Materials Processing Institute

6th Postgraduate Research Symposium on Ferrous Metallurgy

The latest academic thinking on Ferrous Metallurgy

Tuesday 28th February 2023

VENUE:
Armourers' Hall,
Armourers & Brasiers' Company,
81 Coleman Street, London EC2R 5BJ

#Metallurgy6

2023 Programme

Organised by:

Materials Processing Institute

MAKE ALL SURE
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IOM3
Institute of Materials, Minerals & Mining

PRISM

The UK's premier metallurgical event

Showcasing the latest doctoral research

Materials Processing Institute

Foreword by Chris McDonald

Welcome to the 2023 Symposium – a celebration of excellent research in UK ferrous metallurgy!

Excellence is very much the word here, with applications to present at this year's symposium at a record high and a record number of poster presentations. Each of the postgraduate students presenting today has worked extremely hard to secure a place on the programme and this increase in competition for places is testament to both the high level of research in our UK universities and the importance of this event in the annual metallurgy calendar.

We will see excellence today not only in the research presented, but in awards for individual achievement too. Following the successful incorporation last year of the Institute of Materials, Minerals and Mining (IOM3) Iron & Steel Awards into the Symposium, I am pleased that the Iron & Steel Group of IOM3 has decided to continue with this collaboration, cementing both the awards ceremony and the Bessemer Lecture into the Symposium programme. These awards for achievement in the profession of iron and steel, sit alongside our own awards that recognise and support young people, including prizes for the presentations and posters, as well as the Millman Scholarship and Ashok Kumar Fellowship, that will be awarded today.

This Symposium has long been a collaboration between the Worshipful Company of Armourers and Brasiers, the Iron & Steel Group of the Institute of Materials, Minerals and Mining and the Materials Processing Institute, but as we move into our 6th year, I am pleased to announce a further strategic partner. Tata Steel has offered to be the main sponsor for the symposium for the next 5 years, securing this important event to the end of its first decade. We also thank our longstanding sponsors and welcome new ones with support from The Henry Royce Centre at The University of Sheffield, Sheffield Forgemasters, M2A Coated, UK Metals Council, the UKRI Interdisciplinary Centre for Circular Metals and the Cast Metals Federation.

Each year we like to introduce a new innovation in the programme and this year is no different, as we give our symposium presenters and participants the chance to gain a greater appreciation of how to influence research and industry, in the form of a presentation by the UK's innovation agency, InnovateUK. The symposium also forms part of the dissemination activities of the PRISM programme of research and innovation for the UK Steel & Metals sector, funded by the UK government, through InnovateUK and delivered by the Materials Processing Institute.

My personal thanks to the Master, Wardens and Company of Armourers and Brasiers, for their consistent and unstinting support of UK materials research and the highly valued partnership and bursary scheme with the Materials Processing Institute. Thanks also to the Iron and Steel Group of IOM3 for their support of this event as co-organising partners.

I hope that you will all enjoy the symposium today, find new opportunities for research and make new friends from across the community. Please do share your experience with friends and colleagues via social media and encourage others to attend the next version of the Symposium on 27th February 2024.

Chris McDonald
CEO, Materials Processing Institute

Bessemer Lecture

Collaboration to boost evolution and revolution in ironmaking and steelmaking

Collaboration accelerates evolution as well as revolution in steel production technology, however it does not always deliver. Examples are replacement of coke by pulverized coal in blast furnace ironmaking (successful) and the worldwide attempts to direct steelmaking (failed). How to initiate, continue and finish collaboration is demonstrated by the development of sublance sensor technology for oxygen steelmaking control. The ultimate collaborative project to reach ultra-low CO2 steelmaking (ULCOS) as organised by the EU research fund for coal and steel generated four feasible solutions. Two of them were further developed using CO2 capture-and-storage (CCS). Change in public acceptance of CCS made these solutions obsolete. Hydrogen metallurgy is now considered the environmental solution, asking for strong collaboration again. Steelmakers should cherish their collaborative nature which is unique as compared to producers of other metals such as aluminium.

Professor Rob Boom

Rob Boom earned a doctorate in physics from the University of Amsterdam (1974), promoter Prof. A.R. Miedema. He joined Hoogovens Research in the Steelmaking, Metallurgy and Refractories Department. He was appointed Director in 1996, responsible for the total R&D programme that included processes, products, and product applications of steel, aluminium, and new materials. In 1984-1986 he assisted in the reconstruction of the IJmuiden Steel Works. He led the international development of sublance dynamic control in oxygen steelmaking. After the Hoogovens-British Steel merger into Corus Group (1999), he became Director R&D Strategy and Competence Development. After Tata Steel took over Corus (2007), he continued this role until retirement in 2011. Throughout his career he established multiple international collaborations among steelmaking companies in Europe and worldwide.

He became Professor Metals Production, Refining and Recycling at the Department Materials Science & Engineering of Delft University of Technology (1999). He is the Senior Scientific Advisor of the Dutch Materials Innovation Institute M2i, chairing the Programme Committee and the annual conference. He participated in many international committees and boards of institutes bridging the gap between industry and academia. He published close to 300 scientific papers and co-authored three text books. As professor emeritus he is still active in process metallurgy and works with Prof. F.R. de Boer on extension of the Miedema alloying model. In 2016 he was awarded the J. Keith Brimacombe Prize of CIM/TMS. In 2022 IOM3 awarded him the Bessemer Gold Medal.

