Day 1, Jun 23, 2024

02:00PM - 05:00PM	***Pre-Registration/ Reception***

Day 2, Jun 24, 2024

08:00AM - 08:15AM

GLC 236

Opening Ceremony

08:20AM - 09:00AM

GLC 236

Keynote Speaker - Day 1

09:00AM - 09:20AM

Break - 20 mins

09:20AM - 11:50AM

Corrosion, Surface Treatments and Environmentally Sensitive Fracture

GLC 225

How solute atoms control aqueous corrosion of Al-alloys

09:20AM - 09:45AM

Presented by:

Huan Zhao, Xi'an Jiaotong University

Co-authors :

Yue Yin, Max-Planck-Institut Für Eisenforschung

Yuxiang Wu, Max-Planck-Institut Für Eisenforschung

Siyuan Zhang, Max-Planck-Institut Für Eisenforschung

Andrea Mingers, Max-Planck-Institut Für Eisenforschung

Dirk Ponge, Max-Planck-Institut Für Eisenforschung

Baptiste Gault, Max-Planck-Institut Für Eisenforschung

Michael Rohwerder, Max-Planck-Institut Für Eisenforschung

Dierk Raabe, Max-Planck-Institut Für Eisenforschung

Aluminum alloys play an important role in circular metallurgy due to their good recyclability and 95% energy gain when made from scrap. Their low density and high strength translate linearly to lower greenhouse gas emissions in transportation, and their excellent corrosion resistance enhances product longevity. The durability of Al alloys stems from the dense barrier oxide film strongly bonded to the surface, preventing further degradation. However, despite decades of research, the individual elemental reactions and their influence on the nanoscale characteristics of the oxide film during corrosion in multicomponent Al alloys remain unresolved questions. Here, we build up a direct correlation between the near-atomistic picture of the corrosion oxide film and the solute reactivity in the aqueous corrosion of a high-strength Al-Zn-Mg-Cu alloy. We reveal the formation of nanocrystalline Al oxide and highlight the solute partitioning between the oxide and the matrix and segregation to the internal interface. The sharp decrease in partitioning content of Mg in the peak-aged alloy emphasizes the impact of heat treatment on the oxide stability and corrosion kinetics. Through H isotopic labelling with deuterium, we provide direct evidence that the oxide acts as a trap for this element, pointing at the essential role of the Al oxide might act as a kinetic barrier in preventing H embrittlement. Our findings advance the mechanistic understanding of further improving the stability of Al oxide, guiding the design of corrosion-resistant alloys for potential applications.

Optimizing Corrosion Performance of Additively Manufactured 7050-based High Strength Aluminum Alloy

09:45AM - 10:10AM

Presented by:

Rupesh Rajendran, Georgia Tech

Co-authors :

Preet Singh, Professor, Georgia Institute Of Technology

High strength 7xxx aluminum alloys offer high strength to weight ratio which makes them promising candidates for the aerospace and automotive industry. Additive manufacturing (AM) of high strength aluminum alloys can provide more design freedom, improve supply chain efficiencies and can create parts with less material wastage. However, the AM process with extremely high solidification rates, like for laser powder bed fusion (LPBF) can lead to hot tearing and solidification defects associated with their columnar microstructure. Recently, processes were developed to use inoculation process, either by addition of nanoparticles or by using in-situ reactive constituents, to promote equiaxed grain growth and mitigate the defects while improving printability. However, use of inoculants also makes the resulting microstructure complex and unique, compared to the traditional wrought alloys. This study investigates the influence of aging duration on the corrosion behavior of a LPBF 7050-based alloy. The overall goal is to get a balance of high corrosion resistance while reducing the process windows.

Machine Learning Driven Corrosion Resistant AA6XXX Alloy Design

10:10AM - 10:35AM

Presented by:

Shanshan Wang, Senior Scientist, Novelis Inc

Co-authors :

Fatih Sen, Speaker, Novelis

Heath Murphy

Sazol Das, Product And Process Innovation Lead For Advanced Technologies, Novelis Global Research & Technology Center

Aurele Mariaux

Yudie Yuan, Principal Scientist, Novelis Inc.

