibits creep. The creep relaxation response of the damage tolerant alloy AA2139 will be characterised to attain a robust understanding of the materials creep response and sensitivity to pre-strain. A combination of elevated-temperature stress relaxation tests and microstructural characterisation throughout the ageing sequence, will be used to develop a creep relaxation material model. This model should improve the capability to predict final geometry after springback.

A Comparison of Recrystallization Models for use in Through Process Modelling of Sustainable Aluminium

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Through Process Modelling (TPM) can be used to predict the physical properties of an alloy at the end of its production process. This is done by taking into account the evolution of the microstructure. It is widely accepted that recrystallization is an important mechanism that affects the microstructure of the alloy. This project aims to evaluate different recrystallization models for their use in TPM to give an accurate prediction of the properties of the end alloy. Preliminary calculations with published models showed that achieving a high degree of accuracy requires impractical computational costs. As such, it was concluded that a simpler mean field model can be calibrated with existing models to achieve higher degrees of accuracy without excessive computational costs.

Modelling the Thermal Profile of Low Alloy Steels

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There is currently a gap in knowledge between small scale laboratory heat treatments on metallic components, weighing a few grams to that of, large forgings weighing several hundred tonnes, and of the subsequent mechanical behaviour exhibited throughout low alloy steels. In order to better understand these differences in the two extremes, a better understanding of the current methods used to model thermal profiles of large components is required. This presentation will discuss a combination of thermodynamic, finite element modelling and small specimen experimental techniques to try and understand phenomena observed in large components. This work has been undertaken as a precursor to physical heat treatments of structural and bolting steels, in order to determine material properties and microstructures at a range of cooling rates.

A Comparison of Steels for High-Intensity Bolting Applications

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Recent analysis into the behaviour of SA-540 B24 steel, a conventional bolting grade, has observed microstructural inhomogeneity across the thicknesses of some components. This behaviour suggests that SA-540 has a somewhat limited hardenability, which is its ability to consistently form martensite in thick sections, meaning it is not an ideal choice for some applications. It has been suggested that SA-723 Grade 3 steel is potentially a more optimised replacement for the SA-540, as it demonstrates a better hardenability and, thus, should comprise a more homogeneous microstructure in thicker sections. This project aims to both characterise and compare the phase transformation behaviour of SA-540 and SA-723 during continuous cooling and tempering treatments. Quenching dilatometry has been used to simulate typical austenitisation treatments used in industry and to analyse alloy behaviour. A model for predicting continuous cooling transformation (CCT) behaviour has been developed using modified semi-empirical equations by Kirkaldy and Venugopalan. The model is unique in that it considers the effects of carbon partitioning on subsequent transformations, allowing it to predict characteristic CCT behaviours, like martensite suppression, that are not considered in other models. This model will be validated by dilatometry data, and used to predict the microstructures observed in components.

Novel Pre-age Deform and Re-age Processing Route for Tailoring Properties in Al-Mg-Si-(Cu) Alloy

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Experiments were conducted to find the optimum treating parameters for a novel hybrid thermo-mechanical processing route in AA6013 and the strengthening mechanisms in each step. The mechanical tests showed the optimum treating route was either 'pre-ageing, low to medium strain cold rolling and long re-ageing at 140 °C' or 'high strain cold rolling, long re-ageing at 140 °C or short re-ageing at 160 °C'. It is concluded that the pre-ageing step can genuinely strengthen AA6013 at the cost of losing work hardenability and its strengthening contribution of the pre-ageing step decreases with increasing cold rolling strain, which is therefore only recommended for samples with low to medium rather than high cold rolling strain. XRD and EBSD characterisation revealed that the pre-aged samples exhibited higher dislocation density and geometric necessary dislocation during the cold rolling, comparing to the ones without it. DSC characterisation showed the overlapped β" and Q' exothermic peaks in the deformed samples and their height decreased with increasing pre-ageing time, which suggested the competition relationship between the pre-ageing and re-ageing precipitation.

Global and local modelling for fretting in multi-wire copper conductors

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Submarine power cables (SPCs) are specifically designed for power transmission to relay electric currents. In most cases, the cable is trenched but several specific designs have been addressed for dynamic cables, with specific armoring layers and internal components when trenching is not possible [1]. In such cases, it is important to design against the effects of cyclic loading from the environment, which can cause fatigue. For example, one UK study has reported 5 to 8 cable failures per 100 km in offshore wind turbine applications [2, 3]. The complex, multi-layered architecture of SPCs, typically including a number of helically-wound, multi-strand copper wires, among other elements or layers, with nominally large numbers of contacting surfaces, makes fretting wear and fatigue likely contributing factors of damage and failure. Indeed, the occurrence of fretting wear and fretting-induced cracks in the copper wire conductors has been demonstrated in laboratory testing of SPCs [2]. Fretting is normally associated with clamped or nominally static assemblies which experience a vibration or cyclic loading, leading to micro-scale relative movement, e.g. between about 5 µm to 50 µm for macro-scale applications. The fretting fatigue behaviour of copper conducting wires has received relatively little attention. This presentation reports progress on the development of methods for fretting-fatigue of copper conductors in submarine power cables.

Attention is devoted to different aspects of modelling, namely, 2D and 3D finite element (FE) frictional contact of representative geometries and loading, multiaxial fretting-fatigue life prediction and incremental wear simulation, as well initial work on grain-size dependent plasticity. This presentation specifically focusses on a systematic identification of the relationship between loading and geometry of the assumed helical, multi-wire assembly and salient local fretting variables, such as contact tractions (pressure, shear), biaxial relative slip, contact sizes, slip regimes and contact sub-surface stresses. The effects of cyclic plasticity, number of layers, applied axial-bending loads, lay angle etc are quantified using the 3D FE model. The purpose of the global model is to provide representative boundary conditions for local 2D and 3D modelling and testing. It will be used to simulate wear and frictional fretting contact for 2D geometries depending on the grain-size effect, including partial and gross slip regimes. An additional aspect of interest is the material characterisation based on different manufacturing processes including heat treatment, surface treatment and wire drawing. These effects can be included in the model via grain size effect (e.g. Hall-Petch) and perhaps anisotropic plasticity (e.g. Hill model), to determine effect on fretting fatigue life.