Chair of Sessions

SESSION 1
Development of Products and Applications

Dr Richard Thackray
The University of Sheffield

Dr Richard Thackray holds a degree in Materials Science and a PhD in Metallurgy from Imperial College London. Richard joined The University of Sheffield in 2003 as Tata (Corus) Lecturer in Steelmaking and is a key member of The University of Sheffield's team for SUSTAIN - the EPSRC funded Future Steel Manufacturing Research Hub. His current research interests are related to the production of steel, including development of mould powders for continuous casting of steel, inclusion engineering in steels, and using novel powder metallurgical techniques for the production of stainless steel components.

Richard is also involved in several projects that look at aspects of sustainability in steelmaking, in particular, initiatives to quantify and reduce energy consumption in steelmaking, reuse and recycling of waste material, life-cycle assessment of critical elements in steel, and alternative materials for ironmaking. Richard is a past chair of the Iron & Steel Group of IOM3, Gold Medal Winner in 2021 and a current member of the Sustainable Development Group.

SESSION 2
Process Development

Gill Thornton
Liberty Powder Metals Ltd

Gill Thornton holds a degree in Materials Science and an MBA from Warwick Business School. She has worked in the steel industry for 37 years in technical and R&D roles across the UK. Gill has extensive experience in leading collaborative research projects, mainly in BOS, EAF, Concast and Powder Metals. A recent powder metals project led to Liberty Steel starting a new business; Liberty Powder Metals to develop and vacuum atomise high quality steel and nickel based alloy powders. Gill is currently the R&D Manager for Liberty Powder Metals Ltd. Gill is also a board member of the IOM3 Iron and Steel Group, a trustee and past president of the Cleveland Institution of Engineers and was awarded the 2021 IOM3 Thomas Medal & Prize in recognition of scientific or technological contribution to the production of any ferrous alloy.

SESSION 3
Development of Techniques and Fundamental Knowledge

Professor Hongbiao Dong
University of Leicester

Professor Dong is internationally renowned for his work in modelling of metal processing, digital manufacturing, solidification and its application in casting, welding and additive manufacturing of metal. He is Research Chair of the Royal Academy of Engineering/TWI, Science Director of EPSRC CDT in Innovative Metal Processing, and Director of NISCO UK Research Centre. He successfully led a major EU-FP7 project on modelling of welding, was a recipient of the Metrology for World Class Manufacturing Award and was a Royal Society Industry Fellow at Rolls-Royce Precision Casting Facility.

His team's research aims to bring knowledge-inspired decision making to the production routes of high value-added components, such as single crystal aero-engine turbine components and deep-sea oil and gas transport systems.

Programme

09:30 - 10:30 **Registration, Poster Display, Exhibition and Networking**

10:30 - 10:40 **Welcome and Introduction**
Jon Bolton, Chairman, Materials Processing Institute

10:40 - 11:40 **Session 1: Theme - Development of Products and Applications**
Chaired by Dr Richard Thackray, The University of Sheffield

1. *Development of a segregation neutralised dual phase steel for improved formability.*
Presenter: *Pedram Dastur (University of Warwick)*

2. *The effect of antimony additions on the microstructure and performance of automotive Zn-Al-Mg steel coatings.*
Presenter: *Dan Britton (Swansea University)*

3. *Evaluation of metallurgical risk factors in post-test, advanced 9%Cr creep strength enhanced ferritic (CSEF) steel.*
Presenter: *Xiyu Yuki Zhang (Loughborough University)*

11:40 - 12:00 **First Perambulation**
Poster Exposition, Exhibition and Networking

12:00 - 13:00 **Session 2: Theme - Process Development**
Chaired by Gill Thornton, Liberty Powder Metals Ltd

4. *Effect of high FeOx containing material dissolution in HIsarna slag.*
Presenter: *Bharath Sampath Kumar (University of Warwick)*

5. *The effects of deep cryogenic treatment on a PVD - TiN coated M2 high speed steel.*
Presenter: *Christian Chiadikobi (University of Leicester)*

6. *The road to net zero, the testing of a new hybrid fuel for sintering.*
Presenter: *Sam Reis (Swansea University)*

13:00 - 14:00 **Lunch Break**
Poster Exposition, Exhibition and Networking

13:30 - 13:50 **Innovate UK Presentation**
How early career professionals can help transform industry for a better future.
Presenter: *Chris Pilgrim, Knowledge Transfer Manager, Materials*

14:00 - 15:20	**Session 3: Theme - Development of Techniques and Fundamental Knowledge** *Chaired by Professor Hongbiao Dong, University of Leicester* ***7.*** *A rapid CCT predictor for low alloys steels, and its application to compositionally heterogeneous material.* ***Presenter:*** *Joshua Collins (The University of Manchester)* ***8.*** *Oxidation of a dual phase steel during rapid alloy prototyping.* ***Presenter:*** *Lauren O'Donnell-McLean (Swansea University)* ***9.*** *Gigacycle fatigue performance of steel welds.* ***Presenter:*** *Andrew England (University of Strathclyde)* ***10.*** *Avoidance of hydrogen assisted cold cracking in multi-pass weld metal.* ***Presenter:*** *Shaun Smart (University of Leicester)*
15:20 - 15:40	**Second Perambulation** *Poster Exposition, Exhibition and Networking*
15:40 - 16:00	**Presentation of IOM3 Iron & Steel Awards** *1. Dowding Medal and Prize* *2. Stokowiec Medal and Prize* *3. Tom Colclough Medal and Prize* *4. Hadfield Medal and Prize*
16:00 - 16:50	**Bessemer Lecture** **Lecture Title: Collaboration to boost evolution and revolution in ironmaking and steelmaking** *A keynote presentation given by Professor Rob Boom, awarded the Bessemer Gold Medal for 2022*
16:40 - 16:50	**Vote of Thanks** *Dr Kate Thornton, IOM3 President*
16:50 - 17:00	**Awarding of Prizes by the Armourers & Brasiers' Materials Science Committee** *1. Millman Scholarship 2022 / 2023* *2. Ashok Kumar Fellowship* *3. Poster Winner* *4. Presentation Runner-up* *5. Presentation Winner*
17:00 - 18:30	**Symposium ends and Drinks Reception**