6XXX aluminum alloys have been widely used in automobile applications, due to their superior combinations of properties including strength-to-weight ratio, formability, and weldability. However, Cu-containing 6XXX alloys have shown susceptibility to intergranular corrosion (IGC) given certain alloy chemistry and thermomechanical processing. Here, a series of 6XXX alloys has been designed for various automotive applications including structural, outer/inner panels, high recyclability, and high formability, using machine learning models trained on historical data including strength, elongation, bendability, and corrosion. The modelling results show that Cr addition has tendency to improve corrosion resistance. These alloys were manufactured through DC casting, homogenization, hot and cold rolling, solution heat treatment, and artificial aging. We found that Cr addition improved the IGC resistance of both low- and high-Cu-containing 6XXX alloys, which is consistent with modeling prediction. Transmission electron microscopy analysis shows that fine and close-spaced Q phases precipitated at the grain boundaries in a Cu-containing alloy without Cr addition. However, Cr-containing dispersoids formed within the grain and at the grain boundaries in a Cr- and Cu-containing alloy, whereas less Q phase at grain boundaries were observed. In short, Cr addition promoted the formation of the dispersoids and modified grain boundary microstructure, and thus improved IGC resistance.

Filiform Corrosion Behavior of Painted AA7075 sheet

10:35AM - 11:00AM

Presented by:

Xiaorong Zhou, Professor , The University Of Manchester

In the present study, the filiform corrosion behavior of painted AA7075 aluminium alloy sheet was investigated. The filiform corrosion behavior of painted AA7075 aluminium alloy is different from the typical filiform corrosion and is driven by under-paint localized corrosion, i.e. crystallographic pitting and/or intergranular corrosion, depending on the thermomechanical history of the alloy. In addition, the filiform corrosion resistance of painted AA7075 aluminium alloy is significantly influenced by surface pretreatment, with the zinc phosphating treatment providing better performance.

Effect of Copper in Aluminum Alloy and in Pre-treatment Solution on the Filiform Corrosion

11:00AM - 11:25AM

Presented by:

Jichao Li, Surface Treatment And Corrosion, Constellium

Co-authors :

Niamh Hosking, Ford Motor Company

Sabrina Peczonczyk, Ford Motor Company

Daniel Freiberg, Ford Motor Company

Elizabeth Brown-Tseng, PPG

Mark McMillen, PPG

In this work, we undertook a systematic exploration of the interaction effects of the alloy microstructure and pre-treatment conditions on the filiform corrosion performance by analysis of a single AA6111 substrate with controlled variations in thermal treatments, cleaning conditions, and pre-treatment parameters. A combination of surface analysis and electrochemical techniques was used to characterize the alloy surface condition at each stage of the pre-treatment process. A clear dependence of filiform corrosion resistance under cyclic corrosion conditions on the thermal history (i.e., microstructure) of the AA6111 alloy was established. Specifically, a strong influence of the temper, T4 versus T82, was observed, with higher corrosion activity measured for the former. Cleaning time and Cu2+ ion additions to the pre-treatment bath also had a significant impact on the coated panel corrosion resistance, although these effects were minimized when the substrate was in the T82 condition. The efficacy of thin-film pre-treatments in the filiform corrosion performance of automotive panels depends on the system interactions between the pre-treatment and the substrate microstructure, and not on cleaning and pre-treatment parameters alone.

Effect of wire drawing and heat treatment on the exfoliation corrosion mechanism of Al-Zn-Mg-Zr-V wires

11:25AM - 11:50AM

Presented by:
Christoph Altenbach, Postoctoral Researcher, German Aerospace Center, Institute Of Materials Physics In Space

Co-authors :
René Pütz
Tizia Weidemann
Alexander Schupp
Sonja Steinbach
Daniela Zander

To ensure the use of 7000 series for safety-relevant applications in automobiles, such as screws, a comprehensive understanding of their exfoliation corrosion (EFC) behavior is requested. The EFC behavior of Cu-free Al-Zn-Mg-Zr-V wires in solution annealed (T4), peak-aged (T6) and overaged (T7) state is investigated by EXCO immersion tests combined with (quasi) in situ measurements of the dissolved species using inductively coupled plasma mass spectrometry (ICP-MS) and electrochemical impedance spectroscopy (EIS). Supplemented ex-situ investigations of the EFC progress are performed using X-ray computed tomography. The EFC behavior is linked to microstructural features that are investigated using i.a. scanning (transmission) electron microscopy (SEM/STEM) coupled with energy dispersive X-ray spectroscopy (EDS) and electron backscatter diffraction (EBSD). Wire drawing and heat treatment have a significant effect on the microstructure, the EFC susceptibility and the corresponding EFC mechanism. EFC susceptibility decreases from T4 to T7 state and is less pronounced in the wire core compared to the rim zone, while in T7 it is the opposite. Dependent on heat treatment and related microstructure, the corrosion mechanism changes from intergranular corrosion (T4) to pitting (T7). Quasi in situ measurements of the electrolyte species are linked to the corrosion mechanisms.