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Posters

An investigation into surface film properties and corrosion behaviour of gamma irradiated stainless steel

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This study is part of the Advanced Metallics CDT research project and seeks to explore the surface film composition and localised corrosion behaviour of a gamma-irradiated stainless steel sample, originating from a storage rack which would hold cobalt-60 sterilisation sources in a shielded pond facility. The sample material, assumed to be AISI type 316L, was decommissioned after 45 years of operation during which it has received a considerably high dose of gamma radiation. This is thought to have influenced the passive film of the steel, as the sample exterior surfaces appear dull grey and blackened in colour. This is thought to be the product of significant oxidation and its composition may be unique. Localised corrosion behaviour of a reference 316L material in NaCl solutions will be investigated via anodic potentiodynamic polarisation with the application of a miniature EC-pen three-electrode cell, to obtain breakdown potentials. This will then be compared with behaviour of the gamma irradiated stainless steel base material and its surface oxide. Microstructure imaging will be carried out via optical microscopy and laser surface confocal microscopy, to compare the microstructure in each material. The use of Laser Induced Breakdown Spectroscopy (LIBS), and other optical spectroscopy techniques, will be investigated to try and characterise composition of the grey oxide layer and how it might vary from a typical 316L stainless steel oxide layer.

3D Printing of stainless steel fibre reinforced polymer composites

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Additive manufacturing (AM), also known as three-dimensional printing (3D printing), is used to fabricate a range of polymeric, metallic, and composite components, giving excellent design flexibility, while reducing the level of associated manufacturing processing waste. Commercial applications of AM processing include components for the automotive, aerospace, textile, and biomedical sectors. In this study the research focus is on investigating the feasibility of printing continuous metallic wire reinforced polymer composites. The as printed polymer parts exhibit relatively poor mechanical properties, and previous studies have investigated the use of reinforcing fibres including continuous or discontinuous (short) fibres, typically glass, carbon, or basalt. The resulting composite exhibits enhanced mechanical performance. This study investigated the use of continuous stainless-steel wire fibre bundles (SSF), as reinforcement for a polylactic acid (PLA) polymer. The commercially manufactured SSF bundles contain 90 fibres, each with a diameter of 14 µm, a linear density of 111 decitex (TEX) and torsion per cm of 1. Composite printing was carried out using the fused filament fabrication (FFF) technique combines the SSF bundle with PLA, by ex-situ prepreg process, to print the composites. The mechanical and material properties of the resulting wire-reinforced printed composites were investigated using interlaminar sheer strength testing (ILSS), SEM and optical microscopy measurements. The performance of the resulting steel reinforced composites was compared with that fabricated using a continuous basalt fibre reinforced polymer composites.

Ultrashort laser induced selective crystallization of gold thin films

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Ultrashort laser processing is a versatile tool that allows a precise control and manipulation of the state of the material. Compared with longer pulse durations, ultrashort pulses are characterized by their higher peak intensities and interaction with materials on a time scale faster than that of the lattice disorder and heat diffusion into the material [1]. Such short time scales in a femtosecond (1 fs = 10-15 s) laser material interaction results in higher electron temperature within few femtosecond without changing the lattice temperature resulting in a two-temperature phenomenon [2]. Two temperature effects observed in ultrashort laser material interactions can be exploited to modify the electrical properties by a crystallizing process. We demonstrate how a femtosecond laser can improve the crystallinity of gold thin films on a ceramic substrate when scanned at low laser fluences below the damage threshold. An ultrashort pulsed laser of 500 femtosecond pulse duration is used to selectively crystallize 18 nm and 39 nm gold thin films deposited on a yttria stabilized zirconia (YSZ) substrate. The laser scanning is performed with a 515 nm laser wavelength at 100 kHz repetition rate. The comparison of experimental results reveals 20% improved crystallinity for 18 nm thin film and 15% improvement for 39 nm thick gold films, respectively. The results obtained from AFM and XRD agree well with the experimental findings and support the laser induced crystallization process. Our proposed low fluence ultrashort-pulse annealing method is effective and promising to produce high electrical conductivity gold thin films for their better applications in thin film crystallization industry.

Structural Optimization of Graded Lattice Structures for Metal Additive Manufacturing

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Additive manufacturing (AM) is rising in popularity across many manufacturing industries, and one of the benefits of this new technology is the capability to manufacture complex geometries such as lattice structures that are unachievable with traditional methods. Lattices are lightweight porous structures which can exhibit a wide range of mechanical properties depending on the unit cell and individual strut geometric definitions, as well as material selection. AM processes can facilitate the production of unique lattice geometries with graded strut thickness, and spatially varying strut intersection angles and unit cell sizing. By leveraging these design freedoms, this work aims to develop an automated iterative lattice design optimisation tool using finite element analysis for structural analysis. This tool is then demonstrated for the design of lightweight crash structures. An optimisation algorithm is used to iterate design variables, and a macroscale stress-strain response (as determined by a finite element simulation of the compression of the lattice structure) is the objective function. This framework enables automated design of unique lattice structures with tailored mechanical properties for a given application. The optimised structures are then manufactured using metal powder bed fusion and experimentally tested for validation.

Investigating the Impact of Microstructure on Irradiation Damage in Zirconium Alloys Using Convolutional Multiple Whole Profile Analysis

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In boiling water nuclear reactors, the zirconium alloy, Zircaloy-2, is utilised as a structural and fuel cladding material. The alloy experiences high doses of irradiation, which results in an increase in the number of dislocations within the material. A proportion of dislocations are <a> and <c> dislocation loops, which act as sites for diffusion of interstitials and vacancies. Loop formation leads to increasing internal strain, and anisotropic dimensional changes within grains. Results show that the number of <c> dislocation loops within Zircaloy-2 samples increases with irradiation dose across samples with different fabrication methods. In conventionally fabricated, highly textured samples, this results in accelerated irradiation-induced growth (IIG). However, in beta-quenched Zircaloy-2 samples, which have a randomly orientated texture, there is no IIG. This project demonstrates how crystallographic texture influences the degree of IIG in Zircaloy-2, as well as providing a comparison on the effect fabrication methods have on IIG mechanisms.