Development of a segregation - neutralised dual phase steel for improved formability

SPEAKER / LEAD AUTHOR:
Pedram Dastur

INSTITUTION:
University of Warwick

OTHER AUTHORS:
Dr Carl Slater, University of Warwick
Dr Bharath Bandi, University of Warwick
Professor Claire Davis, University of Warwick

ABSTRACT:
The concept of changing the distribution of martensite from a banded to a non-banded structure has been used to improve the formability of dual-phase (DP) steels. In this regard, the effect of manganese segregation on the second phase distribution has been neutralized by redesigning the steel composition compared to conventional DP grades: termed as 'segregation-neutralised (SN)' DP steel. The effect of the distribution of the second phase on the anisotropy of mechanical properties (tensile strength and elongation) has been determined for the hot rolled condition (ferrite+pearlite microstructure) and the final product (ferrite+martensite) using tensile testing in the rolling, transverse and 45° orientations. In addition, the effect of the martensite distribution on the local formability has also been assessed using notched tensile samples with observation of void formation during in-situ tensile testing in the SEM.

The effect of antimony additions on the microstructure and performance of automotive Zn-Al-Mg steel coatings

SPEAKER / LEAD AUTHOR:
Dan Britton

INSTITUTION:
Swansea University

OTHER AUTHORS:
Professor David Penney, Swansea University
Professor James Sullivan, Swansea University
Professor Richard Johnston, Swansea University
Dr Shahin Mehraban, Swansea University,
Dr Tom Dunlop, Swansea University
Dr Clive Challinor, Tata Steel UK
Dr Amar Malla, Swansea University
Matthew Goldsworthy, Swansea University

ABSTRACT:
Since the early 2000's, additions of 1-2wt.% Al and Mg have brought about improvements in the corrosion protection and processability of traditional zinc galvanized coatings. Despite these benefits, the brittle $MgZn^2$ binary eutectic phase that forms in these alloys can cause the coating to crack during automotive body panel pressing. Therefore, a strategy to mitigate these issues but retain the corrosion benefits is investigated here. Additions of 0-2wt.% Sb were added to Zn-Mg-Al alloy and fast cooled from 800°C, resulting in the formation of $Mg3Sb^2$ intermetallics which tie up Mg and reduce the volume fraction of the $MgZn^2$ phase. Scanning Vibrating Electrode Technique showed an addition of 1wt.% antimony resulted in a 45% improvement in corrosion-induced metal loss, whilst Linear Polarisation Resistance found increasing this addition further led to a rise in the kinetics of corrosion. Open-Circuit Potential testing revealed mixed results regarding the effect of antimony on thermodynamic potential.

Loughborough University

Evaluation of metallurgical risk factors in post-test, advanced 9%Cr creep strength enhanced ferritic (CSEF) steel

SPEAKER / LEAD AUTHOR:
Xiyu Yuki Zhang

INSTITUTION:
Loughborough University

OTHER AUTHORS:
Dr Mark Jepson, Loughborough University
Dr Simon Hogg, Loughborough University

ABSTRACT:
9% Cr steels are widely used in the design and fabrication of thick section components in a commonly combined cycle or coal-fired applications and for working temperatures of 600~650°C. This family of materials possesses a martensitic microstructure stabilized by precipitates. The presence of nitrides, inclusions, or evolution of second-phase particles may increase the metallurgical risk. The chemical composition and microstructural evolution of 9% Cr steels contribute to thermal stability and long-term performance. To fully appreciate the development of damage in these steels, it is necessary to link the pre- and post-test conditions, evaluate damage in the parent metal, develop procedures that provide consistency of results, and obtain statistically relevant results. Large Ta-containing particles or inclusions in the 9% Cr steels may have a detrimental effect on its creep performance, as they may act as the preferred sites for cavity nucleation. The evolution of the Ta-containing phase as a risk factor for the creep strength of the 9% Cr steel has been tracked and quantified using a variety of correlative characterization approaches. Utilizing focused ion beam microscopy and two-dimensional electron-based microscopic characterisation, three-dimensional tomography has confirmed the strong relationship between creep cavities and Ta-containing phases from the early stages of creep.

Effect of high FeOx containing material dissolution in HIsarna slag

SPEAKER / LEAD AUTHOR:
Bharath Sampath Kumar

INSTITUTION:
University of Warwick

OTHER AUTHORS:
Professor Zushu Li, University of Warwick
Koen Meijer, University of Warwick

ABSTRACT:
The HIsarna technology is a low carbon and high energy efficient alternative ironmaking process. The HIsarna off-gas contains CO2 in high concentrations, making it CCS/CCU ready. It will emit limited amount of dust; the hot metal contains low phosphorous, and this onestep approach significantly reduces capex and opex. The HIsarna pilot plant experienced sudden and uncontrolled slag foaming. Slag foaming incidents are unwanted and may disrupt the production. One theory of these foaming incidents is due to accretions containing FeOx falling in the liquid bath. High temperature laboratory experiments were done and analysed using various techniques like SEM, XRF and XRD. Slow dissolution of solid FeOx in a non-foaming HIsarna slag was observed, which is in contradiction to the sudden slag foaming. Accretion falling in the liquid bath seems not to be the main cause of slag foaming.

