MCWASP XVII

International Conference on Modelling of Casting, Welding and Advanced Solidification Processes XVII

7th to 12th June 2026

Winchester, UK

Conference Timetable

7th June 2026

14:00 to 18:00

Registration (Hotel check in from 15:00)

18:00 to 21:00

Welcome Reception and Buffet Dinner

8th June 2026

07:30 to 09:00

Breakfast

Industrial Challenges and Perspectives 1
Chair: Mark Jolly

09:00 to 09:20

Conference Opening Ceremony

Andrew Kao and Catherine Tonry, University of Greenwich

09:20 to 10:00

Advanced Research into Crystal Anisotropy and Nucleation Effects in single crystals (ARCANE) – industrial challenges to casting modelling for innovation

Nick Green, The University of Birmingham

The continued trends of increasing complexity and greater precision demanded of single crystal components for high efficiency aeroengines risks increased component cost and reduced tolerance of manufacturing defects. Development of capable, optimised and robust processes necessitates modelling tools for development of right first-time solutions, underpinning design-for-manufacture and manufacture-for-design analysis. In superalloy single crystals defect formation arising from mechanisms as diverse as fluid flow and free surface entrainment, interfacial reactions and heterogeneous nucleation, interdendritic fluid flow, competitive grain growth, thermal and self-induced stresses must be resolved. In this paper we describe mechanisms of defect formation, illustrating them with experimental data, share recent advances in modelling capabilities developed in the ARCANE project and highlight ongoing challenges for the casting modelling community.

10:00 to 10:20

Efficient Thermal–Mechanical Model of Steady and Dynamic Bulging

Brian G. Thomas, Colorado School of Mines, Golden, CO

Mold level fluctuations in continuous casting of steel slabs lead to flow instabilities, strand surface cracks, and, in severe cases, breakouts. Dynamic bulging induced by periodic squeezing of the strand far below the mold is a major contributor to these fluctuations. To investigate dynamic bulging, a beam-bending-based thermal–mechanical model is first developed to predict the steady-state bulging profile. The model is validated using previous plant measurements and is shown to be quantitively and qualitatively accurate. Parametric studies quantify the influence of key casting parameters and match with further measurements. The results demonstrate that the history experienced in the entire caster is important to the local behavior. Next, potential mechanisms for dynamic bulging are incorporated and are being investigated. These include roll warping and misalignment, transverse surface depressions, and thin spots arising from such depressions.

10:20 to 10:50

Coffee Break

Industrial Challenges and Perspectives 2

Chair: Brian G. Thomas

10:50 to 11:10

Simulation of solidification and remelting of accretion (mushroom) on AOD tuyere

Hadi Barati, K1-MET GmbH

Submerged gas injection into a liquid metal bath is a fundamental process in the pyrometallurgical production of metals such as steel, copper, nickel, and lead. In steelmaking processes like the combined blowing converter (KOBM) and Argon Oxygen Decarburization (AOD), inert and/or reactive gases are injected through submerged tuyeres. However, tuyere lifetime can be reduced by thermal wear, back-attack, and liquid-metal penetration. A widely used countermeasure is the formation of a frozen and porous metallic accretion, also called a “mushroom”, on the tuyere tip using a shroud gas. In this work, the solidification and growth of the mushroom under multiphase conditions are simulated using CFD. The presence of a central gas flow (supersonic and compressible) and its penetration length are approximated with analytical calculations. The shroud gas flow through the porous mushroom and the solidification of the liquid metal are modeled using a Eulerian approach. Because of the geometry and boundary conditions, a 2D axisymmetric model is employed; the validity of this assumption is verified by comparison with 3D simulations. Finally, the pressure and flow rate of the shroud gas are compared with process data from an AOD converter.

11:10 to 11:30

In Search of Advanced Sedimentation Techniques for the Mitigation of Inclusions in Aerospace-Grade Structural Aluminium Alloy Casting: Ternary Baffle Configuration for Enhanced Sedimentation of Inclusions in Launder-Crucible Systems

Mark Jolly, University of Greenwich

The effective removal of non-metallic inclusions such as alumina bi-films is critical for producing high-end aluminium alloy castings for structural applications. This study investigates a ternary baffle configuration designed to optimise sedimentation efficiency in launder-crucible systems. The setup features: (i) a primary ‘double-15° inclined’ baffle system within the sedimentation tank, (ii) a secondary vertical baffle at the launder-crucible interface, and (iii) a tertiary vertical baffle within the crucible. The configuration helps control the turbulent flow, redirect inclusions downward, and accelerate gravitational separation. Fluid dynamic simulations (Flow3D) were performed with continuous particle generation across a range of densities (3000 to 3900 kg/m³) and diameters (25 to 1000 µm). The primary baffles in the sediment tank created low-velocity recirculation zones, enabling mid- and high-density particles to settle out efficiently. The secondary baffle further reduced re-entrainment into the melt stream. Notably, the tertiary baffle inside the crucible was found to significantly enhance downward flow alignment, thereby accelerating sedimentation under the most significant, gravitational, forces. This integrated baffle system demonstrated superior sedimentation performance over all other tested configurations. The findings are applicable not only to aerospace castings, where melt cleanness is paramount, but also to automotive applications.

11:30 to 11:50

A comparison of experimental and predicted results for vacuum arc remelting

Caleb Schrad, Materials Engineering, Purdue University

Vacuum Arc Remelting (VAR) is a secondary remelting operation used to produce clean homogenous ingots of high-performance alloys. VAR is a semi-continuous casting process which uses a powerful electric arc to melt a consumable electrode into a water-chilled copper crucible inside a vacuum tight chamber. Control of the process relies on fine measurements of the process power, melt rate, arc gap, and other factors. Pilot scale processes were run with Alloy 718 to provide experimental data to compare to results predicted by a code. Sump marking and melt rate were measured directly and microstructural features were used to infer temperature gradients. These data were compared to predictions of fully transient VAR process model and a model of electrode melting, both implemented in the open-source code OpenFOAM. The process voltage and current are known to affect the estimations of melt rate and the behavior of flow in the melt pool. These measurements are notoriously noisy, varying rapidly about a nominal value. The raw, fluctuating voltage and current and the smoothed data are both used in the code to determine whether the smoothing is advantageous or necessary.

11:50 to 12:10

Control of hot cracking susceptibility by inter-layer heating strategies during L-PBF of IN738 parts

Charles-André Gandin, MINES Paris - PSL - CNRS

During additive manufacturing by laser powder bed fusion (L-PBF), parts made of alloy Inconel 738LC (IN 738LC) are prone to solidification cracking, due to the rapid heating and cooling cycles involved. To mitigate this issue, strategies for inter-layer heating (ILH) during part construction have been proposed. The present study builds on a macro-scale finite element (FE) model of the

printed component tailored to predict the spatial and temporal temperature field during L-PBF process of IN 738LC parts. The model features (i) a homogenized volume heat source, (ii) construction front tracking via Level-Set, and (iii) adaptive anisotropic remeshing to resolve steep thermal gradients at affordable computational cost. Thermal parameters were calibrated using a series of sliding thermocouples localized in the part under construction, in which a single layer was heated. The model reproduces measured temperature histories. Validation against a multiple ILH build confirms its ability to capture both ILH plateaus and the continuous rise of the construction front temperature (CFT). Based on the developed ILH numerical model, the CFT can be captured just before each powder deposition. An inverse correlation between CFT and experimentally measured hot-crack density is demonstrated, establishing a quantitative indicator of cracking susceptibility. The ILH process thus provides a predictive framework for designing crack-free L-PBF IN 738LC components.

12:10 to 12:30

Effects of the slag band physical properties on the heat and mass transfer during initial solidification in continuous casting process

Alexander Vakhrushev, Montanuniversität Leoben

The earliest stage of shell formation in continuous casting (CC) is controlled by coupled mass and heat-transfer near meniscus. It involves initial steel solidification, mold powder melting to form liquid slag and its re-solidification against a water-cooled mold, as well as infiltration into the shell-mold gap. The slag skin consists of a sub-millimeter liquid layer in direct contact with the slab surface and a corresponding solidified part, exhibiting non-Newtonian behavior. The total skin thickness and the liquid-solid slag ratio define the concurrent performance with respect to lubrication and heat transfer in the strand–mold gap.

The slag characteristics are directly linked with its basicity and strongly deviate based on the composition. In the present work, the effects of varying key material parameters of the mold powder are studied, including (i) the interfacial surface tension between the steel melt and the liquid slag and (ii) the break temperature, liquidus temperature, and the rheological law exponent. By varying these properties, we investigate how they determine the mold powder consumption rate and the resulting slag skin thickness, which strongly affect heat extraction in the CC mold and the shape of the initially solidifying shell.

The results, verified against the experimental measurements, relate the infiltration and heat extraction regimes to corresponding slag-skin physical properties, offering the insights to mitigate the formation of CC slab surface.

12:30 to 14:00

Lunch

Defects and Fluid Flow 1
Chair: Miha Založnik

14:00 to 14:20

Prediction and control of the casting defects in the directional solidification of single-crystal nickel-based superalloys

Jun Li, Shanghai Jiao Tong University

Due to the complex geometry of turbine blades and the heat transfer conditions, defects such as freckles, stray grains, and low-angle grain boundaries inevitably form in turbine blade castings. The formation of these defects is associated with the multiscale coupling effects of solute transport, dendrite evolution, and stress fields, making it challenging to directly observe their formation mechanisms experimentally. Therefore, this study employs an advanced multiphase-flow multiscale coupled numerical model to elucidate their underlying mechanisms. We developed a microstructure prediction model by integrating the Eulerian multiphase framework with a cellular automaton model and further constructed a stress and deformation model incorporating dendrite evolution using the finite element method. Simulation results reveal that radial heat flux of the directional solidification greatly promotes the formation of solute plumes. The overgrowing dendritic trunk is partially remelted in the swaying solute plume, and thus the isolated dendritic tip becomes floating grains in arbitrary orientation, which is the origin of the freckle grains. The dendritic stresses near the solidification front were found to be concentrated on the first layer of dendrites at the surface and transferred to the interior through dendritic bridging. Measures are also proposed to reduce the unexpected radial heat flux in the directional solidification process in the Bridgman furnace.

14:20 to 14:40

Phase-Field–Crystal Plasticity Modeling of Solidification and Type-III Residual Stress in Nickel-Based Superalloy CM247LC

Mostafa K. A. Salem, University of Sheffield

Our work employs thermal histories extracted from a temperature-dependent heat conduction model to simulate the solidification microstructure of the nickel-based superalloy CM247LC. The results reveal a transition in solidification morphology from highly cellular structures at low energy densities to predominantly dendritic structures at high energy densities. These dendritic solidification morphologies are concluded to promote the formation of microcracks observed in CM247LC at elevated energy densities through trapping of nanovoids in the interdendritic liquid region.

Furthermore, the inherent processing difficulty of CM247LC is shown to arise from competing defect formation mechanisms: low energy densities lead to lack-of-fusion porosity, while high energy densities promote microcrack formation. These findings are corroborated by coupling the phase-field solidification results to a decoupled, dislocationdensity-based crystal plasticity framework that assumes jog-limited dislocation motion

during solidification. Experimental validation is provided through comparisons between simulated microstructures and those observed via scanning electron microscopy and optical microscopy.

14:40 to 15:00

Modeling of externally solidified crystal formation in aluminum high pressure die casting: physics-based and machine learning approaches

Alan A. Luo, The Ohio State University

Aluminum high-pressure die castings (HPDC) are extensively utilized across various industries to produce lightweight components with exceptional manufacturing efficiency. However, the formation of externally solidified crystals (ESCs) during HPDC process can significantly reduce the mechanical properties, particularly the elongation and fatigue strength, of these castings. This overview paper introduces two approaches to model and predict ESC formation during HPDC.

Firstly, Magma simulation of shot sleeve solidification was used to understand the formation mechanisms of two types of ESCs, which were validated by HPDC experiments. The second approach explores the feasibility of using machine learning (ML) techniques to predict ESC formation in aluminum die casting. Several ML models were developed and evaluated for ESC prediction. The results highlight the potential of machine learning in defect prediction in HPDC products, offering a path to optimize the processing parameters and reduce casting defects.

15:00 to 15:20

Process parameter optimisation to prevent overdwell defects in vertically upwards continuous casting of dilute Cu-Mg alloys

Anna Katsiavria, University of Dundee

Dilute Cu-Mg alloys are widely used in rod for electric railway applications to meet the high strength requirements without significant reduction of conductivity.

Being highly volatile, however, Mg is deposited on the inner walls of the casting die, forming a build-up and impeding the manufacturing process causing breakages. An overdwell is incorporated after a number of casting cycles to remove the build-up and clean the die, allowing the production to continue. Although effective in breakage prevention, the overdwell leads to the formation of a defect consisting of elongated grains curved in the casting direction.

In this work the detrimental impact of the defect on the product elongation is quantified. Combining casting trials with simulations of the microstructure in the mm-scale using Phase-PotTM, the physical mechanism of the defect formation is identified and the casting parametersare optimised to prevent it.