09:20AM - 04:10PM

GLC 233

New directions in alloy and process design (Including Artificial Intelligence and Machine Learning)

Accelerated development of materials using high-throughput strategies and AI/ML

09:20AM - 09:45AM

Presented by:

Surya Kalidindi, Speaker, Georgia Tech

The dramatic acceleration of the materials innovation cycles is contingent on the development and implementation of high throughput strategies in both experimentation and physics-based simulations, and their seamless integration using the emergent AI/ML (artificial intelligence/machine learning) toolsets. This talk presents recent advances made in the presenter's research group, including: (i) a novel information gain-driven Bayesian ML framework that identifies the next best step in materials innovation (i.e., the next experiment and/or physics-based simulation to be performed) that maximizes the expected information gain towards a specified target (e.g., optimized combination of material properties, refinement of a material constitutive response), (ii) computationally efficient versatile material structure analyses and statistical quantification tools, (iii) formulation of reduced-order process-structure-property models that enable comprehensive inverse solutions needed in materials design (e.g., identifying specific compositions and/or process histories that will produce a desired combination of material properties), and (iv) high throughput experimental protocols for multi-resolution (spatial resolutions in the range of 50 nm to 500 microns) mechanical characterization of heterogeneous materials in small volumes (e.g., individual constituents in composite material samples, thin coatings or layers in a multilayered sample). These recent advances will be illustrated with case studies.

Predicting plastic anisotropy of aluminum using Material Data Driven Design (MAD3) software

09:45AM - 10:10AM

Presented by:

David Montes De Oca Zapiain, Sandia National Laboratories

Co-authors :

Hojun Lim, Sandia National Laboratories

Benjamin Greene, Sandia National Laboratories

Co-precipitation High-Strength Al-Mg-Si-Cu-Zn Alloy Design

10:10AM - 10:35AM

Presented by:

Fan Meng, Scientist, Novelis

Co-precipitation is a well-demonstrated effective strengthening strategy for high-strength alloy development, such as β-Mg_2Si and Q-AlCuMgSi co-precipitation in 6111 aluminum alloy. This work describes a CALPHAD-based computational design framework of room temperature formable high-strength Al-Mg-Si-Cu-Zn sheet alloy by Mg-Si and Mg-Zn co-precipitation strengthening for automotive structural applications. The alloy design was based on a Mg-rich 6xxx alloy with sufficient large solution window to accommodate Zn forming Mg-Zn-(Cu) precipitate besides typical 6xxx Mg-Si-(Cu) precipitate by high-throughput calculations using commercial CALPHAD software and database. The computational design was validated by key experiments showing higher hardness at paint bake aging condition than the current highest strength 6111 based auto alloy.

Microstructure, elevated-temperature properties, and simulation of Al-based entropy alloys

10:35AM - 11:00AM

Presented by:

X. Grant Chen, Research Chair, University Of Quebec At Chicoutimi

Co-authors :

Liying Cui, University Of Quebec At Chicoutimi

Zhan Zhang, University Of Quebec At Chicoutimi

Three Al-based entropy alloys (Al85Cu5Zn5Mg5, Al85Cu11Zn2Cr1Fe1, and Al78Cu18Zn2Cr1Fe1) were developed and investigated in this work. Each alloy exhibited a multiphase feature. The first two alloys had an identical Al content of 85 at.%, yet variations in secondary elements led to noticeable distinctions in their phase type and content. This resulted in distinct elevated-temperature properties between the two alloys. The simultaneous addition of Mg and Zn in Al85Cu5Zn5Mg5 led to the emergence of thermally unstable precipitate and secondary phase, deteriorating the thermal stability of alloys. Notably, Al78Cu18Zn2Cr1Fe1 exhibited superior performance, with a yield strength exceeding 200 MPa at 300 °C and remarkable thermal stability up to 450 °C, showing its promising potential for elevated-temperature applications. The spatial microstructure reconstruction showed a highly interconnected intermetallic network. The microstructure-based simulation on compressive properties revealed that the intermetallic network, comprising the rigid and heat-resistant phases Al2Cu and Al45Cr7, served as the principal stress bearers during deformation in Al78Cu18Zn2Cr1Fe1, contributing to the overall mechanical property.