The effects of deep cryogenic treatment on a PVD - TiN coated M2 high speed steel

SPEAKER / LEAD AUTHOR:
Christian Chiadikobi

INSTITUTION:
University of Leicester

OTHER AUTHORS:
Professor Rob Thornton, University of Warwick
Dr Dave Weston, University of Leicester
Dr Dimitrios Statharas, University of Leicester

ABSTRACT:
Deep cryogenic treatment (DCT) is a bulk heat treatment process that is typically applied as an extension to conventional heat treatment (i.e. quenching and tempering) applied to ferrous alloys, with numerous companies offering after-market services. DCT involves treating materials at low temperatures (-180 °C) with aim of causing microstructural and beneficial changes in their properties. In the literature, DCT has been citied to improve hardness, and wear resistance in martensitic steels. However, despite these promising results, there is limited published work on the effects of DCT on hard coated steels, such as industrial cutting tools. Much debate surrounds the topic due to lack of consistency of results encountered and limited work being presented on mechanisms responsible for changes observed. Therefore the effect of DCT have been studied on PVD-TiN coated M2 high speed steel system. A combination of mechanical techniques such as micro hardness and scratch testing have been applied to determine the mechanical changes observed. The result showed DCT can improvement composite hardness of TiN coated M2 high speed steel by 5.16%. For adhesion testing, the result suggests DCT samples had better wear resistance (3.62%) and could be attributed to the elastic modulus mismatch between the coating and substrate.

Swansea University
Prifysgol Abertawe

The road to net zero, the testing of a new hybrid fuel for sintering

SPEAKER / LEAD AUTHOR:
Sam Reis

INSTITUTION:
Swansea University

ABSTRACT:
Iron ore sintering produces a significant portion of CO_2 emissions within integrated blast furnace steelmaking, therefore providing a great opportunity to decarbonise. Use of a novel hybrid fuel made from sustainable biomass and anthracite coal can offset up to 30% of CO_2 emissions. The combustion properties of the hybrid were investigated using a bomb calorimeter and a simultaneous thermogravimetric analyser. Results of which were compared to coke breeze, the current fuel for the process. Heat of reaction was higher for the hybrid fuel 27.911 MJ/kg compared to 26.534 MJ/kg. Although proximate analysis showed higher volatiles content that correlated with slightly lower combustion temperatures. To reveal the impact of hybrid fuel on sinter quality, it was incorporated into a ore blend and evaluated in a sinter pot. The strength and reducibility of the sinter was analysed using standard tests as well as XRD and optical imaging to identify the mineralogy and structure.

A rapid CCT predictor for low alloys steels, and its application to compositionally heterogeneous material

SPEAKER / LEAD AUTHOR:
Joshua Collins

INSTITUTION:
The University of Manchester

OTHER AUTHORS:
Dr Ed Pickering, The University of Manchester
Matthew Dear, Henry Royce Institute, Rolls-Royce

ABSTRACT:
It is well understood that alloy processing has a direct impact on steel performance. By manipulating transformation kinetics, alloy behaviour can be modified to produce unique properties unlike those predicted under equilibrium. It is this relationship that grants the ability, and the ambition, to model steel behaviour and predict the performance of processed components. A rapid model for predicting the continuous cooling transformation (CCT) behaviour of low alloy steels 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. Further work has also involved extending the model to compositionally heterogeneous material with good success. The accuracy of the model has been determined through comparisons with experimental dilatometry data.

Oxidation of a dual phase steel during rapid alloy prototyping

SPEAKER / LEAD AUTHOR:
Lauren O'Donnell-McLean

INSTITUTION:
Swansea University

ABSTRACT:
The growth of oxide scale during high temperature processing routes has a large influence on the surface quality of steels and can result in large quantities of metal loss during steelmaking. Recently, research focussed on rapid product development has resulted in the simulation of the integrated steelmaking route, allowing representative steel samples to be generated and processed on a laboratory-scale. This study explores the effects of oxidation behaviour on a dual phase steel, DP800, using small-scale samples produced through Rapid Alloy Prototyping (RAP). In terms of oxidation, the limitations and opportunities of RAP are not yet fully understood. Experimental interrupted oxidation investigations have been conducted on both RAP and plant-generated samples to understand the scale growth evolution in DP800, with the intention of determining whether the laboratory route is comparable and representative of processes taking place on an industrial scale, and to determine if RAP is suitable for oxidation studies.

Gigacycle fatigue performance of steel welds

SPEAKER / LEAD AUTHOR:
Andrew England

INSTITUTION:
University of Strathclyde

OTHER AUTHORS:
Dr Athanasios Toumpis, University of Strathclyde
Dr Yevgen Gorash, University of Strathclyde

ABSTRACT:
It has been established in the technical literature that the assumption of a "fatigue limit" is not valid for steel welds, with fatigue failures commonly occurring in the gigacycle (1 billion stress cycles) regime. This research project aims to improve the scientific understanding of the gigacycle fatigue of structural steel arc welded joints. Conducting gigacycle fatigue tests within a feasible timeframe requires ultrasonic fatigue testing (UFT), where specimens are excited at 20 kHz. A novel weld specimen was designed which fulfils the natural frequency and size requirements for UFT but captures the geometric features of welds that make them susceptible to fatigue failure. Alongside this, fatigue tests were conducted at low frequency for comparison, as UFT can have a significant effect on the measured fatigue strength of materials. The research on the fatigue performance of flux-core arc welded butt joints of structural steel will be presented.

Avoidance of hydrogen assisted cold cracking in multi-pass weld metal

SPEAKER / LEAD AUTHOR:
Shaun Smart

INSTITUTION:
University of Leicester

OTHER AUTHORS:
Professor Hongbiao Dong, University of Leicester
David Howse, TWI Ltd

ABSTRACT:
Hydrogen assisted cold cracking (HACC) is a common form of fabrication cracking in welding of ferritic steels. HACC occurs when hydrogen becomes trapped inside the weld zone during rapid cooling.