Anomaly Detection during the printing of TiAl6V4 by Laser Powder Bed Fusion

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The TiAl6V4 alloy exhibits a combination of excellent mechanical properties, such as a high strength to weight ratio, as well as good corrosion resistance. As a consequence it has found applications in both the aerospace and biomedical sectors. Laser Powder Bed Fusion is an additive manufacturing technology, which enables the production of TiAl6V4 structures with complex geometries. In-situ monitoring techniques such as melt-pool emission monitoring or image analysis are increasingly being applied with a view to detect anomalies, or defects, which could negatively impact the resultant part quality. In this presentation, the data produced by a Renishaw 500M Laser Powder Bed Fusion system, equipped with a melt-pool emission monitoring system known as InfiniAM is investigated. This system uses two coaxial photodiodes to monitor melt-pool emissions, where the laser interacts with the powder bed, along with a third photodiode to monitor the behavior of the laser. The data generated using the InfiniAM system is then analysed using a Generalized Extreme Studentized Deviate (GESD) algorithm. This approach was used to investigate a manufactured lattice structure, with a known number of induced defective layers, in order to assess its accuracy as an in-process monitoring system. The GESD algorithm analysis was also used to investigate the effect of systematically altering argon gas flow, during the manufacture of TiAl6V4 parts. With reduced flow of this inert gas over the build plate, there was an increase in the level of porosity, identified in the parts based on CT analysis. This porosity data was then correlated with the anomaly data analysed using the GESD algorithm. It was concluded from this study that the GESD

approach has considerable potential for real-time anomaly detection during the L-PBF process.

Neural Network Predictions of Charpy Toughness Based on Steel Composition, Including Chemical and Microstructural Analysis of C-Mn Steel Welds

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Welding is an essential process in joining pieces of steel to form larger structures. Welds are often the weakest part of the larger structure, hence they are the most prone to failure. For any industrial application, it is critical that welds do not fail. Research has found that there is a certain kind of structure present within steels after welding, called acicular ferrite, that toughens the weld and makes it less prone to failure. Toughness is related to how much energy a material can absorb before failure. Acicular ferrite is a microscale structure, a thousand times smaller than a millimeter, hence it is part of the microstructure of the weld. We largely do not know what affects the formation of acicular ferrite within the microstructure. Thus, the microstructure of steel welds need to be analyzed at different conditions to determine how acicular ferrite forms.

Time evolved flow evolution in arc welding

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Welding is the most common approach for joining two or more metal parts, similar or dissimilar, together. Among various welding techniques, the electric arc is widely used as a heat source due to its advantage of resource requirement, process flexibility and economic aspects. Molten metal flow behaviour during the rapid phase transformation process, under heat input from electric arc, has a direct bearing on the final weld pools formation and its functional characteristics. Multi-physics involving complexity and the limited availability of real-time experimental results severely hinder the analysis of the related physical mechanisms that can lead to accurate modeling and prediction of weld pools. Thus, we used high energy synchrotron X-ray imaging to qualitatively and quantitatively reveal the variation of flow patterns in the arc melt pools as well as the weld pool topography features. Experimental results show that the flow behaviour can turn from simple into the complex with the expansion of the weld pool. The analysis reveals how the effects of arc, surface tension and gravity driven forces act on liquid metal during this transformation.

An investigation into X-ray CT Resolutions and Optimisation Methods for Titanium Samples Produced Through Additive Manufacturing

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This project seeks to use X-ray computed tomography to quantify the porosity characteristics within a series of additively manufactured Ti-6Al-4V samples. The samples consist of five tensile test pieces and

two industrial brackets from different suppliers. Initial scans will be carried out under minimally defined parameters before a series of calibration tests are conducted to optimise the system settings to produce high quality images with racked resolutions. Included in these calibrations is the spot size, focal spot wobble, detector distortion and voxel size control as well as the sampling of scans under different filter configurations. Through comparison of the benchmark and adjusted data a clear understanding is formed on the effects of parameter variance on spatial resolution and overall scan speed. By utilising specialised software, porosity size and distribution can be accurately measured, visualised and associated with the system parameters to create a comprehensive array of data for material understanding.

The effect of texture on the stress and strain localisation during aluminium sheets bending

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When bending is applied to Al sheets, early failure may appear between grain boundaries on the surface deformed in tension. The cause is still unknown, but it has been observed that different textures lead to different propensities to failure. In this project, Crystal Plasticity Modelling (CPM) was used to study the relationship between bending failure and texture, focusing especially on the effect of texture on stress and strain localisation. A model which uses the extensions DAMASK, formable and MTEX was developed. This crystal plasticity model was calibrated using textures measured with Electron Backscatter Diffraction (EBSD) and tensile test curves, and it was implemented in the DAMASK modelling framework. Simulations were run under uniaxial and plain strain tensions for three different textured samples and their corresponding simulated microstructures were visualised with ParaView. Finally, the results from the different simulated frames were compared, and the differences were discussed in the context of failure in bending.

Comparative Assessment of Nitronic 60 and Tristelle 5183 Hardfacing Alloys

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Hardfacing alloys are used in applications that require excellent wear and galling resistance such as in valves and seatings. Cobalt based alloys like Stellite-6 demonstrate fantastic wear and environmental resistance. However, in a nuclear primary water reactor (PWR), cobalt can become transmuted to gamma-emitter cobalt-60 which presents a serious workplace hazard. Thus, there is strong motivation to develop cobalt-free hardfacing alloys to replace Stellite-6. Nitronic 60 is a highly alloyed austenitic alloy developed for high temperature hardfacing applications. Specific processing parameters have been little investigated for this alloy. This study explores the effect of cooling rates following annealing above the austenitizing temperature on the microstructure and mechanical properties.