Preparation of Alumina Particle Dispersed Aluminum Composites by Accumulating Roll Bonding Method

11:00AM - 11:25AM

Presented by:

Gen Sasaki, Professor, Hiroshima University

The ARB (Accumulative Roll Bonding) method is attracting attention as a new high-strain processing method that uses only conventional rolling mills. The ARB method is an efficient practical process that produces ultrafine-grained, high-strength metal and alloy thin sheets through repeated rolling. However, there have been few attempts at using this as an aluminum matrix composite (AMC) manufacturing process, and its effectiveness has been sufficiently verified. Therefore, Al2O3 particles dispersed Al composites were attempted to fabricate by the

ARB method and evaluate its mechanical properties. Then, the mechanism of mechanical properties of the composites was clarified by the microstructure observation such as the dispersion form of the particles and the microstructure of the matrix.Alumina (Al2O3) particles with 1 micrometer in average diameter were sandwiched between thin pure aluminum plates (A1050P) with 0.5 mm in thickness. The volume fraction of Al2O3 particles in composites was controlled as 2 vol.%. The composites were prepared using the accumulating roll bonding (ARB) method, which is a huge strain processing process. At first, Six Al2O3 deposited aluminum plates were stacked to form a multilayer composite sheet by cold rolling. After annealing, the sheet composites were cut in half and stacked, and then cold rolled. This treatment was repeated up to 10 times. The mechanical properties were evaluated by a tensile test. At that time, quantitative microstructure evaluation such as particle dispersibility, aluminum grain shape, and particle size was performed.In the composites with 5 cycle times, the Al2O3 layer and the aluminum layer are separated, and there is almost no particle dispersion in the aluminum matrix. On the other hand, at 8 cycles, Al2O3 particles were dispersed in the matrix, and the Al2O3 particle aggregates became smaller and decreased in number. However, traces of the stretched aluminum layer can be seen. At 10 cycles, the traces of this layer become unclear, and individual Al2O3 particles are observed to be uniformly dispersed in the aluminum matrix. As increasing the number of repetitions till 10 cycles, both tensile strength and elongation increased. In this study, the local number of 2-dimension at random points (LN2DR) of Al2O3 particles, the particle volume fraction of Al2O3 particles, the particle density of Al2O3 particles, the average particle size of aluminum, the rate of large angle grains of aluminum, and Kernel Average Misorientation (KAM) in the composites with 8 and 10 cycle times measured by SEM and EBSD. Consequently, the decreases in LN2DR and average grain size of aluminum, and increases in KAM values as increasing cycle number contribute to the improvement of the strength and elongation.

Towards hybrid modeling of extrusion-based aluminum value chains

11:25AM - 11:50AM

Presented by:

Christian Dalheim Øien, PhD Student, Norwegian University Of Science And Technology

Co-authors :

Ole Runar Myhr, Principal Research Scientist, Hydro Aluminium

A company-specific data-driven model trained on production data shows a promising ability in predicting final mechanical properties of extrusions. In continuation of this, a methodology for hybrid modelling is proposed where such models can be used to increase the performance of a physics-based model in the case of available relevant production data. Preliminary results indicate that this hybrid methodology can enable a reliable and gradual increase in model accuracy as the production data availability increases.

In situ conductometry during homogenization of Al-Mg-Si alloys for machine learning–based prediction of the final grain structure of extruded profiles

01:20PM - 01:45PM

Presented by:

Johannes Österreicher, Senior Scientist, Austrian Institute Of Technology

Co-authors :

Dragan Živanović, Associate Professor, University Of Niš

Wolfram Walenta, Profactor

Stefan Maimone, Profactor

Sindre Hovden

Georg Kunschert, Austrian Institute Of Technology

The electrical conductivity of aluminum alloys is closely related to their microstructure. In situ measurement of conductivity during thermo-mechanical processing thus has the potential to yield microstructural information that can be used for process control. We designed a high-temperature eddy current sensor capable of measuring in situ the electrical conductivity during homogenization. Using this sensor, we performed conductometry during the homogenization of six Al-Mg-Si wrought alloys, three of which are experimental recycling-friendly alloys with increased Fe content. The results are interpreted with regard to microstructural investigations and the advantages and limitations of our measurement setup are discussed. As a proof of concept, we demonstrate how the conductivity curves and extrusion process parameters can be combined to predict final extrudate grain structures using machine learning. To achieve this, we employed finite element simulation of extrusion coupled with microstructural simulation over a wide parameter range, validated by extrusion experiments and metallography, and trained a feed-forward neural network. Our interdisciplinary approach may lead to major improvements in the industrial processing of Al wrought alloys facilitated by in situ acquisition of microstructural information and machine learning.