Development of lean composition steels, along with the use of highly alloyed welding consumables leads not only heat affected zone (HAZ) cracking occurs but also weld metal (WM) cracking. So far, techniques for avoidance of HACC are focused on HAZ cracking and do not consider the difference in conditions between the mechanism resulting in HAZ or WM HACC.

In this study a condition that results in both WM and HAZ HACC has been developed on U-groove S690QL samples, welded with a multi-pass, flux-cored technique. A microstructural investigation was carried out to characterise HACC morphology, and the WM diffusible hydrogen quantified. Following this, techniques were applied to the cracking condition to define suitable procedural techniques for the avoidance of WM HACC.

Poster Index

Poster 1

Swansea University Prifysgol Abertawe

Novel galvanic coatings for ground support equipment

AUTHOR OF POSTER:
Daniel Murphy

INSTITUTION:
Swansea University

OTHER AUTHORS:
Professor David Penney, Swansea University
Professor James Sullivan, Swansea University
Dr Amar Malla, Swansea University
Richard Bourke, JBT Aerotech UK Ltd

ABSTRACT:

Hot Dipped Galvanising (HDG) is relatively expensive and time-consuming batch process for large Ground Support Equipment (GSE). The current work focuses on developing a lower-temperature alternative. The aim is to provide a corrosion-resistant coating that can bond with the substrate at lower temperatures, be applied on-site at the sponsor company facility and offer galvanic protection. The novel corrosion resistant coating is applied to the substrate at room temperature then cured at an intermediate temperature.

The coating may also be used for repair of galvanised GSE, which often sees welded areas left susceptible to corrosive attack. Electrochemical studies and accelerated corrosion tests have shown that the coating offers excellent galvanic protection to steel in an electrolyte. Application and curing of the coating have been optimised for industrial use.

The result is a robust, protective, and dynamic coating; a step forward in the fight against corrosion of steel and protection of HDG."

Poster 2

Effects of welding parameters on sigma phase precipitation in 25Cr-5Ni-1Mo-2.5Cu-1Mn-0.18N duplex stainless steel

AUTHOR OF POSTER:
Kenta Yamada

INSTITUTION:
University of Leicester

OTHER AUTHORS:
Professor Hongbiao Dong, University of Leicester
Briony Holmes, TWI Ltd
Kasra Sotoudeh, TWI Ltd

ABSTRACT:
Recently, a new grade of duplex stainless steel, UNS S82551 (25Cr-5Ni-1Mo-2.5Cu-0.18N), has been developed to overcome the drawbacks in super martensitic stainless steel, conventional 22Cr and 25Cr super duplex stainless steels in terms of productivity and cost. The characteristic of the alloy design of S82551 is to use Cu, instead of Mo, to ensure comparable corrosion resistance and strength. In addition, due to the significant decrease in Mo content, S82551 is expected to be less sensitive to sigma phase precipitation during single or multi-pass welding. This work investigated the effect of weld thermal cycling on sigma phase precipitation behaviour in S82551 welds comparing with S31803 and S32750. In addition, based on the isothermal kinetics of sigma phase precipitation, the amount of sigma phase precipitated during thermal cycle can be predicted by applying the additivity rule to the physical model.

Poster 3

Improving serviceability of zinc aluminium magnesium coatings

AUTHOR OF POSTER:
Matthew Alexander Brooks

INSTITUTION:
Swansea University

OTHER AUTHORS:
Dr Amar Malla, Swansea University
Professor James Sullivan, Swansea University
Professor David Penney, Swansea University
Dr Natalie Wint, Swansea University
Professor Geraint Williams, Swansea University

ABSTRACT:
Zinc Aluminium Magnesium (ZAM) alloy galvanised coatings have been the focus of numerous research studies over the past two decades. A variety of compositions exist, each forming complex microstructures containing primary zinc within eutectics rich in magnesium and aluminium. The alloying additions enhance the corrosion resistance and pressing performance. However, studies have shown that eutectic phases are susceptible to cracking on forming. This study investigates the relationship between coating weight and cracking on formed samples and how it influences the electrochemical behaviour of the coated systems. It was found that thinner coatings (8micron) exhibit fewer cracks than thicker, 30micron coatings. Electrochemical measurements showed forming increases the current in both coating weights while the potential was shifted more positive in thin coatings (8 micron) and more negative with the 30micron coating, when compared to their respective flat samples.

Poster 4

Imperial College London

Alloy design for impurity tolerance

AUTHOR OF POSTER:
Katlo Batsile

INSTITUTION:
Imperial College London

OTHER AUTHORS:
Dr Stella Pedrazzini, Imperial College London

ABSTRACT:
Designated a strategic asset, steel scrap, through maximised recycling, would allow the iron and steel industry to cut massively on emissions, reduce mining activity and overall, attain circularity. However, the quality of recycled steel is degraded due to the accumulation of residual elements with continuous recycling, a problem limiting the use of recirculated steel in high-value applications in industries like the automotive industry. It is therefore important that we understand how multiple scrap-related contaminants act on steels and use this knowledge in the development of sustainable alloys. One way of doing this is by focusing on the design of impurity-tolerant alloys and the aim of this project is to investigate how elemental additions can help achieve this.