15:20 to 15:40

Coffee Break

Defects and Fluid Flow 2
Chair: Ivars Krastins

15:40 to 16:00

Characterization of Drag and Permeability of Equiaxed Dendritic Grains by Numerical Simulations

Miha Založnik, Université de Lorraine, CNRS, IJL

Capturing the coupling of equiaxed grain motion with fluid flow is crucial for solidification process simulations. Because dendrites in the µm range cannot be fully represented in process-scale simulations, constitutive laws are necessary to describe the forces acting on them. We characterized these forces by direct simulations of Stokes flow around equiaxed dendrites, obtained from phase field simulations of solidification. We propose a drag correction factor for dendrites expressed as a function of their morphology and of the distance from neighboring grains, the arrangement ranging from dilute to packed. Furthermore, we investigated a description of dendrites as porous and permeable dendrite envelopes. Using a permeability field together with a volume-average description of the flow through the envelope can be used in mesoscopic solidification models to determine the distribution of the forces acting on the fluid and on the dendrite. We propose new constitutive relations for the permeability of dendrite envelopes.

16:00 to 16:20

Modeling of Mushy-Zone Dynamics in Continuous Casting with Temperature Corrections at Phase Boundaries

Anna Ivanova, Colorado School of Mines

This study presents a numerical model for mushy-zone dynamics in continuously cast strands that incorporates temperature corrections at solid – mushy zone – liquid phase boundaries. The formulation is based on the classical heat conduction equation and employs a finite-difference scheme for numerical solution. Temperature corrections are introduced during the calculation process to ensure a consistent treatment of latent heat effects associated with phase-boundary motion. The model enables stable tracking of liquidus and solidus fronts and captures the influence of phase-boundary movement on the thermal field. Numerical results illustrate the impact of the proposed corrections on mushy-zone thickness, temperature gradients, and solidification rates under representative casting conditions. Comparisons with conventional effective heat capacity formulations demonstrate differences in accuracy and numerical behavior. A sensitivity analysis is performed to assess the influence of discretization parameters and thermophysical properties on the predicted results.

16:20 to 16:40

Thermal Boundary Conditions from Experiments: Classical and Adjoint Inverse Heat Conduction

Jan Bohacek, Brno University of Technology

Accurate thermal boundary conditions are essential for heat-transfer modeling but are rarely available by direct measurement. While they could in principle be obtained from detailed fluid-flow simulations, many practical cooling configurations involve complex multiphase phenomena—such as spray cooling and boiling regime transitions—where CFD becomes computationally expensive and often unreliable, while the primary modeling interest lies elsewhere. This contribution compares two sequential inverse heat conduction approaches: a classical method, long established in our laboratory, and a more recent adjoint-based formulation, both implemented in OpenFOAM. The goal is to accelerate the process of inverse calculations while improving accuracy. Temperature measurements inside solid bodies are used to reconstruct transient heat fluxes and heat-transfer coefficients at the solid–fluid interface. The methods are demonstrated and compared using transient data from a single thermocouple obtained in a spray cooling experiment. Advantages and limitations of each approach are discussed, including the potential for extension to multiple thermocouples.

16:40 to 17:00

Exploring Processing Space for Radiological Castings using Fluid Flow Modeling

Spencer Hunt, Los Alamos National Laboratory

A computational fluid flow model simulating mold filling and solidification of a uranium casting was developed using FLOW-3D®. In literature, simulations and instrumented castings have shown that gravity casting into a thin, monolithic (i.e., plate) top-gated mold cavity produces an undesirable temperature gradient in the fluid after filling, which results in porosity formation. Increasing pouring temperature (TPour) and/or mold temperature (TMold) to reduce porosity formation results in long solidification times, which can cause other casting issues. In this work, a mold was designed to reproduce fluid flow, solidification evolution, and porosity distributions observed in simulations from previous work. TPour, TMold, and filling time (tFill) were varied to determine the sensitivity of these parameters on predicted porosity distributions and solidification times of the casting. Comparing

TPour and TMold, TPour had a greater effect on porosity formation, while TMold had a greater influence on solidification time. Reducing tFill reduces the extent of solidification during filling and subsequent porosity formation, without increasing solidification time.

17:00 to 17:40

Poster Preview Session

This session will give those with poster presentations a chance to present for one minute on their poster.

17:40 to 18:00

Free Time

18:00 to 21:00

Poster sesion and Barbeque

Additive Manufacturing and Welding

A1

A Model Experiment of Magnetohydrodynamics in an Additive Manufacturing Melt Pool

Valdemars Felcis, University of Greenwich / University of Latvia

In metal additive manufacturing (AM) there are significant temperature gradients, for alloys with a significant difference in Seebeck coefficient between the solid and the melt this leads to large thermoelectric currents. In the presence of a magnetic field these induce a Lorentz force and so magnetohydrodynamic flows in the melt pool. However, due to the small scale of the melt pool, it is difficult and expensive to directly measure the current in the pools. This work builds upon previous upscaled model experiments, comprising of a macroscopic cobalt bowl filled with gallium, indium, tin alloy. Here we experimentally add an externally induced electric current and show the transition from induced current to thermoelectric current flows. This is then compared to numerical modelling to demonstrate the density of the thermoelectric currents in the bowl. These models are then used to estimate thermoelectric current density in an AM melt pool.

A2

GPU-parallel AMR multi-phase-field simulation of competitive growth of dendritic grains in a melt pool during metal additive manufacturing

Tomoya Okada, Kyoto Institute of Technology

Metal additive manufacturing (AM) has attracted significant attention because it enables the fabrication of complex geometries. In metal AM, the characteristic melt pool shape strongly governs the competitive growth of dendritic grains from the bottom of the melt pool. Although numerical simulations have recently been used to predict and evaluate dendritic microstructures, fully resolving dendrite growth within a realistic melt pool remains challenging because of the extremely large size ratio between the melt pool and individual dendrites. To address this challenge, we introduce a GPU-parallel adaptive mesh refinement (AMR) approach into a multi-phase-field (MPF) model with a double-obstacle potential. This GPU-parallel AMR MPF framework enables large-scale simulations that capture the competitive growth of dendritic grains within a melt pool, as well as subsequent grain growth during metal additive manufacturing.

A3

Highly efficient multi-phase-field framework for microstructure optimization via scan strategies in metal AM

Yuki Takahashi, Kyoto Institute of Technology

Metal additive manufacturing enables the optimization of microstructures through the precise control of the scan strategy (laser scanning pattern). However, the vast number of possible scan-strategy combinations makes experimental optimization difficult, rendering numerical simulation indispensable. While the multi-phase-field (MPF) method is widely recognized for its high accuracy in microstructure prediction, its significant computational cost hinders its application to complex scan strategies. In this study, we develop a highly efficient MPF simulation framework utilizing a subdomain moving frame algorithm. This approach reduces the computational load by restricting the domain to the vicinity of the solid–liquid interface. Using this accelerated framework, we perform microstructure predictions under various scan strategies to evaluate their influence on microstructural evolution.

A4

In Situ Synchrotron X-ray Investigation of Solidification Dynamics During Directed Energy Deposition of 316L Stainless Steel

Xinyi Hao, Mechanical Engineering, University College London, London WC1E 7JE, UK; Research Complex at Harwell, Harwell Campus, Didcot OX11 0FA, UK

Understanding melt pool dynamics during directed energy deposition (DED) additive manufacturing is essential for controlling solidification microstructure and defect formation. In this work, we present multi-modal in situ synchrotron experiments conducted at the ID23 Structural Dynamics Beamline at the High Energy Photon Source (HEPS) on 316L stainless steel DED. High-speed X-ray radiography captured real-time melt pool geometry and boundary evolution, while simultaneous pink-beam diffraction data were acquired at high frame rates throughout the solidification process, enabling the extraction of cooling rates and temperature gradients. These experimental datasets were used to inform and validate coupled multiphysics simulations, which investigated the role of powder particle impact on melt pool thermal and flow fields, specifically the relative contributions of thermal energy deposition and particle momentum in modifying melt pool behaviour. This combined framework provides new quantitative insight into how powder-melt pool interactions influence solidification conditions during DED.

A5

Multiphase fluid mechanics and crystals plasticity approach to predicting surface roughness and localised deformations

Hugh J. Banes, University of Sheffield

Laser Powder Bed Fusion (L-PBF) technique offers exceptional geometric design freedom, making it highly attractive for high value components. However, in safety critical applications, the large number of defects that are produced through process limit widespread adoption, in particular poor surface quality that severely impacts fatigue performance through stress concentrations, early plastic localisation and fatigue crack initiation. The physical mechanisms governing surface formation during solidification in L-PBF and their direct linkage to mechanical performance is not yet fully understood.

In this work, a computational fluid dynamics model for the L-PBF process is presented, incorporating multiphase fluid mechanics, to predict melt pool behaviour and surface formation. The model explicitly resolves powder-liquid-vapor interactions and tracks evolution of the solidification front, predicting the as-built surface topology. Together with predictions of the solidification microstructures, the simulated data is then mapped to a plasticity model that is used to predict fatigue behaviour of different surfaces.

A6

Parallel GPU-AMR accelerated phase-field lattice Boltzmann simulations for melt pool dynamics in metal additive manufacturing

Konosuke Ikeda, Kyoto Institute of Technology

Metal additive manufacturing (AM) enables precise microstructural control repeated melting and solidification using selective laser scanning, allowing grain refinement and texture development. Since the microstructure is strongly influenced by melt pool behavior, optimizing laser scanning parameters is critical for improving the performance of AM products. To achieve this, numerical simulation is essential for both accurate prediction and deeper understanding of AM process.

Our group has developed a phase-field lattice Boltzmann model capable of reproducing melt pool dynamics with high accuracy and temporal-spatial resolution. However, the computational cost is extremely high due to the requirement of hundreds of grid points. In this study, we introduce an adaptive mesh refinement (AMR) method combined with multiple GPU parallel computing to accelerate the simulation. The proposed method enables high-resolution computations that were previously impractical within realistic computational time, providing detailed insights into the flow patterns inside the melt pool.

A7

Revealing the Nature of Melt Pool Flow in Additive Manufacturing using Tungsten Tracer Particles in a Transient External Magnetic Field

Ivars Krastins, University of Greenwich

Melt flow in laser metal additive manufacturing is typically generated by the Marangoni force at the top surface. Due to the high temperature gradients, flow velocities can reach magnitudes of metres per second. The large thermal variations also introduce thermoelectric currents at the solid-liquid interface. When an external magnetic field is applied, these currents interact and generate a Lorentz force driving a thermoelectric magnetohydrodynamic flow which challenges the Marangoni flow dominance. Capturing such a mechanism experimentally is challenging so we present a reduced complexity setup that showcases the fundamental mechanisms. Tungsten tracer particles visualise the interplay between the Marangoni and Lorentz forces using in situ high-speed synchrotron X-ray radiography. However, in the numerical model, only by introducing secondary thermoelectric currents between the particles and the melt, could an excellent match be found to the observed particle behaviour from the experiment. The numerical model then gives insight into the underlying melt pool flow by testing the independent and collective influence of the various complex physics introduced.

A8

Coupling ultrasound and adjustable ring mode beam shaping during laser welding of AA6063 extrusions alloy.

Philip Carr, Carrs Welding

The 6xxx series aluminum alloys are vital for modern lightweight battery designs; however, their weldability is traditionally compromised by steep thermal gradients and rapid cooling, and results in solidification cracks and high porosity[PC4.1]. This study investigates the coupling effects of Adjustable Ring Mode (ARM) beam shaping and contact-based ultrasound (20 kHz and 40 kHz) on the weldability of the extruded AA6063. Results indicate that the 20 kHz frequency ultrasound (US20) significantly reduces area % of porosity from 11.26 % (core only) to 1.2 % through cavitation driven degassing. Further, the core-ring ARM beam shape enhances ultimate tensile strength by 34.6% relative to core-only beam (baseline) by lowering thermal gradients and reduced microcracks. However, while the 40 kHz frequency ultrasound (US40) achieves a higher equiaxed grain fraction of ~ 80% of fusion zone, it destabilizes the melt pool and introduces microcracks, leading to a 60.9% reduction in tensile strength compared to baseline. The higher weld quality was achieved by coupling US20 with the ARM beam shape, which balances microstructural refinement to 42.6 % along with ~34% tensile strength improvement. This research establishes a critical coupling window where controlled acoustic field can compliment beam shaping to ensure high quality joints for battery packs.

Casting and Other Process Models

A9

A Study of Uncertainty in Metal Casting Using a 1D Custom Python Finite Element Analysis Solver

Christopher A Jones, AWE

Computational modelling is an essential tool for exploring processes and conditions. However, performing a single simulation to inform conclusions provides insufficient detail on the suitability of predictions. This work considers an uncertainty study into a gravity casting process, allowing model parameters holding the greatest influence on the predicted output temperature to be identified. Based on the uncertainty in these input parameters, the corresponding uncertainty in the output has been evaluated using one-at-a-time (OAT) analysis and a Gaussian probability (GP) emulator. This has provided a metric for confidence in the results and thus the utility of the modelling approach as a predictive tool. The GP emulator showed strong agreement with simulation predictions, with the rapid runtime ideal for scenario exploration. The future intent of this work is to perform this analysis on 3D commercial solvers to explore both the uncertainty and the suitability of modelling at lower dimensions.

A10

Direct modelling of mechanical deformation of mushy zone for Aluminium DC-casting simulation

Sylvain Gouttebroze, SINTEF

The prediction of the hot cracking in DC-casting simulation requires high quality homogenized material model of the mushy zone at the coherence point. This study focuses on (1) the efficient generation of 3D meshes representative of the complex microstructure when the mushy zone starts to be coherent and (2) simulation of the mechanical response of the so-generated representative volume elements of mushy zone under tension and compression.