Data Transformation and Feature Extraction for the analysis of variables influencing the quality of aluminum ingots

01:45PM - 02:10PM

Presented by:

Manuela Schreyer, Data Analyst, AMAG Austria Gmbh

Co-authors :

Marco Tschimpke, Department For Artificial Intelligence & Human Interfaces, University Of Salzburg

Alexander Gerber, AMAG Casting GmbH

Steffen Neubert, AMAG Casting GmbH

Wolfgang Trutschnig, Department For Artificial Intelligence & Human Interfaces, University Of Salzburg

In many industries, the importance of data science and artificial intelligence is increasing to meet growing demands for high-quality products. Various statistical and machine learning methods are available to analyze the large amounts of process data. Before applying these methods, however, data scientists are challenged to perform several preliminary tasks.It is commonly stated that approximately 80 % of data analysis involves data preparation. This work concentrates on preliminary steps, especially the calculation of suitable parameters from the continuous process-signals (discretization) that may affect the quality of aluminum ingots in the aerospace industry.

This is followed by an overview of current research on calculating a suitable target variable and building a predictive model to assist technologists in decision-making.

Advanced Data Engineering for a cold rolling mill to enable Machine Learning and Data Analysis

02:10PM - 02:35PM

Presented by:

Alexander Haidenthaler, Data Engineer, Austria Metall GmbH

Co-authors :

Patrick Pfeiffer, Data Scientist, Austria Metall GmbH

In recent years, machine learning and data analysis have become increasingly important in the aluminium industry. Cold rolling is a essential step in the manufacturing of aluminium strips. To optimize processes and improve product quality through data analysis and predictive models, it is necessary to have strip- and length-related process data. This is particularly important in the context of position-dependent process information. This paper describes the implementation of the time/length-transformation and its application on continuously recorded, industrial production data. Finally, a short outlook on future research and possible applications in the field of data analysis is provided.

Data Driven Methods in Dimensionally Challenging Settings with an Example of Process Influence on Material Quality

02:35PM - 02:55PM

Presented by:

Patrick Pfeiffer, Data Scientist, Austria Metall GmbH

Co-authors :

Alexander Haidenthaler, Data Engineer, Austria Metall GmbH

Erik Santora, Product Engineer, AMAG Rolling GmbH

As a producer of specialized industrial products, AMAG faces high standards for material properties such as corrosion resistance, mechanical performance, and processability of aluminum products. To gain deeper insight into its processes, AMAG employs various data-driven methods. In this paper, we present an approach using data-driven methods to explore previously unmonitored parameters, using data on foil stock material as an example. Customers who use foil stock rely on high production standards for mechanical properties. This allows them to process the material at higher speeds and roll it to a thickness of 5-160 μm. Instead of using overly complicated models that generalize poorly, this approach focuses on reducing an abundance of data, to a core set of influential factors and a reduced row space. The example demonstrates how augmented data can be modelled to explain unexpected variability in mechanical testing.

Delta Machine Learning for Improved Extrapolation

02:55PM - 03:20PM

Presented by:

Adam Birchall, PhD Researcher, Brunel University London

Co-authors :

Carla Barbatti, R&D Centre Manager, Constellium

Isaac Chang

Zidong Wang

Due to the amount of variables and high cost of data in alloy design data is often limited in scale when predicting mechanical properties, leading models to be required to extrapolate to outperform existing alloys. Extrapolation is a significant weakness of Machine learning models, one that is only started to be addressed in metallurgy. This work demonstrates how Delta Machine Learning models can be used to improve extrapolation predictions, enabling faster progression toward the finding of alloys which outperform existing datasets.