Poster 5

WARWICK
THE UNIVERSITY OF WARWICK

Development of product and process technologies for manufacturing high value alloy steels used in critical applications

AUTHOR OF POSTER:
William Moncaster

INSTITUTION:
University of Warwick

ABSTRACT:
Benjamin Huntsman developed crucible steelmaking in the eighteenth century and found that the steel he produced was excellent for clock springs. This was one of the first industrial examples of the link between steel product quality and processing, and was a starting point for the development of modern clean steels. These steels, which find extensive use in aerospace applications and bearings, have stringent requirements for controlling inclusions based the detrimental impact on properties they have. Ever increasing performance requirements mean the programme sponsor, Liberty Speciality Steels, requires new technologies to link product and process. Three areas were selected to work on:

- Quantification of the inclusion floatation process by vibration monitoring
- Inclusion characterisation by x-ray computed tomography
- Slag chemistry analysis

Ultimately the project aim is to assess the viability of applying these technologies to a speciality steelmaking process with the hope of allowing further process developments to improve final product properties.

Poster 6

Capture and reduction of carbon emissions to maximize circularity in the steelmaking process

AUTHOR OF POSTER:
Azita Etminan

INSTITUTION:
Swansea University

OTHER AUTHORS:
Professor Peter Holliman, Swansea University
Dr Ian Mabbett, Swansea University

ABSTRACT:
With the challenging targets of the climate agreements being set, the steel industry sector logically seeks for possibilities to reduce their greenhouse gas emissions, as well as to incorporate green energy sources in the steelmaking process itself. Waste gases generated during steelmaking are an enormous source of CO & CO2 emissions. Rather than supply heat and power to the plant by combustion, those gases can be utilized efficiently at a low cost to produce renewable fuels. In steel production by blast furnace technology, three main off-gases are generated, namely the Blast Furnace Gas (BFG), the Coke-Oven Gas (COG), and the Basic Oxygen Furnace Gas (BOFG).

As synthetic natural gas can be directly utilized in the integrated steelworks again, substituting for natural gas, the in situ methanation of real steelworks gases in a lab-scaled is provided in our research work. To direct carbon capture and utilization, BFG and BOFG as carbon source and H2-rich COG as hydrogen supplier otherwise using hydrogen production throughout electrolysis process, to reach high methane yield is designed. Therefore, a two steady process, first, production a CO2-rich gas through a catalytic WGS reaction using BFG and BOFG, then methanation of the stream by H2-rich COG as hydrogen supplier is presented.

Poster 7

In-situ tempering to improve the metallurgy of additively manufactured tool steel components

AUTHOR OF POSTER:
Anna Tholen

INSTITUTION:
Loughborough University

OTHER AUTHORS:
Dr Rebecca Higginson, Loughborough University
Nick Jones, Renishaw Plc
Dr Ravi Aswathanarayanaswamy, Renishaw Plc

ABSTRACT:
Macroscale, fatigue-type cracking is a prevalent issue in additively manufactured hot work tool steels. Tool steel alloy, H13, can maintain excellent wear resistance at elevated temperatures for sustained times, making it ideal for metal and polymer casting dies. Laser powder bed fusion (LPBF) additive manufacturing (AM) offers considerable advantages to the manufacture of H13 dies by reducing the technical challenges of machining high hardness material. However, due to rapid and cyclical heating and cooling in the LPBF AM process, H13 cannot achieve its optimal microstructure of tempered martensite and fine carbide precipitates. The resultant microstructure of untempered martensite renders the material brittle and thus susceptible to cracking during LPBF AM fabrication.

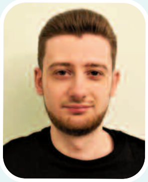
A protocol for in-situ heat treatment was developed to facilitate the evolution of H13's optimal microstructure during the LPBF AM process. Macroscale cracking was minimised to enable a relative density of 99.999%, and residual stresses were reduced and homogenised throughout the fabricated samples. It was therefore shown that by utilising in-situ heat treatment, functional H13 components can be produced by LPBF AM, exhibiting the optimal microstructure and mechanical properties.

Poster 8

Testing ceramics in liquid zinc for upgrading galvanising bath journal bearings

AUTHOR OF POSTER:
Giovanni Paolo Alparone

INSTITUTION:
Swansea University



ABSTRACT:
Automotive grade galvanised steel must comply with stringent quality requirements and, for this reason, galvanisers are interested in extending the service life of the pot hardware, which is a bottleneck to production and quality of premium 'full-finish' product. The pot roll bearings are submerged in the galvanising bath and are subjected to deterioration due to the reaction of the bearing materials with liquid zinc. Ceramic materials are chemically stable in molten metal applications and have the potential to outperform the bearing materials currently in use by the industry. In this research, selected ceramics were immersed in liquid zinc alloy for five weeks. The performance of the materials in molten zinc was assessed by characterising the samples after testing with SEM and EDX. The results showed that some of the tested ceramics remained inert in liquid zinc and, therefore, they are promising candidates for making optimised pot roll bearings.

Poster 9

Designing a characterisation toolkit to provide frequent and objective measurement of ferrous scrap quality

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ABSTRACT:
Amongst the carbon emission reduction solutions available to the steel industry, increasing the proportion of recycled content in new steel is a method with a technology readiness level suitable for immediate deployment. There are many barriers to using more steel scrap in the production of steel, one being the ability to measure the quality (chemical composition) of this end-of-life material. This poster reviews preliminary X-Ray Fluorescence (XRF) work showing that surface contamination has an influence on the reliability of XRF results. In addition, exploratory X-Ray Computed Tomography (X-Ray CT) and radiography scans indicate promising results for identifying different materials to metallurgically meaningful parameters due to differing X-Ray absorption. Ready detection of extrinsic contaminants has been shown to be possible under ideal conditions. The development of this technique to more industrially representative environments with increased and more variable feedstock, will follow as an essential next step to real life use.