Laser surface treatment of stainless steel for improvement in corrosion properties

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The goal of this project is to address the challenge of electrode corrosion and fouling in the operation of electrodes used within food and bio-processing vessels. The corrosion and fouling of electrodes is a common problem due to electrochemical reactions which occur during the process. Electrode corrosion can result in the release of small quantities of metal from the electrodes which mixes with the fluid. The focus of this project is to develop a laser based surface modification to enhance the anticorrosion properties of the PEF electrodes. Corrosion is a way in which a substance is degraded usually due to the presence of oxygen in the contact fluid. The oxygen will combine with the metal causing an oxide which is commonly seen as rust. A common method that is used to reduce the formation of rust on the surface is by painting it. This produces an outer layer over the metal stopping the oxygen from coming in contact with the metal which will minimize the oxide formation. The disadvantage with painting and other protective coatings is that they can contaminate a reaction vessel which would be a huge concern in terms of possible contamination in the food and bio-processing industry. In stainless steels, the surface can be passivated by the reaction of the chromium in the material with oxygen causing a chromium oxide layer. This layer stops the oxygen from coming into contact with the Iron which will cause rust. Since this layer is very thin oxygen can still get through the layer by a process called diffusion and cause corrosion of the electrode. A laser can produce really high amounts of energy into a very small spot on the work piece. This high energy can be converted into heat. This heat causes the elements inside the steel to move around more easily. Since chromium likes to react with oxygen more than iron, the oxygen will pull the chromium toward the surface so it can react with the oxygen more easily. This process causes a larger chromium oxide layer to be produced. This will make it harder for the oxygen to go through the layer increasing the corrosion properties of the metal. Since the protective layer is already present on the surface, this process can make this layer thicker further avoiding degradation of the electrode surface and any contamination issues. As the fluence is increased the temperature of the surface also increases. This makes it even easier for the atoms to move around causing a larger oxide layer. A secondary effect of this is the change of colour caused by this increased thickness of the oxide layer or the change in surface chemistry due to the diffusion of atoms. The goal of the project is to perform a DOE using 3 different parameters these are power, scan speed, and laser pulse frequency and Identify the main factors affecting the formation of these oxide layers. X-ray photoelectron spectroscopy will be used to analysis the surface chemistry and identify the concentration of each element on the surface. An electrochemical corrosion test of cyclic polarization will also be preforming an all 81 samples to identify the maximum corrosion parameter and correlate the results to the surface chemistry. A combination of reflectance spectroscopy and SEM will then be used to analysis the thickness and absorption properties of the oxide layer.

Powder Metallurgical Processing for Graded Alloy Microstructures

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Nickel-based superalloys and steels are widely employed in demanding environments owing to the combination of desirable properties they possess. The inherent corrosion resistance of nickel-based superalloys and steels can prove inadequate under particularly aggressive conditions, leading to

deterioration by oxidation and hot corrosion mechanisms. Literature reports that the corrosion resistance of nickel-based superalloys and steels are improved by bulk alloying with precious metals, though this is expensive. Alternatively, a precious metal coating can be applied to protect the underlying substrate, however, research reveals that the coating may debond in aggressive environments. This project aims to incorporate precious metals into nickel-based superalloys and steels by introducing a functionally graded microstructure, whereby composition changes with depth. Since the precious metal additions are concentrated where corrosion resistance is needed – at the interface between the component and the environment – the raw material costs are reduced compared to bulk alloying.
Powder processing will be used to achieve the functionally graded microstructure. The metal powders used will be characterised to assess parameters such as particle morphology and size distribution. Sintered parts will be analysed by SEM to investigate grain size and elemental segregation. Testing will also be carried out to evaluate the effect of the precious metal graded microstructure on mechanical performance and corrosion resistance.

Influence of processing parameters on the evolution of porosity, and microstructures in AISI 316L Steel Samples fabricated by selective laser melting.

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The use of additive manufacturing (AM) to process steel has grown in recent years. This is due to the ability to process prototypes or individually designed component parts in a short amount of time. In this study, the influence of several selective laser melting (SLM) parameters on the porosity, microstructure, and associated material properties of austenitic 316L stainless steel was investigated. Different SLM parameter sets were employed for the specimen build-up in a Renishaw AM250. The resulting microstructure was investigated by means of optical microscopy, which revealed that the different samples possess similar microstructures. Porosity, which has a big impact on material properties, was found to be related to the process parameters. Low porosity SLM parameters have been established, and mechanical properties will be explored after various heat treatments in future studies.

Additive manufacturing of 3D architectures using metallic inks

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Inkjet printing recently became more than a personal printing outlet, with differentiating utilization within varying areas, including, printable electronics including epidermal electronics, ceramic component manufacture, sensors and many more. Employment of conductive metals as inks, in the form of nanoparticles, brought new horizons to the field due to enhanced properties of nanoparticles with respect to their bulk counterparts. Therefore by designing nano-sized building blocks, surface patterning and creation of rather complex hierarchical surface patterns can be achievable. This project aims to create intricate surface patterns employing differentiating nano particle morphologies to deepen the

understanding of the 'printability' of an ink, and ink-substrate interaction, keeping in mind the constraints of the inkjet printing method, such as droplet generation and solidification process. Additionally, a comparison study between synthesized and commercially available inks to be held.

Integrated Computational-Experimental Study of Microstructurally Short Crack Propagation in AA7xxx alloys

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This project seeks to use X-ray computed tomography to quantify the porosity characteristics within a series of additively manufactured Ti-6Al-4V samples. The samples consist of five tensile test pieces and two industrial brackets from different suppliers. Initial scans will be carried out under minimally defined parameters before a series of calibration tests are conducted to optimise the system settings to produce high quality images with racked resolutions. Included in these calibrations is the spot size, focal spot wobble, detector distortion and voxel size control as well as the sampling of scans under different filter configurations. Through comparison of the benchmark and adjusted data a clear understanding is formed on the effects of parameter variance on spatial resolution and overall scan speed. By utilising specialised software, porosity size and distribution can be accurately measured, visualised and associated with the system parameters to create a comprehensive array of data for material understanding.