3D microstructure simulations were performed on a simplified AA6005 alloy with the phase field model MICRESS coupled with Thermo-Calc. Representative volume elements are generated from these voxel domains using different libraries (CGAL, Iso2Mesh). Different approaches were tested to create meshes as smooth as possible, to avoid numerical issues during finite element simulations, while keeping the global structure of the grains.

The coherent matrix is assumed to behave as a plastic solid, and large deformation and contact between grains are accounted for in an attempt to apprehend the different tension to compression responses observed in experiments.

A11

Modeling and simulation of liquid in-fill process for sustainable manufacturing

Mark Jolly, University of Greenwich

Ti alloys are used extensively throughout the aerospace industry. Most products have been designed with extensive machining leading to large volumes of swarf which are then reprocessed through the original high energy primary metal production routes (VAR) with a concomitant high carbon footprint. The EPSRC funded Sustainable Additive Manufacturing (SAM) project proposes to develop new AM techniques using Ti machining swarf as the feedstock for the process. This paper investigates the modelling and simulation of micro-scale Ti-6Al-4V (Ti64) swarf casting, with particular emphasis on how a new process called liquid-in-fill (LIF) can support the development of continuous-micro-casting process. A Finite Volume method CFD software is used to determine optimum process conditions such as mould tilt angle, temperature and flow rates. A sensitivity analysis to understand the heat transfer coefficients between the various materials was also undertaken.

A12

Optimisation of horizontal break ring continuous casting process using CFD Simulations.

Badarudeen Kalappurakkal Mohiyudeen, University of Dundee

Continuous casting of wire remains essential for high-volume, low-carbon footprint production of conductor and structural alloys; increasing casting speed raises throughput and lowers unit energy and cost while — with appropriate mold material, cooling rate and casting motions[1], [2] — producing finer solidification microstructures without defects and porosity that improve downstream drawability and mechanical performance.

This project aims to understand the influence of casting motions (dwell, push back and double pushback) on the occurrence of centreline defects and surface defects observed on High manganese steel and ER70s-6 steel wire(φ5-8mm) manufactured using horizontal break ring continuous casting process. The heat transfer and solidification front developed in the casting arrangement is simulated using Ansys Fluent. The result of the simulation is validated based on data from experimental casting trials and by performing metallography analysis of wire samples collected from these trials. The validated model is used to predict optimum casting parameters for the alloy systems in discussion.

[1] T. D. A. Jones et.al, “Computational fluid dynamic simulations of solidification for enhancing speed of continuous cast copper,” Engineering Science and Technology, an International Journal, vol. 24, no. 1, pp. 92–104, Feb. 2021.

[2] T. D. A. Jones et.al, “Optimising Computational Fluid Dynamic Conditions for Simulating Copper Vertical Casting,” 2021.

A13

SHELL-CRACK: From Microstructure to Caster-Scale — Predicting and Preventing Cracks in Continuous Steel Casting

Nils Å.I. Andersson, Swerim

Hot cracking in continuous casting cannot be explained by material properties alone. RFCS SHELL-CRACK introduces an integrated experimental–numerical–sensor-based framework that links microstructure evolution, thermo-mechanical behaviour, and real casting conditions to derive new predictive cracking.

Preliminary results use Yamanaka's criterion as reference, as it is a widely validated industrial standard for predicting internal cracking. However, since this criterion is exclusively limited to mechanical dimensions associated with strain accumulation, the simultaneous incorporation of thermal and solidification dimensions is essential. By integrating process variables and metallurgical sensitivity, the proposed model systematically addresses physical dimensions and process parameters. A modular design guarantees scalability towards various geometries and grades, facilitating real-time monitoring via Level 2 and establishing the necessary rigor to evolve towards more complex predictive criteria.

This work is carried out within the RFCS-funded project SHELL-CRACK (Grant No. 101156718), involving ten European industrial and academic partners.

A14

Multifrequency Ultrasonic Treatment for Molten Metal Processing of Aluminum Alloys- Mechanisms and Inputs for Modeling

Raquel F Jaime, University of California, Irvine

Multifrequency Ultrasonic Treatment (UST) is a novel liquid metal processing method with high potential for microstructural refinement in secondary aluminum alloys. UST has been proven to refine grain size and modify intermetallic phases in the literature, but the liquid-state mechanisms that enact these changes are not well established. This research will present key results of microstructural modification in commercial aluminum A380 and discuss them alongside a model study. High-speed imaging and shadowgraph technique is employed in water to gain a mechanistic visualization for understanding the results experimentally observed in Aluminum alloy -A380. In this study we prove that multifrequency liquid-state UST can refine grains and produce unexpected phase formations in A380. The study in water reveals relative cavitation bubble size and distribution around a hollow ceramic ultrasonic probe. The latter are useful inputs for development of simulation models for molten metal processing.

Multiphysics Modelling

A15

Dendritic Fracture Mechanics: A Comparative Modelling Study

Mathursan Vinayakamoorthy, University of Greenwich

Experimental observations suggest the existence of various forces and mechanisms that induce critical loads causing the deformation of dendrites within the microstructure, which can ultimately lead to fragmentation. However, in many cases, the available experimental data are unable to fully isolate what forces are operating on the dendrite and prove whether the fracturing is mechanical in nature. In this work, a comparative study will be conducted on cantilevers with various cross-sections, progressing from foundational geometries to more representative dendritic morphologies. Utilising both the Euler-Bernoulli and Timoshenko-Ehrenfest beam theory analytic solutions and the commercial numerical modelling package Abaqus, different geometries will be analysed in a parametric study to quantify the type and magnitudes of loads that could realistically induce significant deformation leading to mechanical fracture within a dendrite. These results will be compared with experimental data to aid in elucidating the phenomena which may lead to deformation or fracture of the dendrite.

A16

EIGA and cold crucible combined melting technique

Koulis A. Pericleous, University of Greenwich

We propose an extended technique for melting reactive metal alloys in a modified electrode induction heating process, combined with a cold crucible holding vessel and an electromagnetically controlled exit nozzle, to produce a steady stream of liquid metal for further treatment, such as casting or gas atomization to produce metallic powder. The new method improves normal EIGA, which is limited to batch processing of the feedstock and often suffers from the process instabilities, by adding the cold crucible holding vessel for steady liquid metal outflow even during a temporal disruption due to electrode replacement or, operated in holding mode, to maintain the liquid metal balance volume and temperature in the furnace while the feedstock is replaced. The holding vessel permits mixing to homogenise the alloy while extracting electrically nonconducting contaminant particles. The new technique is demonstrated using the dynamic multiphysics MHD software SPHINX, previously validated in experiments and industrial applications.

A17

Improving Benchmark Validation with Uncertainty Quantification

Levi Dickson, Materials Engineering, Purdue University

Benchmark experiments featuring unidirectional solidification of metals in prismatic geometries are commonly used to validate solidification models. The effect of epistemic and aleatoric uncertainty of model inputs, such as material properties and evolving boundary conditions, on the uncertainty of selected outputs of interest (OOI) should be considered when comparing experimental and simulation results. A sensitivity analysis is used to eliminate variables whose uncertainty has little influence on the OOI, even if their input uncertainty was lessened by more precise measurements or more sophisticated methods. The effect of the remaining uncertain inputs was evaluated using the TASMANIAN tool to identify the role of various parameters on the overall model uncertainty. This modeling work, using a finite volume multicomponent solidification code, was compared to previous experimental work with a static investment cast IN718 . The results of this sensitivity analysis and the uncertainty analysis are discussed in the context of improving experimental design and computational fidelity.

A18

Molecular dynamics study of deformation induced fragmentation in a semi-solid state

Akihiro Niwa, Kyoto Institute of Technology

Fragmentation of solid grains is known to occur readily when external forces are applied to metals in a semi-solid state. Because such phenomena are difficult to observe in detail through experiments alone, simulation studies are essential for elucidating the underlying mechanisms. In this study, we perform molecular dynamics (MD) simulations to examine semi-solid behavior arising from the combined effects of solid deformation, grain boundary dynamics, and associated phase transformations in metallic materials near their melting temperature under applied external forces. Based on these simulation results, we investigated the mechanisms governing force-induced solid fragmentation. All MD simulations were carried out using LAMMPS on a GPU-accelerated computing environment.

A19

Numerical Simulation of Acoustic Bubble Dynamics: Analysis of Rayleigh-Plesset Solvers

Nurul Islam, University of Greenwich

The Rayleigh-Plesset Equation (RPE) is the governing framework for modelling Bubble dynamics, derived from Navier-Stokes equation for describing the non-linear relationship between external acoustic pressure and the evolving radius of a gas bubble in a liquid. This paper explores numerical solutions of RPE driven by ultrasound of varying frequencies and magnitudes, including non-sinusoidal acoustic waves. Two numerical strategies are examined: a basic Euler-method implementation and a higher-order approach using Runge-Kutta (RK4) methods,

The study investigates how variations in driving frequency and amplitude influence the transition from stable oscillation to violent bubble collapse. Results compare the accuracy and stability of these methods, providing a roadmap for simulating bubble driven phenomena in additive manufacturing and fluid systems.

A20

Phase-field multi-physics simulation of granular fragmentation due to contacts among solids

Gensei Kobayashi, Kyoto Institute of Technology

In recent in-situ X-ray observations, transgranular fragmentation was reported in a semi-solid state subjected to external loading by an indenter [S. Karagadde et al., Nat. Commun., 6 (2015) 8300]. Several mechanisms have been proposed to explain this phenomenon, including deformation induced grain boundary formation followed by liquid penetration, and local remelting caused by strain energy accumulation and increased interfacial roughness. However, the fragmentation mechanisms have not yet been consistently clarified. To address this issue, we developed a multi-physics framework to simulate granular fragmentation under semi-solid compression. The framework couples phase transformation and grain boundary formation via the phase-field method, liquid flow via the lattice Boltzmann method, and solid deformation and contact mechanics via the material point method. Based on the simulation results, we investigated the governing factors responsible for the onset of granular fragmentation.

9th June 2026

07:30 to 09:00

Breakfast

Microstructure Formation 1
Chair: Damien Tourret

09:00 to 09:40

Solidification of Aluminum Wrought Alloys with Elevated Hydrogen Content

Janin Eiken, Access e.V.

Porosity formation due to elevated hydrogen levels remains a major challenge in aluminum casting, directly compromising material properties. This issue is particularly critical in direct-shape castings, but also affects large-scale billets and ingots produced via semi-continuous direct-chill casting. This paper presents ongoing work from a joint research project within the AMAP cluster at RWTH Aachen, aiming to investigate the influence of hydrogen and the mechanisms of porosity formation in wrought aluminum alloys through combined numerical and experimental approaches.

Process simulations are carried out using MAGMASOFT® to predict temperature evolution in the castings. Microstructure simulations are performed using MICRESS®-7.4β coupled to Thermo-Calc databases. A demonstrator casting provides experimental data for validation. Key challenges include accurately capturing cooling behavior, phase transformations, and multicomponent microsegregation in a thermodynamically consistent manner. A particularly demanding aspect of the microstructure modelling is the prediction of gas pore formation resulting from local hydrogen supersaturation.

09:40 to 10:00

3D mesoscopic modeling of equiaxed grain growth in a thin sample

Ifzal Hussain, Université de Lorraine, CNRS, IJL

The growth kinetics in thin samples used for in-situ time-resolved X-ray transmission imaging of solidification are governed by three-dimensional phenomena. However, obtaining information about evolution of the three-dimensional features of the sample is challenging. To provide further insight into a benchmark microgravity experiment of equiaxed solidification of Al-20%Cu (A.G. Murphy et al., J. Crystal Growth, 2016), we conducted 3D numerical simulations of the sample. We combined the quantitative phase-field (PF) method and the mesoscopic Grain Envelope Model (GEM) to fully resolve solutal interactions and dendrite shapes. These simulations investigate the influence of the grain orientation relative to the crucible, determined using post-mortem EBSD, on the interactions between the growing dendrites and the sample walls, as well as on the growth speed of the dendrite arms. Additionally, we analyze the dynamic solutal interactions between the grains, influenced by the successive nucleation of new grains.

10:00 to 10:20

Simulation of mechanical property evolution for die-cast Al7SiMg castings with subsequent heat treatments

Fengxin Mao, MAGMA GmbH

AlSi7Mg alloys are widely produced in die-casting processes. The mechanical properties are influenced by various physical phenomena and process parameters. Simulation tools like MAGMASOFT® are often used to help predict the property evolution during the casting process and subsequent heat treatment. In this study, the mechanical property model of MAGMA Non-ferrous has been modified and improved with new validations. Yield stress is calculated through a combination of various effects from SDAS, Mg-containing particles, solute concentration, and defects. A damage factor is introduced to predict the distribution of elongation to failure, considering the reduction of potential elongation based on defects. Experimental validation was carried out on a die-cast commercial AlSi7Mg alloy subjected to T6 heat treatment. Mechanical properties were investigated on various positions of the casting after different stages in the manufacturing. The simulation shows good capability in predicting the evolution of yield stress and elongation for the studied case.