Poster 10

Leaching of metals in BOS slag via acid digestion

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ABSTRACT:
Basic oxygen steelmaking (BOS) produces slag as a by-product which currently has limited low value use. Although there is a plethora of research conducted on recycling the material, due to the variability in composition from batch to batch, the scale-up on a single site, let alone multi-site solutions, is difficult. Metal extraction via acid digestion is a promising way of recycling slag due to its resilience and robustness. This poster presents the initial stages of this project focused on understanding the variability of both legacy and newly produced BOS slag before attempting to leach metals with different acids conducting a comparison of effectiveness for further separation downstream. By valorising an extraction route of certain slag components, not only can high value selective reuse of the material be achieved.

Poster 11

Assessing the bendability of UHSS (Ultra-high Strength Steel) in plane strain conditions

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ABSTRACT:
Inconsistent behaviour and premature failure are common when bending UHSS (Ultra-high Strength Steel). Practicality limits laboratory testing to smaller samples, which may not replicate the conditions of production, and larger volumes of material used in manufacturing may increase the likelihood that material inhomogeneities will cause failure.

A rig was developed, capable of replicating the size and scale of production. Tests have been undertaken on a grade of UHSS at 5 forming radius/thickness ratios, with strains measured using digital image techniques. Results show that punch separation occurs on specimens that ultimately fail, causing the bend severity to increase unexpectedly. This phenomenon occurs at consistent bend displacements, with bending strains matching those not displaying the phenomenon until a deviation point. Separation occurs more frequently when the bend line is parallel to the rolling direction. Upcoming investigations will focus on behaviour at this deviation point to try and better understand this separation behaviour.

Poster 12

Use of sinter pot pilot facility to optimise sinter plant performance

AUTHOR OF POSTER:
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ABSTRACT:
Using the sinter pot to trial blends has economic and environmental benefits and for this reason is important to Tata Steel. It has the potential to reduce the production costs on the large scale, by using the pilot pot to trial different experiments which may give rise to more efficient ways of operating. Maximising the quality of the product would mean identifying key operating positions for the sinter pot. This project looks at a mineralogical focussed study of high temperature reactions during iron ore sintering. Specifically, when varying the level of basicity, silica, MgO and flux particle size to see gains in productivity and quality. Laboratory testing, thermodynamic prediction using FactSage, materials characterisation using optical microscopy & machine learning driven image analysis via a software called Intellesis. As well as this, chemical analysis through XRF and XRD data will also be investigated.

Poster 13

The influence of cooling rate during solidification on segregation behaviour in low alloy steels with and without residual elements

AUTHOR OF POSTER:
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OTHER AUTHORS:
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Dr Carl Slater, University of Warwick

ABSTRACT:
Next generation casting technologies, for processing to strip steels, such as thin slab, belt or strip casting have gained popularity due to the reported energy saving, which can be as high as 1.6 GJ/tonne when compared to conventional thick slab casting. However, these casting approaches result in changes in the cooling rate during solidification, influencing as-cast segregation which may have a knock-on effect on the final microstructure and properties.

A COMSOL multi-physics model has been used in the design of a wedge mould that gives the range of cooling rates representative of belt, thin and thick slab casting. The wedge mould has been used to cast a low alloy structural steel and the as-cast microstructure (secondary dendrite arm spacing and interdendritic levels for Mn) have been characterised and correlated with the cooling rate. The impact of residual elements (particularly Cu, Sn and Cr) on the solidification microstructures is being considered.

Poster 14

Assessment of antimicrobial coated steels for indoor use

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ABSTRACT:
Steel is one of the most common materials in the world. One application of steel is as a substrate for antimicrobial coatings. A combination of the COVID-19 pandemic and rise in healthcare associated infections has resulted in heightened interest in infection prevention control measures. Studies have shown a link between contaminated surfaces and infection transmission rates, with some bacteria surviving for months at a time; antimicrobial coatings have shown to aid in the reduction of transmission. Coated steels embedded with potential antimicrobials were assessed using a combination of microbiological assays, scanning electron microscopy and X-ray fluorescence. Initials findings have been unable to confirm significant antimicrobial activity, potentially due to the irregular distribution of the antimicrobials within the coatings. This correlates to assays where reductions in bacterial growth were not always noted. These findings provide an insight into the future research direction for antimicrobial coated steels.

Poster 15

Multiscale deformation modelling of small scale mechanical tests

AUTHOR OF POSTER:
Tristan Hearsey-Mc Kay

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ABSTRACT:
In this poster the deformation of small-scale mechanical tests on dual-phase (DP) steels is modelled. A focus on continuum finite element modelling to simulate the deformation of punch tests in ABAQUS software is done. However, at small scales the macroscopic material properties are dependant on the microstructural properties, it is necessary to characterize the deformation at the granular level. A micro-scale model is developed to simulate deformation the DP alloy's micro-constituents. Combining the continuum and micro-scale modelling can provide a more accurate behaviour. The derived material characteristics can then be applied to larger scale models and aid with the screening of prototype alloys. This complements the rapid development of novel steel alloys.

Poster 16

Development of formable steel grades through alternative steelmaking technologies

AUTHOR OF POSTER:
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Martyn Dranfied, Tata Steel UK

ABSTRACT:
Environmental considerations mean alternatives to the traditional blast furnace/ basic oxygen furnace (BF/BOF) steelmaking route are being explored, such as electric arc furnace (EAF) steelmaking. An EAF operating using scrap as the feed material is less energy intensive and produces significantly less CO2 than the BF/BOF route. However, steel made in the EAF route typically has higher carbon and nitrogen levels. Interstitial free (IF) steel requires very low levels of carbon and nitrogen, making it a particular challenge for transitioning to EAF steelmaking. For this reason, the focus of my project is looking at ways to produce IF steel in an EAF. Experimental work so far in the project has aimed to investigate the impact of increasing carbon and nitrogen levels on the product performance of formable strip steels, initially by creating lab scale casts of IF steel with different nitrogen levels.