Development of a Mid-Wave Infrared Thermometer for Metal Machining Operations

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Computer Numerical Control (CNC) Machining is a Thermo-Mechanical process. Machining science is currently emphasising on the mechanical portion of the process by relying on cutting forces simulations for the machining loading parameters. However, the thermal portion is a key component to help obtain more information to better understand the process. Temperature is an important parameter in machining processes and a primary loading condition that can lead to secondary machining outcomes, including variations in the metallurgical properties and tool life reduction. These secondary outcomes can lead to a significant increase in waste and operating costs. The two most used temperature monitoring approaches for metal machining are thermocouple and infrared radiation thermometer configurations. The first step of this work focuses on developing a Fibre Optic Infrared Radiation Thermometer (IRT) to be integrated with machine tools to monitor the temperature at the tool-workpiece interface in various CNC machining processes. The temperature at the tool-workpiece interface during metal machining can be in the range of 20 - 850oC, corresponding to the Mid-Wave Infrared region of 3 -10µm, depending on the workpiece alloy. Furthermore, this works aims to compare the performance of the developed IRT prototype with that of commercially available thermocouples. To validate the use of IRTs over thermocouples for machining applications, the critical criteria used for comparing the two approaches are the accuracy and response time of the thermometers. Lastly, to eliminate external sources of errors, an approximate blackbody furnace is utilised as a heat source to maintain a steady temperature as well as being performed under static laboratory conditions.

1D and 2D Finite Volume solvers for solid mechanics

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The finite volume method has been extensively used in recent years for modelling many different physical problems, such as linear-elasticity, orthotropic elasticity, thermo-elasto-plasticity, thermo-viscoelasticity, incompressible elasticity, contact mechanics, fracture mechanics and fluid interactions. Compared to the finite element method, the finite volume formulation shows a local conservativeness of the governing equations, which may be important for coarser meshes. The following mini-project will start by implementing a 1D transient explicit finite volume solver based on the wave equation, in order to have a basic understanding of the implications of the governing equation in a 1D solid. Subsequently, the mini-project will go on to the investigation of a 2D transient explicit finite volume solver for elastic wave propagation, which needs to take in account of the stresses in the x and y directions. The main goal of the mini-project is to be able to create simple finite volume formulations, which can act as a starting point for future Ph.D. work. As a matter of fact, the implementations performed in the mini-project will be useful when dealing with plasticity for small and large strains and elasto-plasticity.

In situ characterisation of the thermomechanical deformation behaviour of powder processed Ni-based superalloys

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The operational limits of superalloys for use within jet turbine engines are being pushed in order to increase engine efficiency and reduce fuel consumption, requiring an increase in operational temperature. Consequently, new alloy compositions are necessary to meet the adverse conditions within jet engines. Nevertheless, compositional changes must be carefully considered. Alloying elements such as Ta and Ti have been found to decrease crack propagation, increase mechanical strength, and affect resistance to environmental degradation. However, whilst the individual effects of Ti and Ta in polycrystalline Ni-based superalloys are well understood, few studies have been conducted that provide insights into the co-additions of Ti and Ta. In order to understand the relative merits of Ti and Ta additions in combination, three powder-processed Ni-based superalloys with varying Ti:Ta ratios were manufactured and investigated. This work focuses on the analysis of a set of synchrotron diffraction data collected at the Diamond Light Source and the European Synchrotron Radiation Facility aimed at revealing the load partitioning behaviour between the gamma and gamma prime phases in these alloys as a function of temperature. The results enabled the quantification of the effect of the Ta:Ti ratio on the lattice misfit, elastic constants and load partitioning as a function of Ti:Ta ratio as well as temperature, providing invaluable information on the deformation characteristics of the constituent phases and how optimal strength may be attained.

Investigating the Performance of New Cutting Tools for Machining Nickel-Based Superalloys

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As new aerospace materials are developed, capable of withstanding increasingly hostile operating conditions, processing challenges continue to emerge. When machining superalloys, high stresses and temperatures are generated in the cutting zone, due to inherent material properties, namely high temperature strength, work hardening behaviour and a low thermal conductivity. This leads to complex wear mechanisms and short tool life, which adds costs to production in terms of both time and energy. To develop the next generation of cutting tools, it is necessary to study observed phenomena at a higher level of detail, using a combination of experimental and modelling techniques. The high cost and scarcity of aerospace alloys warrants the use of rapid, small-scale, imitational testing methods that require only limited amounts of material. Used alongside standard light microscopy, this project aims to explore the relationship between alloy chemistry and tool wear, for a range of materials and cutting tools.

Modelling Radiation-Induced Defects in Nuclear Zirconium

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The effects of a-type and c-type defect loops on XRD line profiles in pure a-zirconium are analysed by implementing the Debye scattering equation on virtual atomistic cells of 10^7 atoms, and using Convolutional Multiple Whole-Profile (CMWP) fitting to generate and analyse peak features in a theoretical line profile. In an initial investigation, Bragg-peak shoulder features first observed by T. Semour et al. (2017) are isolated and correlated to size, orientation and population characteristics of circular defect loops, with the goal of predicting loop behaviour and annealing through the use of XRD. The primary motivation is to develop understanding of the degradation behaviour of irradiated zirconium cladding structures during lifetime within nuclear light-water reactor cores, and subsequent waste processing.

Material and Process Design for Additive Manufacture of Hard Metals

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High entropy alloys have been identified as a potential candidate to replace the Co binder in WC-Co hard metal cermets used in metal forming tooling applications. These high entropy alloys can display improved mechanical properties such as hardness and wear resistance due to entropic stabilisation effects enabling formation of a single solid solution phase. However, there is a substantial number of possible high entropy alloy combinations making experimental testing of every possibility impossible. Hence, a machine learning approach has been explored to predict single phase high entropy alloy formation and hardness of different compositions. A random forest regression methodology has been applied to make predictions based on the parameters of the individual elements such as atomic size difference and enthalpy. A set of down-selected compositions from the machine learning methodology were also compared against predictions made using thermodynamic calculations in ThermoCalc coupled with the TCHEA4 database. The resulting suitable high entropy alloy candidates will be fabricated using arc melting and experimentally evaluated using hardness, mechanical integrity testing and microstructural analysis. This work was supported by Oerlikon AG GmbH, Science Foundation Ireland \newline [18/EPSRC-CDT/3584] and the Engineering and Physical Sciences Research Council UK [EP/S022635/1].