10:20 to 10:50

Coffee Break

Microstructure Formation 2
Chair: Tomahiro Takaki

10:50 to 11:10

Coarse-Grained Molecular Dynamics Simulation of Solidification Dynamics in Al–Cu Alloys

Yasushi Shibuta, The University of Tokyo

A coarse-grained molecular dynamics (CG-MD) framework was developed for alloy systems and applied to Al–Cu solidification. Large-scale simulations were performed across a range of solute concentrations and melt undercoolings. The growth velocity increased as temperature decreased, peaked at an undercooling of $\Delta T = 225$ K, and then declined, resulting in a characteristic peak-shaped trend. Morphology depended strongly on temperature and composition: pure Al and Al–1.3at%Cu formed rhombic, highly anisotropic crystals at moderate undercooling, whereas nearly isotropic circular structures appeared at $\Delta T = 275$ K. Al–3.0at%Cu exhibited weak anisotropy under all conditions. Although CG reduces atomic resolution, it enables micrometer-scale simulations far beyond the reach of all-atom MD, demonstrating its effectiveness for exploring solidification behavior in alloy systems

11:10 to 11:30

Phase-field modelling of secondary dendrite arm fragmentation in a Fe–C alloy during solidification

Ahmed Kaci Boukellal, Université de Lorraine, CNRS, IJL

The study of the microstructural evolution during solidification is critical for the mechanical performance of steels, particularly in nuclear power applications. Among the mechanisms involved, dendritic fragmentation plays a key role in the columnar-to-equiaxed transition, which strongly influences segregation. However, the exact conditions leading to secondary arms detachment remain unclear. This work aims to improve the understanding of secondary dendrite arm fragmentation at the microscale using a phase-field model, and to explore how quantitative metrics can improve macroscopic fragmentation laws.

To do so, simulations of directional solidification of a binary Fe–0.18 wt.%C alloy were carried out in real thermal conditions of big ingots. The first results show promising trends in arm radii, secondary dendritic arm spacings stability and merging phenomena. A decreasing trend in dendrite arm radii was observed, allowing the data to be fitted to the pinch-off power law and draw some conclusions and outlooks.

11:30 to 11:50

Cellular Automata Simulation coupled with CALPHAD Based Interface Response Functions for Dendritic Solidification

Jyothirmai Bethanapalli, Indian Institute of Technology Bombay

Solidification microstructure in multicomponent alloys is governed by coupled thermodynamics and interface kinetics, particularly under non-equilibrium growth conditions. The present work presents a hybrid framework that integrates a cellular automata (CA) model with a thermodynamic database-coupled interface response function (IRF) reported in the literature, enabling the efficient prediction of dendrite growth and solute segregation. In this model, the IRF coupled with Thermo-Calc®, which accounts for non-Fickian diffusion and velocity-dependent interface partitioning, is employed to calculate the local growth kinetics, including the growth velocity and partition coefficient at the solidification front. We utilise the data of Al-Zn alloy that exhibits non-linear liquidus and solidus profiles. The CA component uses the growth kinetics as inputs to update the dendritic growth and solute distribution. The results are validated by comparing the kinetics and sizes of primary dendritic arms, growing into an undercooled melt. The model is further used to simulate 3 different compositions, and the difference in solidification characteristics with linear and non-linear profiles are presented. This CA–IRF coupling preserves the physical rigor of non-equilibrium kinetics while achieving computational efficiency suitable for large-domain microstructure simulations.

11:50 to 12:10

A data assimilation system for estimating interfacial anisotropy parameters and crystal orientation in polycrystalline zinc dendrites

Ayano Yamamura, Kyoto Institute of Technology

Zinc alloys are extensively used, particularly in steel galvanizing; however, accurate data regarding solid–liquid interfacial parameters remain scarce. Recently, in situ observation using time-resolved X-ray computed tomography revealed a characteristic dendritic growth morphology with 14 growth directions in a Zn–4wt%Al alloy. Motivated by this discovery, we investigated the effects of interfacial energy anisotropy on dendrite morphology via systematic phase-field (PF) simulations. Our results indicate that the parameter a_{06} is essential for capturing these specific morphologies, in addition to the a_{02}, a_{04}, and a_{66} terms typically used for zinc alloys. Furthermore, to quantify these properties, we developed a data assimilation system capable of estimating material parameters and crystal orientations in polycrystalline dendritic growth systems.

12:10 to 12:30

Casting and solidification of magnesium alloys

Yuanding Huang, Helmholtz-Zentrum Hereon

Magnesium alloys have a high specific strength with their good castability and machinability which are interesting for lightweight construction applications. However, they have a poor room temperature formability and low high-temperature strength. Microstructural modifications such as refining and precipitation were popularly used to improve their ductility and strength. Regarding the subsequent microstructural optimisations, the first step casting and solidification plays a key important role because the quality of initial microstructure directly influences the subsequent one. The present work introduces our recent investigations on the casting and solidifications of Mg alloys. First, the influence of alloying elements on the hot tearing of magnesium alloys is simply summarised, including the elements Al, Zn, Y, Gd and Ca. Second, the applications of synchrotron radiations in the in-situ observations of solidification is introduced for magnesium alloys. Finally, the grain refinement of magnesium alloys inoculated by the external particles SiC is reported.

12:30 to 14:00

Lunch

Multiphysics Modelling and Numerical Methods 1
Chair: Peter Soar

14:00 to 14:20

On statistical evaluation and characterisation of local damage and material performance in megacastings

Jakob Olofsson, Jönköping University

The development of large, high-pressure die-casting machines, particularly in the automotive sector, has led to the introduction of a new generation of large structural castings. These castings are typically subjected to fatigue loads, but also require reliable and predictable performance during crash loads. This work explores a methodology for evaluating local tensile performance in large-scale castings numerically with statistical certainty. The methodology aims to identify statistically significant variations in tensile elongation and help determine the metallurgical and process-related causes of these variations. It is demonstrated that the upscaling of forces and filling velocities enhances the turbulence and air contact effects that lead to the formation of oxide films and bifilms, resulting in a local reduction of material performance. The results underscore the importance of simulating and predicting these effects using a probabilistic approach, as well as the significance of melt quality in achieving high-performance castings.

14:20 to 14:40

Producing Green Hydrogen from Liquid Aluminium

Koulis A. Pericleous, University of Greenwich

Hydrogen has high solubility in liquid aluminium, being absorbed from ambient water vapour through the exothermic reaction $2Al + 3H_2O \rightarrow Al_2O_3 + 3H_2$. As the aluminium solidifies during casting, the hydrogen is again released becoming a source of porosity, an undesirable event from the structural point of view. For this reason, degassing is a necessary step to remove hydrogen and improve casting quality. Hydrogen is then essentially discarded, quite a waste, since it can be used as a green fuel replacing hydrocarbons in combustion, or batteries in fuel cells. In this study, we demonstrate a practical way of increasing the amount of hydrogen that can be then captured for later use in a two-step process that: (a) first saturates molten aluminium with hydrogen using steam, and (b) extracts the hydrogen via ultrasonic cavitation, through rectified diffusion. The process is demonstrated numerically with support from preliminary experiments.

14:40 to 15:00

Fully Coupled Cellular Automaton–Finite Volume Model for Grain Evolution

Paolo Airoldi, Flow Science Mediterranea

A Cellular Automaton–Finite Volume (CAFV) framework for simulating grain nucleation and anisotropic growth during alloy solidification is presented. The CA algorithm operates on a sub-grid scale, capturing heterogeneous nucleation and competitive dendritic growth, dynamically coupled to the finite-volume solver governing heat transfer and phase change in FLOW-3D® CAST. The bidirectional coupling ensures that microstructural evolution influences the macroscopic thermal field and solidification front kinetics, enabling accurate prediction of grain morphology under transient conditions. The model incorporates orientation-dependent growth kinetics, providing a physically consistent representation of grain selection mechanisms in directional solidification. Validation against benchmark cases and experimental data confirms the model's capability to reproduce grain nucleation and evolution, while tests on industrial cases demonstrate the efficiency of its implementation with low computational cost.

The CAFV approach offers a robust tool for optimizing process parameters in single-crystal and other advanced castings, with possible extensions to welding and additive manufacturing processes.

15:00 to 15:20

<u>A new generation of finite difference methods for the phase-field modelling of dendritic solidification based on the strong-form local meshless methods</u>

Tadej Dobravec, University of Ljubljana, Faculty of Mechanical Engineering, Slovenia

In this paper, we introduce improvements to the classical finite difference method (FDM), which is commonly applied for the phase-field (PF) modelling of dendritic solidification. Namely, we investigate the performance of the radial basis function generated FDM (RBF-FDM) and the generalised FDM (GFDM), two strong-form local meshless methods. We test the two methods for the 3-D PF modelling of dendrite growth in pure melts and binary alloys. The results show that both methods improve the accuracy of the FDM. The GFDM, however, yields better computational efficiency than the RBF-FDM, similar to that of the classical FDM. Neither method requires a mesh to solve partial differential equations and is usually applied for modelling in complex computational domains. In this paper, we focus on the meshes used in the FDM; therefore, our insights can be directly applied to improve existing FDM codes for modelling of microstructure evolution.

15:20 to 15:40

<u>Coffee Break</u>

<u>Multiphysics Modelling and Numerical Methods 2</u>
Chair: Jakob Olofsson

15:40 to 16:00

<u>Three-dimensional point automata method for simulation of ECT and CET in continuous casting of steel</u>

Božidar Šarler, University of Ljubljana, Faculty of Mechanical Engineerin

The two-dimensional point-automata numerical approach for simulating ECT and CET in continuous casting of steel was extended to three dimensions. A heterogeneous nucleation model with a log-normal distribution for nucleation density was employed, together with the Lipton-Glicksman-Kurz grain growth model. Single grain growth was verified under constant undercooling for different crystallographic orientations and compared with the analytical solution for dendrite tip length. For continuous casting simulations, the point automata method was coupled with a temperature field model. Results from two- and three-dimensional simulations were compared for a C50-grade square billet measuring 18 cm. The three-dimensional model produced a more refined and physically correct grain structure by including crystallographic orientations in the z-direction. At the same time, the metallurgical length and positions of the ECT and CET zones remain comparable to those in the two-dimensional model.

16:00 to 16:20

Free Energy Surface of Nucleation via Metadynamics

Takumu Yamamura, The University of Tokyo

Controlling the solidification microstructure is particularly important for structural materials. However, the experimental determination of high-temperature properties such as the critical nucleus radius and the solid-liquid interfacial energy is challenging, and this uncertainty can significantly affect the resulting solidification microstructure. Therefore, various computational methods have been developed. In this study, we derived the free energy surface of nucleation by applying metadynamics to molecular dynamics simulations. Metadynamics is a computational method that can calculate the free energy surface by adding bias potential to the system. Physical properties are determined by fitting the classical nucleation theory equation to the obtained free energy surface. Here, the metadynamics simulation for nucleation was applied to undercooled pure iron. Based on the obtained free energy surface, the critical nucleus radius and solid-liquid interfacial energy were estimated. The estimated properties were consistent with experimental data and thermodynamic equations, indicating the effectiveness of this method.

16:20 to 16:40

Accelerated defect prediction for part-scale powder bed fusion builds using semi-analytical modelling and machine learning techniques

Shaun R. Cooke, The University of British Columbia

Semi-analytical thermal models provide a faster alternative to high-fidelity simulations for powder bed fusion, yet their application to part-scale, multilayer builds remains limited. Building on previous work incorporating temperature-dependent properties and radiative heat losses, we further extend the FAST model to improve computational efficiency for large, multilayer simulations. This approach opens the door to employ these predictions in a machine learning framework. FAST-generated thermal histories were used to train a random forest classifier capable of quickly detecting problematic regions in multilayer builds. This combined semi-analytical and machine-learning approach significantly reduces time-to-results compared to the original FAST model and equivalent finite-element simulations while maintaining predictive utility.

16:40 to 17:00

Influence of rotating magnetic field on the precipitation of α-Fe phase during unidirectional solidification of Al-6Si-4Cu-2Fe alloy

Chenbo Xu, Montanuniversität Leoben

Solidification experiments on aluminum alloys with Fe content were carried out in the MICAST project. The forced flow was induced by rotating magnetic field (RMF), and the α-Fe phase precipitated during unidirectional solidification of Al-6Si-4Cu-2Fe alloy.

Based on the previous work (Zhang et al., Metall. Mater. Trans. A., 2021), a volume-average solidification model has been developed for Al-6Si-4Cu-2Fe alloy. The α-Fe phase is considered by introducing the empirical constant g-α that affects the precipitation of α-Fe phase. The calculated phase fractions obtained by using the numerical model and the thermodynamic equilibrium data show good agreement under pure diffusive condition. The precipitation and growth of the α-Fe phase are influenced by applying the RMF. The forced flow induced by the Ekman effect consists of an azimuthal component of ~ 20 mm/s and a meridional component of ~ 8.0 mm/s. These insights contribute to a deeper understanding of the influence of FMF on the precipitation of α-Fe phase in the Al-6Si-4Cu-2Fe alloy.

17:00 to 17:40

Poster Preview Session

This session will give those with poster presentations a chance to present for one minute on their poster.

17:40 to 18:00

Conference Photograph

18:00 to 21:00

Poster Session and Hog Roast (Vegetarian and vegan alternatives available)

Defects and Fluid Flow

B1

CFD modeling of calcium chloride solidification

Shizhan Zhang, Montanuniversität Leoben

To develop a fundamental understanding of the solidification of high-temperature molten slag in metallurgical furnaces—specifically, the formation of a so-called freeze lining (FL)—Guevara and Irons (2011) conducted a series of laboratory-scale experiments using an aqueous calcium chloride solution as a model analogue material. Their study characterized the steady-state FL shape and thickness, as well as the local fluid velocity, under a range of superheat conditions.