Poster 17

Development of improved formability interstitial free steels

AUTHOR OF POSTER:
Talal Said Abdullah

INSTITUTION:
Swansea University

ABSTRACT:
Improving the formability of Interstitial Free steels is the project's aim, and rapid alloy prototyping (RAP) is an effective way of tackling this endeavour. While examining the microstructure evolution, the idea is to roll out a 40 - 140g RAP DX57 cast in the mini hot and cold rolling mill and to have several Mini 2 & 1 bars fabricated and tensile tested for mechanical properties. Elements such as titanium, niobium, and nitrogen are subject to manipulation to observe any promising notable effects on the steel's mechanical properties. If small-scale production of alloys, showing representative structures and realistic results from miniature specimens, could be achieved, this would represent a significant improvement and acceleration in novel steel-grade design.

Poster 18

Scaling of heat treatment behaviour of low alloy steels

AUTHOR OF POSTER:
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Dr Daniel Cogswell, The University of Sheffield
Dr Matthew Dear, Rolls-Royce PLC

ABSTRACT:
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, first a better understanding of the current methods used to model thermal profiles of large components is required.

This work shows initial modelling results, thermocoupled Jominy end-quench tests and application of thermocoupled data to dilatometry heat treatments. Work is precursory to demonstrate changes in microstructure and material properties across modelling and small to meso-sized specimens throughout heat treatments.

Poster 19

Improving the formability of automotive steel grades via hot rolling and run out table simulations

AUTHOR OF POSTER:
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Swansea University

OTHER AUTHORS:
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Ian Gibson, M2A Coated

ABSTRACT:
This research focuses on optimising rolling parameters at industrial and laboratory scale using bespoke software, which can be adjusted to incorporate microstructural information from the industrial scale to augment the processing conditions at the laboratory scale. This poster will address some of the challenges of rolling at the laboratory scale when trying to replicate plant produced processes, and methods used to try and mitigate or eliminate such challenges to create a representative simulation of the finishing mill and run out table. The end goal of this research is to create a laboratory scale, based hot rolling simulation for Tata Steel's DP800 grade in order to optimise the rolling schedule and run out table cooling parameters to reduce coil waste in line with TATA Steels sustainability goals. This work also aligns with the Prosperity Partnership in paving the way to scale-up novel RAP produced alloys.

Poster 20

The development of sustainable paint for coil coated steel

AUTHOR OF POSTER:
Jakub Kramp

INSTITUTION:
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OTHER AUTHORS:
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Dr Peter Barker, Tata Steel

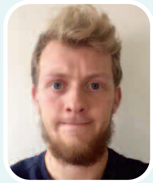
ABSTRACT:
The use of organic coatings on coil coated steel is widespread among the construction, automotive industries and for use in domestic appliances. Almost all commercially available protective organic coatings are derived from fossil fuel origins. Increased environmental awareness has driven the requirement for alternatives to fossil fuel based paint chemistries. The main aim of this work is to derive a suitable coating formulation using renewable or recycled feed-stocks that match or exceed current industrial coating performance. Two polyester resins were synthesised with 46% and 30% renewable content and their respective mechanical properties and resistance to accelerated weathering were compared against a standard industrial formulation. The incorporation of 30% renewable content into a polyester resin is optimal to achieve greater flexibility, improved salt spray and QUV resistance when compared to the industry standard coating formulation.

Poster 21

Effects of cryogenic treatment on the precipitation behaviour in En31 bearing steel

AUTHOR OF POSTER:
Kyle Nicholls

INSTITUTION:
University of Leicester



OTHER AUTHORS:
Professor Rob Thornton, University of Warwick

ABSTRACT:
Deep cryogenic treatment (DCT) is a supplementary treatment step in between hardening and tempering of steel, providing permanent microstructural changes not solely attainable by conventional heat treatment (CHT) processes alone. However, the mechanisms by which DCT is reported to alter the microstructure are contradictory in nature, and often lack correlation to prior thermal history and chemical composition. Roller bearings fabricated from En31 bearing steel typically retain up to 10wt% austenite on quenching, with the presence of austenite causing uncertainty in wear performance and dimensional stability at operating temperatures of 373-523 K. Therefore, tempering using diffraction, calorimetry and dilatometry on En31 bearing steel has been studied after a DCT cycle (93 K, 24 hrs), with varied austenitising temperatures employed prior, to investigate the effects of austenitising temperature and DCT on precipitation behaviour versus CHT samples. DCT is found to reduce the activation energy for the decomposition of retained austenite during tempering.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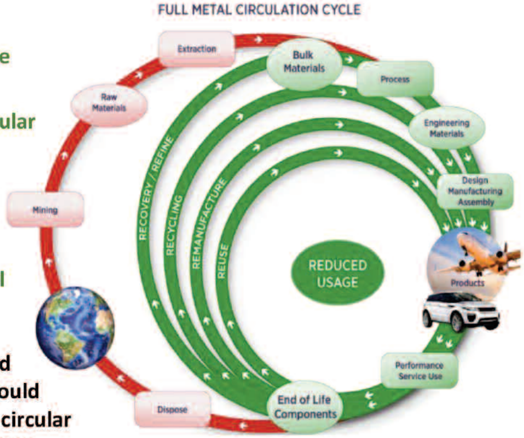

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