Understanding microtexture effects on the properties of Ti forgings

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During production of titanium alloys for use in aerospace applications, abnormally coarse grains structures (ACGS) can grow within the material. These ACGS have anisotropic properties which could cause premature failure, as strain localisation causes local yielding, reducing the fatigue life of the part. Therefore, understanding how the stress, total strain and plastic strain localisation is affected by the unusual microstructure is vital for determining part life. Some initial results show, local stress and local total strain is higher near a thick section of grain boundary alpha. Grain boundary alpha is known to cause issues with stress and strain localisation as it is generally stiffer than the neighbouring grains. These results confirm the detrimental effects of grain boundary alpha. If thick sections of grain boundary alpha are present then localised plastic strain will cause permeant damage and reduce the life of the part, increasing maintenance and environmental costs of the aircraft.

Fabrication of Microalloyed Steel for Automotive Applications

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Current fabrication of steel automotive parts such as connecting rods can be improved by using additions of vanadium (V), niobium (Nb) and titanium (Ti) in conjunction with an innovative processing approach. With vacuum induction melting (VIM) and field-assisted sintering technology (FAST), improved microstructural characteristics and mechanical properties can be attained, especially after incorporating a thermomechanical post processing technique such as hot rolling to refine grain structure. There is great potential in creating automotive components using VIM and FAST, utilising precious elements (Ti, Nb, V) in a carbide matrix composite to see their 'pinning' effect in medium carbon high manganese steels of ferritic-pearlitic nature. The results and conclusions obtained from the mini-project can be developed during the full PhD project which is in collaboration with Volkswagen; for instance, looking at the affects of adding small amounts of boride-based ceramic composites such as TiB_2, VB_2 and NbB_2, followed by mechanical and hardness testing.

Osteoinduction Augmented Magnesium Medical Implants for Skeletal Repair

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Magnesium (Mg) and its alloys have been identified as promising bone implant materials. In addition to their good biocompatibility, osteoconductivity, mechanical properties similar to those of bones, and ability to positively stimulate new bone formation, they have biodegradable properties that enable them to degrade in situ in the body thus eliminating the need and trauma associated with a second surgical procedure for implant removal. However, too fast a degradation rate in a physiological environment usually results in a premature disintegration of mechanical integrity and local hydrogen accumulation, which can limit their clinical use in bone repair applications. Advanced manufacturing methods offer great potential for increasing the commercial scope and clinical applicability of Mg alloys for medical implants. However, the increase of surface area in more complex geometries results in increased degradation kinetics and faster rates of corrosion. Surface coating is one of the most efficient and cost effective routes to reduce the degradation rate and improve corrosion resistance while maintaining biocompatibility. For an medical implant material, the optimal coating should be non-toxic and biocompatible. Also, it should degrade at an acceptable rate to match the rate of bone formation. Bioactive calcium phosphate (Ca-P) coatings are of great interest because Ca-P is the main constituent of human bone.n This research aims to design, fabricate and characterise magnesium-based medical implants for enhanced bone repair and regeneration. The focus of this research is to use an experimental approach to understand and provide novel strategies to control the interrelationship between process-structure-property and the influence of different factors that are critical to the long-term clinical success of Mg medical implants for skeletal repair.

Methodology for Representative Microstructure Calculations

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A plethora of simulation models exist that predict the microstructural evolution and various properties. Methods in combination with computational tools, for instance the “Monte Carlo”, the “cellular automata”, the thermodynamic and kinetic (e.g. ThermoCalc, DICTRA, TC-Prisma, FactSage), the macro & meso (CFD and FEM tools), the micro and nano (RVE-FEM and CP – crysal plasticity via DAMASK for instance), the microstructure evolution utilizing the phase field (PF) method via MICRESS and many more incarnate the ICME – Integrated Computational Materials Engineering approach. These models and approaches take into account a variety of case specific characteristics like the total deformation and dislocation density, the shape and size of the grains etc. However, the credibility of the input data and how accurately these describe/represent the original microstructure significantly affect the accuracy of final computational results. An important microstructure characteristic is the initial microstructure geometry that can be described in terms of grain size, morphology and orientation. A software tool that depicts a microstructure through reading pole figures and grain sizes, is DREAM 3D. However, grain boundaries may differentiate significantly and in turn affect nucleation points during recrystallization. In addition, certain microstructure elements cannot be read from the EBSD (e.g.) due to the severe deformation. This is why tools like DREAM 3D can lose significant information when transferring real microstructure data into the digital – software supported interface, the virtual microstructure. The current work aims to present an alternative methodology to create a statistically representative virtual

microstructure that attempts to increase the accuracy in metal processing modelling providing thermodynamic predictions of higher quality. The microstructure of a metallic alloy after forming was reconstructed by measuring the grains (in this case we used the AutoCAD software for grain size and Image J program for area measurements) and their dimensions individually and importing them in MICRESS PF software. The methodology has been built on rolled AA – 3104 strip with thickness of 0.2mm and is compared to conventional methods of measuring the grain size. This is work in progress.

Understanding the contribution of Intermetallic Compounds on crack propagation between automotive silver tracks and lead-free solders during pull testing

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Since 2016, EU legislation require all new car models must use lead-free soldering technology for soldering connectors on glass. Understanding the underlying mechanisms of soldering T-piece connectors to Conductive Silver tracks is a critical step in developing suitable automotive silver pastes for heated windscreens. The fired Conductive track is composed of glass frit and silver and the solder is required to endure temperature variations , have high electrical conductivity and good corrosion resistance. Historically Lead based solders were used for this application due to being cheap , having good surface wetting properties and low melting point . However , these properties do not out way the fact that lead is inherently toxic which meant its use was prohibited by EU in electronics.
Based on the Sn-Ag-Cu system, the near ternary eutectic composition of 96.5Sn-3Ag-0.5Cu (SAC 305) is one of the most promising composition for automotive solders. In comparison to the homogenous lead-tin system , SAC 305's tendency to form intermetallic compounds has been detrimental to the strength of the joints. The dominant reaction product at the interface is the formation of the brittle intermetallic Ag3Sn, between solder and the silver particulates in the conductive track . The formation of Ag3Sn in the interface between conductive paste and solder facilitates crack initiation and propagation leading to a significant weakness of the joint in comparison to Lead-based solders . Furthermore, tin based solders have lower ductility than lead-based solder materials, often too brittle and cannot fully compensate the mechanical stresses of the soldering process. This is further amplified during the industry standard weathering and climate tests, which the joints need to undergo as part of QC, leading to tin-based soldering joints failing and also in real-world conditions during the warranty period. There are multiple challenges in understanding the joining of lead-free solder to silver track . First , the interaction between the lead free solder and silver particulates in the silver track . Second , the relationship between the glass and silver within the conductive paste . Although research has been carried out to understand the welding of SAC305, this research has been based on optimisation for semi-conductor manufacture . Even then , most of the research has been in the joining of SAC305 to a Copper Substrate . Although there are some similarities between the reaction mechanisms between SAC305 and Copper to that of SAC305 and Silver the results are not directly transferable. Through systematic investigation , this project aims to investigate the fundamental reactions at the interface between Lead-Free solders and Silver based conductive tracks for the development of enhanced joints for Automotive manufacture .