In the present study, these experiments were reproduced using a volume-average solidification model that couples the conservation equations of mass, momentum, species, and enthalpy for both liquid and static columnar phases. A satisfactory agreement was achieved between the experimental data and the simulation results.

The validated model was then applied in a parametric study to gain additional insights into the mechanisms governing FL formation. The effect of key parameters on the resulting FL thickness, shape, and local fluid velocity was systematically examined. This comprehensive analysis provided a deeper understanding of slag solidification kinetics, an area where further fundamental development remains necessary.

B2

Simulation of macrosegregation and macrostructure in continuous casting of high-carbon steel billets

Miha Založnik, Université de Lorraine, CNRS, IJL

We investigate the impact of continuous casting process parameters on the solidification structure and on the chemical homogeneity of high-carbon steel billets. We use OpenSOLID, an advanced multiscale model of solidification, which describes molten steel flow within the solidifying billet, the movement of solidifying crystal grains, solidification kinetics, the columnar-to-equiaxed transition, and the interplay of these phenomena on macrosegregation. We provide insight into the coupling of physical mechanisms causing segregation and we compare the simulation results to metallographic and chemical analyses conducted at different scales, from the microstructural level to the entire cross-section of the billet.

Numerical Methods

B3

Macroscopic columnar front tracking with a phase-field interface capturing method

Miha Založnik, Université de Lorraine, CNRS, IJL

The tracking of the columnar front in macroscopic solidification models is mostly based on bespoke marker- or mesh-based interface tracking methods. The implementation of these methods is complex, especially in 3D. We propose a novel approach based on a phase-field like interface capturing method (PFIC). The advantage of the PFIC is that it avoids explicit tracking of the front and instead propagates a phase field by solving a partial differential equation on a fixed domain. The position of the columnar front is then defined by a level set of the phase field. We couple this approach with a volume-average solidification model of columnar solidification. The fully coupled model is used to simulate the columnar growth in a directionally solidified Al-7%Si alloy. The results show good agreement with a CAFE and a pseudo-front tracking model. We also discuss advantages and disadvantages of the PFIC approach.

B4

A Lattice Boltzmann Approach to the One-Fluid Formulation of Multiphase Flow

Snehil Srivastava, University of Greenwich

A multiphase lattice Boltzmann model is presented for the numerical solution of the one-fluid flow equations for immiscible fluids. The capillary stress tensor is embedded within the first non-conserved moment of the discrete velocity distribution function, so that its divergence is captured without the need for further on-lattice differencing. The normal to the interface can be computed by either finite different approximations to the gradient of the phase field, or approximated via moments of the lattice Boltzmann equation for the density. The model with approximation methods are compared and validated through simulations of a static droplet across a range of density ratios and numerical parameters. More complex flows including the Rayleigh–Taylor instability and bubble rise problem are simulated, with results in good agreement with trusted benchmark data.

B5

Flow-driven particle deposition and clog network formation on refractory walls

Hadi Barati, K1-MET, Austria

Deposition of solid Non-Metallic Inclusions (NMIs) in Submerged Entry Nozzles (SEN) remains a critical challenge in continuous casting of steel, as it disrupts the melt flow, reduces the process efficiency, and contributes to product defects. This problem arises because turbulent flow inside the SEN carries a fraction of the NMIs toward the SEN wall, where strong adhesion forces cause them to deposit and gradually form dendrite-like networks.

In this study, a coupled Computational Fluid Dynamics (CFD) - Discrete Element Method (DEM) framework is developed to investigate the microscopic phenomena of NMI deposition, clog growth, and potential fragmentation near the SEN wall. The model is applied under varying flow conditions to capture the dynamics of clog evolution. The results demonstrate how flow conditions govern the development of clog networks, offering detailed microscopic insights into NMI transport, deposition, and growth phenomena.

B6

<u>The calculation of kinetic interface contact condition phase diagram for the melting of multi-component aluminium alloys</u>

Qiang Du, SINTEF Industry

While melting has been considered to be asymmetric to solidification, the fundamental kinetic processes at the migrating interface are common for solidification and melting. It is demonstrated in this contribution that the three kinetic process solute drag and trapping model, proposed by authors recently for rapid solidification within the framework of irreversible thermodynamics and linear kinetic law, is applicable to calculating the interface contact conditions during melting. As in our treatment of solidification, it is assumed three kinetic processes occur during the melting, i.e., interface migration, compositional adjustments via diffusion on both of the solid side and the liquid side. The diffusional flux from the solid into the liquidised interface causes the increase from the solid phase composition to the interface composition. This flux is scaled to the interfacial diffusivity. The diffusional flux from the liquid phase to the interface raises the interfacial composition. This flux is scaled to the liquid diffusivity. The model solution algorithm is described in detail, and its implementation in Fortran is shared via copy-left license. The model is employed to calculate the kinetic melting phase diagrams for an ideal AB solution model system, binary Al-Mg and multi-component Al alloys. It is concluded that the asymmetry in interface contact condition calculations between solidification and melting is about numbers, not fundamental mechanisms.

<u>Insitu Experiements</u>

B7

<u>Heat transfer and solidification model of thermographic differential thermal analysis for the study of steel solidification</u>

Jose M. Flores Herrera, McMaster University

Traditional thermal analysis such as Differential thermal analysis (DTA) and Heat-Flow Differential Scanning Calorimetry (HF-DSC) are typically constrained to cooling rates lower than 30°C. To study solidification at faster cooling rates an improved technique was developed coupling a High-Temperature Infrared Furnace with a Thermal Imaging Camera to analytically determine the onset temperatures for solidification and peritectic transformation at cooling rates between 120 to 720°C/min. A heat transfer and solidification model was developed to determine the capability of the technique and predict thermograms. The model was calibrated using the melting and freezing of pure Cu and Fe. The technique was demonstrated with low C steels from 0.05 to 0.25%C.

B8

Investigating hot-tear nucleation, growth and merging behaviour during aluminium alloys solidification using high-speed synchrotron X-ray imaging

Akash Aggarwal, University of Oxford

Hot tears form late in solidification when liquid-to-solid shrinkage cannot be fed through the low-permeability mushy zone. Local pressure drops and tensile stresses cause grain-boundary decohesion of the last liquid, producing elongated, tortuous cracks. In this study, we used synchrotron in-situ X-ray imaging to capture solidification of aluminium alloys and to resolve the dynamics of hot-tear nucleation, growth, coalescence, and their relationship with interdendritic flow. Because hot tears often appear as hairline features in radiographs, conventional thresholding leads to poor and fragmented segmentation. Building on our group's existing hot-tear tracking framework, we developed an automated, AI-assisted semantic segmentation and tracking pipeline that robustly identifies hot tear nucleation, growth kinetics, and merge events during the late stages of solidification. To further probe the coupling between interdendritic flow and cracking, trace amount of lead was added to the alloy; a monotectic reaction produces lead droplets that move through the interdendritic network. We tracked droplet trajectories using particle-tracking algorithm to quantify correlations between interdendritic flow, hot-tear propagation, and in selected cases, the influence of intermetallic phases. Investigated samples includes aluminium alloys with small amount of Fe/Si to mimic scrap impurities, plus specimens cast with an embedded ceramic die to impose industrially relevant cooling stresses.

B9

Heuristic Operando X-ray Microscopy: An Entropy-Based Sampling Framework for Large-Scale Facilities

James Le Houx, University of Greenwich

Operando X-ray microscopy increasingly tracks microstructural evolution in real time, but most experiments still scan on a fixed schedule. The instrument visits every region at uniform cadence, regardless of where the interesting physics is happening. For systems where rare, localised events drive the outcome, solidification fronts, defect nucleation, stress-driven failure, fixed scheduling systematically misses the moments that matter.

Here, we propose a heuristic sampling framework that replaces fixed schedules with active, information-led measurement. Rather than maximising the volume of data, the instrument maximises the information gained per unit cost, a metric we call Entropy-Scaled Measurement Efficiency (ESME). Closing the loop in real time requires total feedback latency to stay below the timescale of the physics; above that, the method collapses back to scripted scanning.

We demonstrate the framework on operando strain mapping of an NMC 811 cathode particle, using topographical kurtosis to isolate lattice disorder and stress concentrations near the yield point. The approach generalises to solidification, fatigue, and stress-corrosion regimes.

B10

Toward accurate reconstruction of dendritic morphology and material property identification from X-ray imaging data using phase-field-based data assimilation system

Ayano Yamamura, Kyoto Institute of Technology

Advances in time-resolved X-ray imaging (4D-CT) technologies have made direct observation of dendritic growth possible in opaque alloys. To address the resolution limitations associated with fast phenomena, we aim to develop an X-ray image reconstruction technique using data assimilation incorporating phase-field (PF) method. Here, material parameters are estimated simultaneously to achieve accurate PF simulations. In our previous study, we developed and evaluated a data assimilation system that uses only the solid fraction distribution of thin-film samples, which imitates the brightness distribution in X-ray images, through numerical experiments. The results indicated that estimation is feasible to some extent; however, accuracy decreases as sample thickness increases. As the next step, we aim to extend the system to rotating cylindrical samples used in 4D-CT. We assess how accurately morphologies and parameters can be estimated using rotating samples through systematic numerical experiments. The results show that sample rotations can improve estimation accuracy.

B11

In Situ Synchrotron Imaging of Ga-In Alloy Solidification Under Pulsed Electromagnetic

Natalia Shevchenko, Helmholtz-Zentrum Dresden-Rossendorf

Pulsed electromagnetic fields (PEMF) are promising for microstructure control during solidification, yet their impact on dendrite growth and fragmentation remains poorly understood. This study investigates the solidification of a low-melting Ga-In alloy under a vertical temperature gradient. Using in situ synchrotron X-ray imaging at the Diamond Light Source, we observed dendritic evolution under PEMF (8–11 mT, 10–300 Hz, 50% duty cycle). Frequencies above 100 Hz significantly increased dendrite fragmentation. To clarify the underlying mechanisms, numerical simulations are required to complement the experimental data on interdendritic melt flow. Furthermore, direct observations revealed that large dendritic clusters (10–20 dendrites) can collectively move within the mushy zone, forming new subgrain boundaries. This phenomenon is proposed as an alternative mechanism for grain refinement. This experimental approach provides new insights into PEMF-induced fragmentation and establishes a benchmark for future numerical models.

Microstructure and Macrostructure Formation

B12

Effect of Alloying Elements on the Microstructure and Mechanical Behaviour in Recycled Al-Si Alloys

Anish G P Nand, Cranfield University

Sustainability-driven manufacturing has increased the use of recycled aluminium alloys. However, this also introduces challenges related to compositional variability and impurity accumulation. This study systematically investigated the role of alloying additions and melt treatments in recycled Al-Si-based cast alloys. Recycled alloys with controlled variations in Mg and Mn contents were produced by casting, along with selected melt treatments, including degassing, grain refinement, and eutectic modification. Microstructure characterisation was performed using computed tomography, optical microscopy, and electron microscopy, while the mechanical properties were examined through hardness and tensile testing. This study examined the intermetallic phase morphology, porosity, grain refinement, and their influence on strength and ductility. The results indicate that Mg plays a key role in enhancing the strength of recycled aluminium alloys through solid solution and precipitation effects, whereas high levels can promote embrittlement. Degassing and grain refinement are effective in reducing casting-related defects and improving mechanical performance. In contrast, the addition of Mn and Sr primarily affected the intermetallic and eutectic structures, with a limited influence on the tensile properties of the alloys. This study supports the development of alloying and processing strategies that facilitate the effective use of recycled aluminium in demanding structural applications.

B13

<u>Formation of bicontinuous structures through distributed internal melting</u>

Zhongyang Li, Institute of Materials Physics and Technology, Hamburg University of Technology

Peritectic melting (reverse peritectic reaction) is an emerging approach to forming small-scale bicontinuous microstructures with interesting mechanical properties and forming convenient precursors for microporous metals. Liquid film migration was predicted as the main microstructure formation mechanism during peritectic melting in early phase field simulation studies. Our studies on various alloy systems provide experimental evidence supporting that hypothesis. More importantly, we reveal that the final microstructure is determined by the nucleation (homogeneous or heterogeneous) and growth (planar or cellular) mechanism of the new solid phase, as well as the original microstructure of the master alloy. Based on these observations, we want to propose the idea of distributed internal melting, which utilizes the pre-melting sites (vacancies, dislocations and grain boundaries) to initiate liquid film migration, resulting in refined bicontinuous structures.

B14

<u>Liquid/Solid Interface energy and Its Anisotropy of Pure Metals</u>

Zhongyun Fan, BCAST, Brunel University London

Solid/liquid (S/L) interface energy (γ_{sl}) and its anisotropy (φ) play a critical role in understanding of nearly every single phenomenon that occur during solidification of metals, such as nucleation, morphological instability and dendrite growth. However, due to difficulties associated with both experimental measurement and computer simulations, our current understanding of this topic is rather limited. In this work, a simple analytical model is developed to predict γ_{sl} and φ for pure metals. This model suggests that S/L interface energy originates from atomic ordering templated by the crystal plane in the liquid adjacent to the crystal plane. Therefore, γ_{sl} can be expressed as the sum of contributions from both atomic layering (γ_z) and the in-plane atomic ordering (γ_{xy}). Further analysis shows that both γ_{sl} and φ for pure metals are determined by two key parameters; one is the solid fraction in the diffuinterface (f_s), and the other one is the heat of fusion per atom (ΔH_f^a). The analytical model reveals that the physical origin of γ_{sl} is solid atoms in the S/L interface templated by crystal plane while the physical origin of anisotropy is the difference in structural templating power between different crystal planes. It is demonstrated that the current analytical model is capable to predict solid/liquid interface energy (γ_{sl}) and its anisotropy (φ) for any metallic element using available parameters readily available in the literature.