Predicting Porosity in L-PBF Manufactured Components Using a Process Variable Input Based Meta-Data Approach

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Laser powder bed fusion (L-PBF) is a common additive manufacturing technique for the rapid production of complex components. The manufacturing process can have up to 50 separate process variables most of which appear to be ignored when it comes to output characteristics, making repeatability potentially difficult. This study focuses on the use of Ti-6Al-4V and the resulting porosity in a manufactured piece. A literature review has been conducted and an attempt been made to model the resulting porosity based on input parameters such as laser power, laser scan speed and laser scan spacing.
A meta-analysis indicates that for a given set of inputs a wide range of porosities may result. Furthermore, relying on a small number of input parameters for porosity forecasting can also lead to poor results. Work has been done on dimensionless multiple regression modelling, using a combination of 20 different parameters, indicating that predictions with adjusted R-squared values of around 0.7-0.75 can be achieved with modelling equations having 10+ terms. Resulting data fits for an input range also vary significantly with porosity measurement technique. For example, Archimedes method invariably results in lower R-squared adjusted values than methods such as X-ray CT scanning.

PGR Skills Workshops

'When EDI goes wrong' with Barry Wall, Polkadot Consultants

Barry is the founder of Polkadot Consultants and the EDI Lead It and Live It training program for academic staff and students. Barry has worked in recruitment, consultancy, organisational development and learning for many years. He emphasises the use of learning as a tool for personal and organisational success. This workshop is guaranteed to provoke discussion around the subject of EDI as Barry Wall offers an insight into a hoax that captured thousand of scientists worldwide and led the EDI field to become a figure of ridicule for many. As well as offering the STEM community a chance to explore our shared humanity, EDI can morph to become DIE, a divisive field that uses clever tactics to trap the unwary in an ever downward spiral of identity politics, postmodernism and grievance mining. Without a trigger warning in site, and certainly not a safe space, we dare you to come and learn about the "tinfoil hat" end of Equality, Diversity and Inclusion that has fooled many an academic mind.

'Manage your PhD as a project' and 'Thriving through adversity' with Dr Lisa Cox, Life Compass

Lisa is an experienced Project Manager and Training Consultant with 25 years' experience in scientific, management and training roles within the pharmaceutical sector. She has qualifications in Chemistry (D.Phil), Project Management (PMP) and Neurolinguistic Programming (Diploma). Lisa is an energetic, pragmatic individual with a reputation for leading popular, effective workshops with clear take-home messages and 'quick win' tools. She is leading two workshops during the conference. Students will learn fundamental processes of project management, to manage scope, schedule, quality, risks and stakeholders. By adopting this approach in their PhD project, students will improve the likelihood of completing their PhD in the desired timescale, with appropriate content and quality, and less stress.

'Coping with Covid-19 impact and personal resilience' with Leni Robson, Unique To You

Leni Robson has 15 years in project and executive support within the NHS prior to qualifying as a celebrant and advanced certified grief recovery specialist. Away from work, Leni enjoys theatrical pursuits, leads a charity (Coffin Club Derby) and features on radio programs (typically when someone famous has died). This workshop provides a skill set of techniques ('action steps') for resilience to manage the challenges brought to everyone by the COVID pandemic. The session is appropriate to a range of experiences, including bereavement, redundancy, ill-health, and professional and/or social isolation, and has been successfully delivered to the public and private sector. Managing a doctoral project in the aftermath of COVID needs more than advanced project management skills - it needs resilience and personal attributes that lie beyond Microsoft Project or a spreadsheet. Hence, this workshop is valuable for PGR students needing to get fully back into a research-progression and writing mindset.

'Communicating your research' with Dr Chris Smith from 'The Naked Scientists

Known for his regular TV appearances during Covid-19, radio and podcast presenter, medical doctor and "Naked Scientist" Dr Chris Smith will host a training workshop to help you to learn some of the key skills that will make your presentations, communications and outreach endeavours sing. You'll find out what makes a good interviewee and a good interviewer, how to prepare for an outreach initiative, how to give the best presentations, and what to expect when the media come calling...

'Accessible academic writing skills' with Dr Claire O'Connell

Have you ever read a journal paper and struggled to stay focused after the first few sentences, wondering what points the authors were trying to get across in such laboured language? Or maybe while listening to someone's conference presentation you have found yourself drifting off or even dangerously close to having a snooze? Of course researchers need to communicate their findings in standard and professional ways - the journal paper, the report for an industry partner, the conference presentation or poster - but why not inject a bit of life into it and come up with something more engaging? In this workshop, we will explore ways of making the language that we use in papers and presentations more accessible, we will find and replace jargon and we will explore ways to creatively engage with our audience while keeping to high standards of academic rigour and quality. Participants are encouraged to take part in practical and exercises using their own research. The workshop moderator, Claire, is a science writer with more than 25 years of experience communicating about scientific and technical research in journals, media, books and outreach. Before doing her Masters in Science Communication, she was a scientist, she has a PhD in cell biology and has worked as a post-doc around the globe. This means she knows something about lab life and how incredibly precious those hard-won results are, and she also knows how important it is to make research topics, issues and findings relatable to audiences.

Industry Workshops/ Sandpit Bios

Sustainable Manufacturing workshop led by Dr Dan Cogswell, University of Sheffield

This interactive session, led by Dr Daniel Cogswell and supported by professional engineers representing a wide range of metals manufacturing sectors will discuss ideas and challenges for manufacturing companies in reaching Nett Zero. Delegates will be asked to work together to consider the immediate and long-term challenges faced by metal processing and ceramic processing companies to make the adaptations and changes required for this critical global goal.

Dr Daniel Cogswell - ESPRC Leadership Fellow, University of Sheffield

Dan has recently started a UKRI Future Leaders Fellowship at the University of Sheffield, researching how to standardise and take advantage of digital material property information in supporting better design, processing and materials selection for high integrity applications. Daniel spent the first stage of his career focussed on improving and estimating the mechanical properties of steels used in nuclear steam raising plants. Daniel has worked closely with UK metal suppliers on linking up research activities, supporting studentships and joint programmes. Looking to add more weight to subjective judgements common in property estimation, Daniel also has an interest in Statistics.

Industry Panel Discussion – Metals for a Better Tomorrow

Following on from the earlier session, a panel of professional engineers representing a wide range of metals manufacturing sectors will provide their thoughts on how metal manufacturing can support a better tomorrow. The panel members will be given an opportunity to share how their company is addressing sustainability and Nett Zero. There will be an opportunity for delegates to put questions to the panel.

Kevin Parkin – Chairman, Castings Technology International

Kevin has qualifications in Engineering Accounting and Marketing. He has been described as a 'No nonsense, hands-on MD'. Health and safety, effective communications, training and succession planning are always in his toolbox. In January 2021, Kevin and Richard Cook undertook an MBO Castings Technology International Ltd with Kevin taking the position of Executive Chairman. In 2015, he led a Panoramic Growth Equity backed MBI of Precision Technologies. After transforming the business from private to VC ownership, Kevin exited the business after 24 months. In 2008, he led an MBO of DavyMarkham which was backed by Endless LLP where the equity investors realised a 13.5 times return in 21 months. Kevin has extensive experience operating as MD or Chairman and has headed several successful turnarounds of seriously troubled manufacturing companies. He has led all types of transactions from MBO, BIMBO, MBI, Refinancing, Restructuring and Disposals (22 transactions in total) and is extremely well networked in both manufacturing, banking and private equity. Kevin founded the Work-Wise Foundation, is a Freeman of the Company of Cutlers in Hallamshire, an Entrepreneur in Residence with Yorkshire Connect, and a member of the Steering Group for the Advanced Metallic Systems and Chairs the Steering Group for the Managing Directors' Club at Sheffield University. He also sits on the Committee of Made in Sheffield and chairs several networking business groups in the Sheffield City Region. He is also been involved with the Make UK, Santander Bank's Ambassadors and named by the Manufacturer Magazine one of the Top 100

Manufacturing People in the UK. During the last 12 years many prestigious National awards have been made to either him personally or to organisations he has run.

Kate Fox - Technical Capability Manager, Rolls-Royce plc.

Kate Fox obtained her first degree in Materials Science at Birmingham University and continued there to study for a PhD investigating Titanium SiC metal matrix composites. After completing her PhD she worked at an automotive component research centre for three years and then joined Rolls-Royce in Derby in 1997 working in the Materials Function. She has stayed in a Materials role, working on aero-engine safety-critical components (titanium discs and blisks) and becoming a Technical Specialist in this field. She is currently a Technical Capability Manager with a team who control and maintain the material condition, support new product introduction, service safety, failure investigation, life extensions and research programmes for predominantly light alloy and steel components. Kate has been an Industrial supervisor for a number of Eng D and PhD students, a role she very much enjoys. She values working with students and academic staff to enhance understanding of materials behaviour and also to keep in touch with developments in academia. Kate is a Chartered Engineer and Fellow of IOM3 and was awarded the Harvey Flower prize for work on titanium alloys in 2019 by IOM3. She is also an elected representative for the Midlands region for the Advisory Council of IOM3 and a committee member for the East Midlands Metallurgical Society. She is an active STEM ambassador. Her interests include microstructure and crystallographic texture relationship to mechanical properties, influence of thermomechanical processing of microstructure/texture, cold dwell fatigue in titanium alloys, influence of machining, shot peening and other surface enhancements on residual stress, mechanical behaviour, modelling approaches to predicting mechanical properties and effects of material processing on mechanical behaviour.

James Ashby - Technical Manager, Liberty Powder Metals Ltd

James Ashby is Technical Manager at Liberty Powder Metals Ltd. He has been with the group since 2015 leading quality improvement initiatives across the speciality steelmaking business unit before joining a small team to establish the new spin-out company, which was created to supply metal powders for net shape and additive manufacturing applications in demanding sectors. His MEng degree is from The University of Sheffield, where he studied Materials Science and Engineering. James is a Chartered Engineer and Member of the IOM3.

Matthew Lunt - Senior Principal Scientist, Materials and Structures Principal Advisor, Materials for Strategic Advantage Programme Platform Systems Division, DSTL

I'm a Senior Principal Scientist at the Defence Science and Technology Laboratory (Dstl), which is part of UK MOD. I graduated from Brunel University in 1994 in Materials Science and Technology, which included three six-month work placements in Materials R&D. I went on to receive my doctorate from the University of Oxford on the study of single crystal superalloys. I joined MOD in early 1999 to work on R&D of high temperature materials for propulsion. I've been working for Dstl since 2001 as a Technical Advisor to MOD on Propulsion Materials and Light Alloys. I'm a member of Dstl's #PRISM network which provides support to DSTL's LGBT employees.

Jaya Vaithilingam - Research Group Leader, Johnson Matthey

BIO: Leading the industrial materials research portfolio at a global level for Johnson Matthey, Jaya and his team are heavily involved in both improving and developing new materials, products and processes that involves the use of platinum group metals (PGMs). In order to efficiently use these scarce materials for industrial applications, their particular focus is on understanding and improving material properties and workability of PGMs, exploring opportunities for thrifting PGMs in existing products and identifying new applications. Prior to this appointment, Jaya led the ceramic additive manufacturing research portfolio at Johnson Matthey Plc. Jaya holds a PhD in Additive Manufacturing from the University of Nottingham and in his post-doctoral role, he explored additive manufacturing of metallic, polymer and ceramic materials for a wide range of industrial applications.