B15

<u>Electromagnetic Control of Metal Solidification: From Fundamental Physics to Industrial Applications</u>

Qingwei Bai, University of Greenwich

Solidification is arguably the most fundamental process in materials processing, as most metals around us are formed through it. We have been dedicated to using electromagnetic fields to control the solidification microstructures, ensuring optimal material performance. In industry, this approach has delivered outstanding results in grain refinement, segregation reduction, orientation control, purification, and intermetallic optimization, establishing it as a low-carbon and highly promising innovative technology. However, from a physical perspective, a unified theoretical understanding for fully exploiting electromagnetic fields in solidification is still lacking, as the process involves complex, multiscale coupling among electrical-magnetic-mechanical-thermal-fluid-phase transformation-, spanning from primary crystals/dendrites (nm–μm) to final grains (mm–cm). Here, we are integrating cutting-edge technologies such as synchrotron radiation, advanced modeling, and AI with industrial experiments to elucidate the magnetohydrodynamic mechanisms governing metal solidification within a multiscale multiphysics framework, thereby enabling precise control of microstructure and properties in casting, welding, and additive manufacturing.

B16

Adaptation of a Spherical Neural Network Approach for Estimating the Solidification Time of Complex Geometries

Maximilian Erber, Technical University of Munich

Previously, assessing solidification of complex, arbitrary geometries was linked to the necessity of performing solidification simulations. In order to enable a rapid assessment during the design process or the structural optimisation of cast components, rapid modelling approaches are desirable.

Some initial approaches do exist to predict process parameters based solely on the casting geometry. This study evaluates the limitations of a previously proposed model using a spherical neural network, and introduces strategies and model adaptations to enhance the possibilities of this approach.

This new approach evaluates more complex geometries. Therefore, an automated routine is developed to simulate the solidification of arbitrary geometries taken from existing databases for mechanical parts. The existing model is then adopted to allow for more complex geometries with varying mould materials. The accuracy of the model is evaluated for unknown geometries and limitations of the model are critically evaluated.

Machine Learning and Big Data

B17

Data Acquisition for Data-Driven Mold Filling and Deviation Analysis in High Pressure Die Casting of AlSi10Mg

Rohit Randhavan, University of Augsburg

Die casting of aluminum structural components increasingly requires for process-chain level optimization of dimensional accuracy and robustness under uncertainty. This work presents a computational framework for optimization of die casting mold filling in which a physics-based fluid simulation is used to model turbulent mold filling of aluminum alloys, with focus on the evolution of the melt front and flow patterns in complex geometries To support inverse calibration and validation, a scaled die casting mold is equipped with a high-speed thermocouple array that provides spatially and temporally resolved data on the melt front progression and local heat transfer. Additionally, the mold is equipped with glass window which enables high speed imaging of mold filling. The combined simulation and experimental framework are designed to enable local, time-resolved inverse identification of boundary conditions and process parameters, forming the basis for integration into a full process-chain optimization.

B18

Integration of rapid process modelling into a digital twin of a wire arc additive manufacturing cell

Robin C. Laurence, University of Manchester

Due to high temperatures and temperature gradients during Wire arc additive manufacturing (WAAM), the large-scale industrial components manufactured can be subject to significant distortion and residual stresses. Prediction of residual stress and distortion through process modelling is therefore a common endeavour. The process models require information about the true manufacturing history to better represent the manufactured component. Here a digital twin of a WAAM cell is used to capture relevant data for populating process modelling of an example build, this includes deposition conditions and history with time stamped robot positions and laser scans of the build geometry after each pass. This history can be played back within a 3D virtual environment powered by Nvidia omniverse. The options for rapid process modelling which do not require full moving heat source calculations and their integration into the digital twin are explored including pass lumping finite element and the inherent strain method.

B19

Machine learning surrogates for phase field modelling of rapid solidification

Simon A. Savukoski, VTT Technical Research Centre of Finland

Phase-field (PF) models resolve microstructural solidification in metal additive manufacturing, but their high computational cost remains a bottleneck, particularly for high-throughput and 3D simulations. We use phase-field simulations of Al–Cu under additive-manufacturing-relevant thermal fields to train neural surrogates. As a baseline, an architecture based on a U-shaped convolutional network with attention bottleneck, learns to advance the phase and solute fields while emphasising the solid–liquid interface via wavelet-based weighing. In single-step forecasts, it achieves low relative L2 errors in pixel-wise and spectral metrics. However, errors accumulate in multi-step forecasts, and the deterministic model cannot represent the stochastic variability inherent to dendritic-cellular solidification patterning. Motivated by this, we introduce denoising diffusion and flow-matching models as surrogates. In addition to statistical microstructural metrics, performance is assessed via forward-time prediction speed-up relative to the PF simulator. Both stochastic models preserve key microstructural statistics satisfactorily across thermal conditions while delivering up to three orders of magnitude speed-up over the PF simulator.

B20

A strong form meshless method for through-process thermo-mechanical modelling of the steel production process

Gašper Vuga, Faculty of Mechanical Engineering, University of Ljubljana

The Radial Basis Function – Finite Differences (RBF-FD) method presents a novel strong-form meshless approach enabling modelling on arbitrary domains. While the RBF-FD method performs well for problems with smooth solution fields, it becomes unstable when sharp interfaces arise from geometric or material data. Such challenges commonly appear in elastoplasticity. To address this issue, we propose a hybrid RBF-FD formulation that combines RBF-FD with the classical FD method. It employs the FD method for evaluating the divergence operator acting on non-smooth stress fields. In addition to the novel Neumann boundary stabilisation technique, it provides a strong, robust and accurate approach to modelling elastoplasticity. The developed model is one-way coupled to the thermal diffusion model and applied as a travelling slice model to various stages of the thought-process steel production path. The model demonstrates its capabilities not only in benchmark tests but also in real industrial problems.

10th June 2026

07:30 to 09:00

Breakfast

Honoury Syposium for Christoph Beckermann 1
Chair: Jon Dantzig and Michel Rappaz

09:00 to 09:40

Advancing Solidification Science: The Legacy and Impact of Christoph Beckermann

Jon Dantzig, Charles-André Gandin, Michel Rappaz and Brian G. Thomas

09:40 to 10:00

Volume average modeling of alloy solidification and applications

Menghuai Wu, Montanuniversität Leoben

Christoph Beckermann, one of the pioneers of volume-average (VA) modeling of alloy solidification, introduced this method to the solidification community. The first part of my presentation provides an overview of his early work, focusing on the development of various VA models from the 1980s up to the turn of the last century.

The second part summarizes the key contributions of the Leoben group to the further development of VA models. Highlighted milestones include work on mixed columnar–equiaxed solidification, coupling dendritic morphology with convective melt flow and crystal sedimentation, modeling shrinkage cavity formation, and incorporating dendrite fragmentation.

The third part presents most recent application examples of VA models in engineering processes. On one hand, these models are used to study the formation of as-cast structures and macrosegregation, helping industry to optimize processes such as steel continuous casting with electromagnetic stirring, and vacuum arc remelting of titanium ingots. On the other hand, the models are applied to support the design of new casting processes, such as rotational mold casting of steel ingots and the development of digital twins for the unidirectional solidification of superalloy turbine blades.

10:00 to 10:20

Phase field as a front propagation method for modeling grain growth and texture evolution in additive manufacturing

Murali Uddagiri, Ruhr University Bochum

A mesoscopic grain-envelope model coupled with a phase-field front-propagation method is developed to simulate grain growth and texture evolution under additive manufacturing conditions. The envelope represents the outer surface of dendritic grains through a diffuse interface. A modified heat-conduction model that incorporates moving heat sources and latent-heat release provides the local thermal field. Envelope propagation is governed by the phase-field formulation, with the interface velocity supplied by a microscopic-solvability-based kinetic law derived from the local undercooling. The model is validated through two- and three-dimensional simulations and subsequently applied to examine the influence of material and process parameters on microstructure evolution. The results demonstrate that the proposed mesoscopic model offers an efficient and predictive approach for modeling grain growth and texture evolution in additive manufacturing.

10:20 to 10:50

Coffee Break

Honoury Syposium for Christoph Beckermann 2

Chair: Jon Dantzig and Michel Rappaz

10:50 to 11:10

Multi-Modal Investigation of Porosity in Aerospace In-vestment Casting: from Micrographs and CT-imaging via simulation to AI Models

Jürgen Jakumeit, Access e.V.

Microporosity in investment castings limits the mechanical properties and fatigue behaviour of critical parts such as turbine blades. To get a comprehen-sive understanding of the parameters influencing the porosity, a complex test bar assembly was analysed experimentally and by process simulation. 3D porosity distribution obtained by computer tomography (CT) were calibrated by high resolution micrographs and used for the validation of the porosity prediction from simulation by a quantitative spatial comparison. Beside the full simulation of the complex casting process a reduced simulation model was established to generate sufficient validate data for the training of AI-models. The results demonstrate that combining precise measurement, vali-dated simulation, and fast AI prediction enables a detailed understanding of how material properties, process parameters, and geometrical modifications influence defects such as microporosity. This approach further provides an AI-based tool for rapid optimization of casting processes aimed at reducing such defects.

11:10 to 11:30

Probabilistic Prediction of Local Mechanical Properties applied to High-Pressure Die Castings

Fengxin Mao, MAGMA Gießereitechnologie GmbH

Reliable prediction of mechanical properties in cast components is challenging due to process variability, complex microstructures, and the stochastic nature of defect formation. Conventional deterministic simulations provide single property values and cannot represent the expected local scatter in properties, limiting their applicability for design and process optimization. To overcome these limitations, a probabilistic methodology for predicting local mechanical property distributions in castings has been proposed. The approach builds on casting process simulations and enables statistical evaluation by incorporating the process variability through an expectation function. Local stress–strain curves are obtained from microstructure simulations, while simulated defects are evaluated and combined into a reduction function that modifies the local material behavior. The resulting stress–strain responses are statistically assessed for arbitrary component regions, allowing the determination of property distributions. The methodology is implemented in a development version of MAGMASOFT® and demonstrated for high-pressure die casting, with validation against experimental data.

11:30 to 11:50

Dendrite Growth behaviour under coupled fluid flow and structural mechanics

Peter Soar, University of Greenwich

During directional solidification the misorientation of dendrites is often identified as a potential causes of various unwanted microstructural features. However, the precise physical mechanisms driving this and how this impacts the transient morphological development of the dendrites remain under-explored and poorly understood. One phenomena often posited for this is the impact of fluid flow in the melt, such as could occur from solute buoyancy or magnetic stirring. This paper presents initial results from the coupling of existing solvers for dendritic solidification, fluid flow, and structural mechanics, allowing for a close examination of the transient morphological development of a dendrite under different conditions. This has served to highlight a potential mechanism where the preferential growth behaviour induced by fluid flow leads to a smaller misorientation than would be suggested by resolving structural mechanics independently

11:50 to 12:10

A Local Eutectic Growth (LEG) Map For Al-10Si-0.4Sc (Wt.%) Alloy"

Akankshya Sahoo, University of Alberta

Eutectic morphology affects the properties of Al-Si alloys, yet the kinetics controlling microstructures such as secondary phases and divorced eutectics in rapid solidification (RS) regimes remain unclear. This work introduces a Local Eutectic Growth (LEG) Map as a microstructure selection map for Al-10Si and Al-10Si-0.4Sc alloys. Using the Kurz-Trivedi solute trapping model, the LEG-Map uses the eutectic solidification rate (SR_eut= G_eut × V_eut) as a process-unifying metric for eutectic evolution. It shows synchronized Si and AlSc2Si2 morphological transitions: from flaky Si and AlSc2Si2 networks to fibrous Si and irregular AlSc2Si2 above 120 K/s, globular Si and compact AlSc2Si2 above ≥1450 K/s, and divorced Si and globular AlSc2Si2 above ≥36,000 K/s. These transitions coincide with morphological changes of the primary phases, such as cellular to dendritic growth or a growth direction transition from <100> to <320>. A Solidification Continuous Cooling Transformation was then developed to present the entire solidification path of the alloy.

12:10 to 13:40

Lunch

13:00 to 17:00

Stonehenge Trip

13:40 to 16:00

Bombay Sapphire Distillery, MRT Castings and Winchester Trip

18:00 to 19:00

Scientific Committee Meeting/Free Time

19:00 to 21:00

Dinner

11th June 2026

07:30 to 09:00

Breakfast

In Situ Experiments and Machine Learning 1

Chair: Natalia Shevchenko

09:00 to 09:20

Investigating the solidification of ‘dirty’ recycled aluminium alloys with X-ray imaging and artificial intelligence

Enzo Liotti, University of Oxford

As aluminium production increasingly relies on scrap, higher impurity levels—particularly Fe and Si—challenge the traditional concept of “clean metal.” In primary alloys, these impurities are commonly mitigated by adding neutralising elements such as Mn to promote compact α-AlFeSi intermetallic compounds (IMCs) instead of the more harmful, β-AlFeSi. However, these approaches relies on low Fe contents (~0.6 wt.%), leaving phase-selection mechanisms at the higher Fe levels, typical of recycled feedstocks, poorly understood. This study presents real-time observation of Fe-rich IMC nucleation, growth, and morphological evolution during solidification of recycled Al alloys containing up to 2.5 wt.% Fe. By quantifying the effects of thermal history and local chemistry, the work clarifies conditions favouring α- or β-AlFeSi formation and links these transitions to feeding behaviour and hot-tear susceptibility, providing guidance for alloy and process design that supports increased scrap utilisation while limiting defects.

09:20 to 09:40

Solidification and fluid flow model validation using in-situ proton radiography (pRad) imaging

Nadira E. Surghani, Lawrence Livermore National Laboratory

Experimental validation is essential to the use and development of modeling/simulations to establish predictive capability for manufacturing processes. Here we demonstrate the use of 800 MeV proton radiography (pRad) to image the dynamics of casting mold filling and solidification of a 50 wt.% Sn-Bi alloy gravity die casting (GDC) for the first time, along with a complementary computational fluid dynamics (CFD) simulation informed by instrumented thermocouples and ex-situ microstructure analysis. Fluid flow was well replicated when using 104 − 105 W m-2 K-1 metal-mold heat transfer coefficients, which exceed values typically used for casting simulations of this type. In addition to fluid flow, the model can adequately track temperature evolutions in the mold which was confirmed using instrumented thermocouple data. The exponential relationship between secondary dendrite arm spacings (SDAS) and solidification velocity was used to evaluate the solidification model predictions; the model had good agreement with empirical models. These novel experiments combined with modeling/simulation enable the prediction and control of casting quality and advanced manufacturing of high-density metallic alloys.

09:40 to 10:00

Multi-scale in situ experiment/simulation integration to predict rapid solidification microstructures in additively manufactured AlCu

Tatu Pinomaa, VTT Technical Research Centre of Finland

Rapid solidification (RS) in laser powder-bed fusion enables alloy design by confining chemical and microstructural heterogeneities to individual melt pools, producing statistically repeated local variations. RS can refine grains, extend solid solubility, and stabilize non-equilibrium microstructures, improving strength and corrosion resistance. Realizing these benefits requires predictive modeling that links melt-pool thermodynamics to microstructure selection. Here, we couple computational fluid dynamics (CFD) for melt-pool behavior with phase-field (PF) simulations for microstructural evolution, and address three key challenges: (1) experimental calibration and validation of melt-pool temperature fields and resulting microstructures, (2) improving the representation of temperature distributions used in PF simulations, and (3) quantifying the local distribution of solidification conditions to guide processing toward targeted microstructures. Synchrotron X-ray imaging and dynamic transmission electron microscopy validate simulations in pure Al and Al–Cu. The resulting framework integrates experiments and multiphysics modeling to connect processing parameters with solidification mechanisms and microstructure selection, supporting RS-driven alloy and process design.

10:00 to 10:20

Directional melting dynamics of the irregular Al-Al3Ni eutectic

Rajesh Kumari Rajendran, CNRS- SU-INSP

The fast development of additive manufacturing techniques motivates in-depth studies of the melting of multiphase materials. For this purpose, in situ experiments using real-time observation of the melting front are necessary. We present an experimental investigation of the directional melting dynamics of the Al-Al3Ni eutectic in thin samples. Two different setups, namely, a visible-light microscopy system, and a nano x-ray radiography apparatus using synchrotron radiation, were used, which provide real-time images of the melting front over different spatial and time scales. As a reference, in a nonfaceted eutectic system, the steady-state melting dynamics of a regular two-phase microstructure is essentially governed by the chemical diffusion in the liquid. In a faceted/nonfaceted eutectic, solidification microstructures are commonly irregularly spaced, and strongly anisotropic. This opens the question of how far an irregular spacing imposed by the previous solidification, and the interfacial anisotropy of the faceted solid influence the eutectic melting dynamics.

10:20 to 10:50

Coffee Break

In Situ Experiments and Machine Learning 2
Chair: Andre Phillion

10:50 to 11:10

Synchrotron-Based High-Resolution Imaging of the Ternary Ga–In–Bi Alloy

Natalia Shevchenko, Helmholtz-Zentrum Dresden-Rossendorf

Previous studies [Shevchenko et al., Acta Materialia, 2025] on the solidification of a low-melting-point ternary Ga–In–Bi alloy using laboratory-based microfocus X-ray radiography have shown that the combined effect of bismuth addition (2.5 wt%) and fluid flow strongly influences dendritic morphology. In contrast to the Ga–In binary system, dendrites in the ternary alloy exhibit pronounced curvature, tip splitting, and the development of branched or seaweed-like patterns. These morphological changes, caused by bismuth, are attributed to a reduction of the anisotropy of the solid–liquid interfacial properties making the interface more susceptible to convection-driven perturbations.

To further elucidate the interplay between flow and microstructure, synchrotron radiography experiments were performed at the ID19 beamline (ESRF). This technique provides high-resolution (< 1 µm), low-noise two-dimensional imaging, enabling direct in situ observation of transitions between stable dendritic growth and branched growth regimes. Quantitative measurements of dendrite tip shape, local morphology, growth velocity, and branching dynamics under systematically varied solidification conditions are obtained. This experimental platform combines a model alloy system with advanced imaging capabilities, providing insights into the mechanisms of morphological instabilities and enabling benchmarking for future simulations and high-temperature alloy studies.

11:10 to 11:30

In situ experiments for quantitative validation of core physics during external field assisted additive manufacturing processes

Harry E. Chapman, University College London

Additive Manufacturing (AM) processes involve rapid non-equilibrium solidification governed by complex phenomena. This makes in situ synchrotron techniques key to unpicking the mechanisms involved, especially when external fields such as ultrasound and magnetic fields, are applied. In situ synchrotron techniques have inherent limitations, such as radiography's 3D-to-2D nature, poor density contrast, and diffraction's limited temporal and spatial resolution. Coupling in situ observations with multi-physics simulations can bridge these limitations and mutually validate methods. Despite the advantages of coupling, correctly identifying the essential physics to be incorporated in process modelling can be challenging. We've designed simplified in situ experiments to help determine the key physics, enabling quantitative bridging of the gap to the full AM manufacture of complex components. In this work, we present two cases where simplified in situ studies helped isolate, identify and quantitatively validate key physics and providing gold standard experiments for model validation.

11:30 to 11:50

Interface Energy Anisotropy in Hexagonal Alloys Revealed by Time-Resolved In-Situ Tomography

Hideyuki Yasuda, Kyoto University

Anisotropy in the solid–liquid interface energy governs the preferred growth directions of dendrites and, consequently, the resulting solidification microstructure through dendrite competition. However, direct measurement of the interface energy and its anisotropy remains extremely challenging, as no experimental technique has yet been established. In addition, determining the preferred growth directions solely from post-solidification microstructures is difficult. By contrast, time-resolved in-situ tomography (4D-CT) combined with X-ray diffractometry at a synchrotron radiation facility (SPring-8) enables direct observation of dendrite arm development at the early stages of solidification, where interactions among dendrite arms are still limited. For example, in Mg–Zn alloys, dendrite arms preferentially grow along directions normal to the $\{11\bar{2}0\}$ and $\{11\bar{2}4\}$ planes, whereas no growth is observed along the normal direction of the {0001} plane. Ti–Al alloys exhibit similar growth behavior. Based on these observed growth directions, the anisotropy of the interface energy is discussed, providing useful input for modeling and simulation of solidification microstructures in hexagonal alloy systems such as Mg–Zn, Zn–Al, and Ti–Al.

11:50 to 12:10

Development of 4D tomographic observation of grain motion and microstructure evolution during semisolid deformation using synchrotron radiation X-rays

Taka Narumi, The University of Tokyo

Deformation of semisolid alloys frequently occurs during casting, leading to defects such as macrosegregation and cracking. To accurately predict defect formation, physical models of semisolid deformation must be validated and further developed using quantitative experimental data. This study presents observations of semisolid deformation in Al–Cu alloys using time-resolved X-ray computed tomography (4D-CT). The results show that non-uniform deformation develops at solid fractions exceeding 0.8 due to mechanical interactions between discrete solid grains. The deformation stress initially increases, then decreases, and finally converges to a steady value as compression proceeds. The peak stress corresponds to the onset of deformation localization associated with grain contact and rearrangement. The maximum stress is approximately one-tenth of the steady-state stress of the fully solid phase at the same temperature. These observations provide direct experimental evidence linking grain-scale microstructure evolution to macroscopic stress response, supporting the validation and development of physical models for semisolid deformation.

12:10 to 12:30

Exploring the Forest – Computer Vision and Image Processing Applied to In-situ Competitive Dendritic Growth Video Sequences

Shaun McFadden, Ulster University

In-situ directional solidification experiments were performed with transparent alloy Neopentyl Glycol-35 wt% (D)Camphor (NPG-35wt.%DC). Several experiments were conducted using two temperature gradients (23 and 16 K/cm) and three cooling rates (0.16, 0.30 and 0.45 K/min). Sequences showed multiple dendrites (a forest) competing and growing upwards. Video data were analyzed using bespoke digital methods to extract growth information including tip locations, growth rates, and directions. This information was then used to (1) graphically augment the video sequences with dendrite velocity vectors and (2) generate macrostructure images by cropping and concatenating image slices of the observable mushy zone. In some cases, it was observed that the classic Walton-Chalmers rule of preferential competitive growth was not always observed due to the unique crystallography of the NPG-35wt.%DC dendrites with <111> secondary arm orientation. The augmentation of the dendritic forest video sequences with tip velocity vectors greatly improved the observation of growth patterns and, when combined with thermocouple data, was used to compare with theoretical growth models (LGK and Cantor-Vogel). Across all sequences, 385 dendrites were tracked and quantified via computer vision, hence, increasing the sample numbers for improved statistical interpretation. Such analysis would be impractical to perform manually; thus, highlighting the value of the methods developed.

12:30 to 14:00

Lunch

Casting and other process models
Chair: Catherine Tonry

14:00 to 14:40

The History of Bell Casting and the Whitechapel Bell Foundry

Alan Hughes, Whitechapel Bell Foundry

14:40 to 15:00

Microstructure evolution of peritectic Cu-24%Sn alloy during stationary melting under a thermal gradient: insights from experiments and phase-field simulations

Mehdi Medjkoune, Université de Lorraine, CNRS, IJL

Melting exhibits unique and complex behaviors, far from being a simple reverse process of solidification. Recent phase-field simulations have highlighted key phenomena such as Temperature Gradient Zone Melting (TGZM) and Liquid Film Migration (LFM), which provide insights into steady-state configurations and solute dynamics at trijunctions. To experimentally validate these findings, we focus on melting dynamics and microstructural evolution in multiphase peritectic alloys, aiming to understand pattern formation and microstructure selection during melting and melting/solidification processes. We investigate the directional melting of Cu–Sn peritectic alloys under imposed thermal gradients. Bulk samples are maintained at fixed gradients to quantify the migration velocity of the mushy zone (Properitectic phase Cu+ Liquid) and its dependence on the thermal gradient. Ex situ SEM, EBSD and EDX measurements provide quantitative access to phase fractions and solute redistribution. Depending on the gradient intensity, either a progressive melting or a thickening of the pro-peritectic phase is observed. These results are complemented by ex situ X-ray tomography revealing the three-dimensional morphology of the evolving microstructure and are quantitatively compared with phase-field simulations.

15:00 to 15:20

Modelling the Effect of Bulging Driven Fluid Flow on Centerline Segregation in Steel Continuous Casting

Araf Al Rafi, McMaster University

Deformation of the solidifying shell between support rolls, also referred to as bulging, is widely considered a major contributor to centerline segregation in steel continuous casting. This work presents a simplified yet industrially realistic two-dimensional finite volume model, coupled to the external heat transfer model CON1D, to simulate how bulging influences macroscale fluid flow in the mushy zone and promotes centerline segregation. Applied to the full roll configuration of the CC22 caster at Tata Steel IJmuiden, the model predicts periodic shell deflection and the associated interdendritic flow field. Results show that bulging generates a transverse flow that transports solute-enriched liquid toward the slab centerline, producing a pronounced segregation peak consistent with industrial observations. Implemented entirely in C++, the model computes the flow field within minutes, making it an efficient tool for parametric studies under industrial casting conditions.

15:20 to 15:40

Coffee Break

Casting and other process models

Chair: Koulis Pericleous

15:40 to 16:00

Industrial-Scale Validation of a CFD Model for Ingot Casting Using the Rotating Casting Mold Technique

Christian Gomes Rodrigues, Montanuniversität Leoben

A physics-based volume-average model was developed to compare casting quality between conventional ingot casting and the Rotating Casting Mold (RCM) technique. The model couples multiphase fluid dynamics, solidification kinetics, fragmentation, and rotational forces (Euler, Coriolis, and centrifugal). Following successful laboratory-scale validation, this work extends the model to industrial-scale RCM applications.

Two industrial-scale steel ingots, each weighing 21 tons, were cast and sectioned—one with RCM and one without. These experiments provided essential input and validation data, including casting geometry, process parameters, molten steel composition, time-resolved temperature measurements, and final microstructure and macrosegregation analysis of as-cast samples. Comparison between simulations and experiments showed strong agreement, confirming the model's predictive capability in real-world conditions.

The simulation results highlighted the influence of mold rotation on flow patterns, grain structure, and defect formation. The validated model will serve as a tool to guide and optimize industrial RCM operations, by selecting appropriate rotation schemes and other process parameters to minimize casting defects and improve product quality.

16:00 to 16:20

The integration of multi-scale process modelling with virtual commissioning of Aluminium billet DC-casting equipment

Qiang Du, SINTEF Industry

In a previous industry innovation project, it has been demonstrated that a digital replica of the physical casting process can be established with high throughput micro-macro scale computation, SQL database and an artificial neural network (ANN). The digital replica is able to efficiently predict sump depth and hot-tearing tendency in the center of billets for a range of industrial AA6xxx alloy composition, casting parameters including casting speed and casting temperature. In this work, we assess the possibility of integrating the established digital twin with virtual commissioning of Aluminum billet DC-casting equipment. The high performance computing facility, Idun, offered by Norwegian University of Technology, is used to enable the massive simulations to cover the whole potential processing parameter window. SQL database is used to provide the meta descriptions of the simulation results, and artificial intelligence is used to parameterize and analyze the simulation results. It is expected that this work will improve the reliability of virtual commissioning.

16:20 to 16:40

Towards an Intelligent Continuous Caster Mould: Unifying Full-Scale Water Modelling and CFD

Ali Asgarian, University of Toronto

Advancing continuous caster mould technology requires real-time insight into flow behavior, and argon bubble dynamics within the mould, conditions that are inaccessible in operating steel plants. This work presents a framework for developing an intelligent continuous casting mould by integrating full-scale water modelling, sensor-driven data analytics, and high-fidelity CFD simulations. A geometrically accurate, full-scale water model replicates mould hydrodynamics, enabling visualization and controlled investigation of meniscus fluctuations, jet impingement behaviour, and bubble dynamics under variable casting conditions. A complementary CFD model captures three-dimensional transient flow, and multiphase phenomena, providing physics-based interpretation of experimental observations and predictive capability across a broader parameter space. By fusing calibrated CFD outputs with data extracted from the water model and plant-representative sensors, this research aims to establish a validated digital twin that can support adaptive control strategies. The resulting intelligent mould architecture provides a pathway toward improved quality, and fully data-enabled steel casting operations.

16:40 to 17:00

Melt-flow-induced loading on multilayer sand cores in high-pressure die casting

Erwin Reberger, Technical University of Munich

The use of sand cores in high-pressure die casting (HPDC) remains limited due to the conflicting requirements of high mechanical strength during cavity filling and mechanical decoring after casting. Recently, multilayered inorganic sand cores have been proposed to address this challenge by combining an outer shell with increased binder content to enhance load-bearing capacity during filling and an inner core with reduced binder content to facilitate vibration-based decoring. However, the mechanical loading of such cores during HPDC are not yet quantitatively validated. In this work, a fluid–structure modelling framework is presented to assess melt-flow-induced loading on sand cores under realistic HPDC conditions. Melt filling is simulated for different runner system designs and plunger velocities, yielding time-resolved pressure fields on the core surface. These pressure fields are transferred to a finite-element model of the multilayered sand core as spatially distributed surface loads. Simulated strain responses are compared with in-situ strain gauge measurements from casting trials, enabling validation of the load transfer and identification of critical loading regimes. By quantifying the mechanically admissible core loading during cavity filling, the approach enables consistent solidification simulations in the presence of sand cores. Therefore, this study also provides a reference for assessing deviations in solidification behaviour compared to core-free configurations.

17:00 to 17:40

Exploring Plasma Transferred Arc Processing for Metallic Glass Claddings

Paschal A. Ubi, Cranfield University

Bulk metallic glasses (BMGs) offer exceptional hardness, wear resistance, and corrosion performance, and these unique properties have increasingly motivated efforts to explore scalable processing routes. Cladding BMGs onto structural substrates provides an attractive pathway to exploit their functional advantages while overcoming the constraints of size and scalability limitations of bulk BMG processing routes; however, there is not much previous research reported in this domain. This study investigates the feasibility of producing Fe-based metallic glass claddings using plasma transferred arc (PTA) processing, an industrially mature technique characterised by high deposition rates, robust process stability, good control of dilution and lower capital investment compared to laser systems. The findings highlight PTA cladding as a promising and scalable route for integrating metallic glass functionality into conventional engineering components.

18:00 to 18:30

Bus to Conference Dinner Venue

18:30 to 22:00

Conference Dinner

22:00 to 22:30

Bus to hotel

12th June 2026

07:30 to 09:00

Breakfast

Additive Manufacturing and Welding 1
Chair: Peter Lee

09:00 to 09:40

Toward full-scale melt pool dynamics simulation and scan-strategy-based microstructure prediction in laser powder bed fusion

Tomahiro Takaki, Kyoto Institute of Technology

The ultimate objective of this study is to fully reproduce melt pool dynamics in the laser powder bed fusion (LPBF) process through very large-scale, high-fidelity simulations. Building upon these results, we aim to enable accurate prediction of polycrystalline microstructure evolution under various scanning strategies. To achieve these objectives, we are currently developing three core technologies. The first element is a phase-field lattice Boltzmann method that resolves melt pool thermal–fluid dynamics with high spatial and temporal resolution. This approach captures key phenomena such as Marangoni convection and keyhole formation, while reproducing realistic melt pool morphologies over a wide range of laser powers, scanning speeds, and powder-bed conditions. The second element is a multi-phase-field model designed to describe competitive growth among dendrites and cellular structures under rapid solidification conditions. The integration of the first and second elements enables full-scale melt pool dynamics simulations that consistently couple thermal–fluid flow with microstructural solidification, thereby revealing the intrinsic grain growth competition governed by the evolving thermal–fluid field. These simulations are accelerated using adaptive mesh refinement implemented on a GPU supercomputer. The third element focuses on predicting polycrystalline microstructure under diverse scanning strategies using a coarse-grained multi-phase-field model. To enhance computational efficiency, the simulation domain is confined to the vicinity of the melt pool, with crystalline anisotropy determined from the full-scale melt pool simulations. Upon completion, this framework will establish a robust foundation for microstructure design and process optimization in LPBF, encompassing phenomena from melt pool dynamics to scan-strategy-dependent microstructure evolution.

09:40 to 10:00

Multiscale modelling of additive manufacturing microstructures

Tatu Pinomaa, VTT Technical Research Centre of Finland

Refractory metals and alloys have outstanding high temperature properties, resulting in many potential use cases, for example as plasma facing materials in fusion reactors. We showcase a multiscale simulation approach to simulate solidification microstructures of these materials under various additive manufacturing processing conditions where non-equilibrium effects can occur.

Our framework consists of three separate pieces. First, molecular dynamics simulations are used to obtain anisotropic interface energies and kinetic coefficients which are used as inputs in the phase field model. Secondly, computational fluid dynamics simulations are used separately for the modelling of melt pool dynamics, from which a distribution of representative thermal gradients and solidification velocities are obtained.

Thirdly, all these properties are used together with large-scale solidification phase field simulations to predict solidification microstructures under different processing conditions and sections of the melt pool. The simulation results are finally compared and validated with experimental single scan tracks.

10:00 to 10:20

On the micromechanics of nanoscale solidification void formation during 3D printing of a nickel-based superalloy

Hector C. Basoalto, University of Sheffield

Solidification-induced void and lack-of-fusion defects arising during 3D printing can lead to process-induced cracking. This study investigates the micromechanical mechanisms governing nanoscale void formation during selective laser melting (SLM) of a difficult to print γ′-precipitate-strengthened nickel-based superalloy.

A multiscale modelling framework is developed to capture the relevant physical phenomena across multiple length and time scales. Melt-pool dynamics and associated multiphase flow behavior are simulated using a volume-of-fluid (VOF) approach, accounting for solid–liquid–vapour phase transitions. Solidification microstructures such as cellular and dendritic morphologies are simulated using a phase field model coupled to a crystal plasticity framework. Conditions leading to nanoscale void nucleation are derived which are supported by experimental observations.

10:20 to 10:50

Coffee Break

Additive Manufacturing and Welding 2
Chair: Hector C. Basoalto

10:50 to 11:10

Correlation between Solidification Microstructure and Thermal Flow of the Molten Pool in Laser Additive Manufacturing

Qiang Zhu, Southern University of Science and Technology

Laser additive manufacturing uses a high energy density laser beam as a heat source, to melt an alloy powder and then solidify quickly. Molten pool is the most basic unit and solidification behavior is directly affected by thermal conditions at solidification interface and flow behavior in molten pool. Models were established to describe solidification behavior and modelling results were verified by comparing experimental observations. Characteristics of Columnar to Equiaxed grain Transition in the high solidification rates were revealed. Once temperature gradient exceeds a threshold value, epitaxial growth is main mechanism regardless of solidification rate variation. The established model was also coupled with alloy phase diagram to study mechanism of mass transfer and heat transfer in molten pool during in-situ alloying. Melt flow dominates mass transfer behavior of an in situ alloying molten pool. Finally, a process parameter map guiding the design of process parameters of the in-situ alloying was obtained.

11:10 to 11:30

Exploiting Electromagnetic Forces for Improved Control of Melt Flow in Metal Additive Manufacturing

Imants Kaldre, University of Latvia

Metal additive manufacturing faces various problems which can be addressed by improving molten metal control. Exploitation of electromagnetic forces is one of the perspective approaches for better heat and mass transfer in melt pool. During AM process thermal gradients can reach extremely high values, which for some materials can create thermoelectric currents. This current in combination with external magnetic field can create significant melt flow which is called thermoelectromagnetic convection (TEMC).

In this work we present series of experiments dedicated to exploration of the TEMC. We used cobalt/GaInSn scale model to experimentally investigate flows with various magnetic field strength and orientations. Experiments are compared with numerical simulations and analytical scaling analysis aiming to predict these processes in realistic AM situation. Results demonstrate that if the symmetry is broken, the flow in the melt pool deforms. Results also show that applied external electric current can be used to enhance or cancel TEMC flow.

11:30 to 11:50

Cellular Automaton Simulation of Grain Refinement in LPBF of Al–10Si: Influence of Laser Rescanning Parameters and Scanning Strategies

Kai Kang, McMaster University

A three-dimensional sequentially coupled heat-transfer–Cellular Automaton model is used to investigate grain structure evolution during LPBF with laser rescanning (LPBF-LR) of Al–10Si. Starting from a fixed first scan (130 W, 0.2 m/s), we systematically vary (i) rescanning power and speed, (ii) scanning strategies, (iii) scanning length with alternating reversal, and (iv) rescanning rotations to evaluate their effects on microstructure. Grain geometry is quantified using Principal Component Analysis, and texture is assessed through simulated pole figures. Reduced power and higher speed promote grain refinement by shallowing the melt pool and modifying the local thermal conditions (G/v and cooling rate). Among the strategies, an island-type pattern produces the strongest refinement due to localized reheating and overlapping melt pools, which expand equiaxed zones. Rotation angle has minimal influence on grain size in single-layer LR but systematically rotates the dominant <100> texture, indicating a potential route for texture homogenization in multi-layer builds.

11:50 to 12:10

Multiple physical fields of laser powder bed fusion of nickel-based superalloys.

Neng Ren, Shanghai Jiao Tong University

Multiple physical fields in the laser powder bed fusion of nickel-based superalloys, including temperature field, flow pattern, solute distribution, are of great importance to estimate the properties and performances of the built parts. At the macro scale, a thermal-fluid-solute model is developed to real the evolution of these multiple fields. At the microstructural scale, solute transport leads to non-equilibrium, non-uniform microstructure remains to be studied. Here, fully-coupled fluid dynamics and microstructure simulations at the multiple scales are developed to rationalise the dynamic solute transport process and elemental segregation, and to gain better understanding of nonequilibrium nature of intercellular solute segregation and cellular structures at sub-grain scale during the melting-solidification of the laser powder bed fusion process. It reveals the solute transport induced by melt convection dilutes the partitioned solute at the solidification front and promotes solute trapping, and elucidates the mechanisms of the subsequent microstructural morphology transitions.

12:10 to 12:30

Coupling ultrasound and adjustable ring mode beam shaping during laser welding of AA6063 extrusions alloy.

Philip Carr, Carrs Welding

The 6xxx series aluminum alloys are vital for modern lightweight battery designs; however, their weldability is traditionally compromised by steep thermal gradients and rapid cooling, and results in solidification cracks and high porosity[PC4.1]. This study investigates the coupling effects of Adjustable Ring Mode (ARM) beam shaping and contact-based ultrasound (20 kHz and 40 kHz) on the weldability of the extruded AA6063. Results indicate that the 20 kHz frequency ultrasound (US20) significantly reduces area % of porosity from 11.26 % (core only) to 1.2 % through cavitation driven degassing. Further, the core-ring ARM beam shape enhances ultimate tensile strength by 34.6% relative to core-only beam (baseline) by lowering thermal gradients and reduced microcracks. However, while the 40 kHz frequency ultrasound (US40) achieves a higher equiaxed grain fraction of ~ 80% of fusion zone, it destabilizes the melt pool and introduces microcracks, leading to a 60.9% reduction in tensile strength compared to baseline. The higher weld quality was achieved by coupling US20 with the ARM beam shape, which balances microstructural refinement to 42.6 % along with ~34% tensile strength improvement. This research establishes a critical coupling window where controlled acoustic field can compliment beam shaping to ensure high quality joints for battery packs.

12:30 to 12:40

Conference Closing Ceremony

Andrew Kao and Catherine Tonry, University of Greenwich

12:40 to 14:00

Lunch (Packed Lunch available for those who need to leave early)

14:00

Last Shuttle Bus Departs