09:20AM - 05:25PM

GLC 236

Microstructure Design; Alloying and Heat Treatments

Suppressing effect of Al3(Sc,Zr) dispersoids on PLC behavior in AlMgScZr alloy

09:20AM - 09:45AM

Presented by:

Youcai Qiu, PHD Student, Speaker, Chongqing University

Co-authors :

Xiaofang Yang, Corresponding Author, Chongqing University

Robert Sanders, Corresponding Author, Chongqing University/Novelis

The Portevin-Le-Chatelier (PLC) effect, as a plastic instability, extremely limits the application of Al-Mg alloys as a material for visible outer auto body, as it leads to the formation of stretcher-strain markings on the sheet surface during shape-forming processes. In this study, the PLC behaviors at room temperature were investigated in annealed 5182 and Sc/Zr modified 5182 alloy sheets, by combining tensile tesing, DIC analysis, and microstructural characterization. It was shown that the presence of Al3(Sc,Zr) dispersoids can reduce the severity of PLC effect, highly relying on their particle size and number density. The alloy with the finest subgrain structure and the densest Al3(Sc,Zr) dispersoids showed the slightest PLC effect. The reduced PLC severity was attributed to the fact that the presence of Al3(Sc,Zr) dispersoids and subgrain boundaries hinder dislocation motion, thus significantly suppressing local strain softening.

Cluster strengthening of aluminium alloys

09:45AM - 10:10AM

Presented by:

Christopher Hutchinson, Monash University

Co-authors :

Yixin Wang, Monash University

Xinren Chen

Chengbo Zhu, Research Fellow, Brunel University London

Baptiste Gault, Max-Planck-Institut Für Eisenforschung

Precipitation behavior of Al-7Si-0.35Mg casting alloy during T5 heat treatment

10:10AM - 10:35AM

Presented by:

Young-Hee Cho, Principal Researcher, Korea Institute Of Materials Science

Co-authors :

Saif Kayani

Kwangjun Euh

Jung-Moo Lee

This study examines the precipitation evolution during T5 heat treatment (casting and direct aging) of an Al-7Si-0.35Mg (A356) casting alloy with varying thicknesses. A step mold casting with cavity thickness ranging from 40 to 4 mm was employed to investigate the effect of cooling conditions on the aging behavior and the resulting properties of the T5 heat-treated A356 alloy. While cooling rates during solidification determine the initial solubility of solute elements in the matrix, cooling conditions even after the solidification was found to affect the amount of pre-precipitates (e.g., Si clusters and B´) and the subsequent aging hardening response directly after casting. Analysis of precipitation kinetics and number densities of precipitates indicates that the pre-precipitation can interfere with the precipitation of β˝, otherwise promoting the precipitation of coarse β', U2 and Si, which reduced the overall T5 precipitation hardenability. Electrical/thermal conductivities of the Al-Si-Mg alloys, which are in a trade-off relationship with strength, were also assessed during T5 heat treatment. Based on the characterization of precipitates at different aging steps, the interrelationship between the microstructural evolution particularly within the matrix and the elongation/conductvity is further discussed.

Effect of quenching rate on microstructure formation in Al-Zn-Mg alloy sheets

10:35AM - 11:00AM

Presented by:

Yuki Aisu, Japan / UACJ Corporation

Co-authors :

Koji Ichitani

Hiroki Tanaka

Genki Saito, Nagoya University

Shunsuke MUTO, Nagoya University

Toshihiro OKAJIMA

A phenomenon that Al-6.0%Zn-0.75%Mg alloy sheets furnace-cooled after solution heat treatment had higher strength than water-quenched sheets under specific aging condition was reported. However, the strengthening mechanism related to furnace-cooling had not been clarified yet. In this research, a replication study of the strengthening phenomenon of furnace-cooled sheets was conducted, and then microstructural change during aging in Al-5.9mass%Zn-0.75mass%Mg alloy sheets furnace-cooled after solution heat treatment was investigated using SAXS measurements and STEM observation. The strengthening phenomenon of furnace-cooled sheets was reproduced. In furnace-cooled sheets, lattice strain contrasts with diameters of 2-5nm were observed in LAADF (Low-Angle Annular Dark-Field)-STEM (Scanning Transmission Electron Microscope) images. The lattice strain contrasts seemed to be a kind of clusters, which generated during furnace cooling and seemed to cause suppression of reversion and promotion of age hardening in furnace-cooled sheets.

Creep aging behavior of aluminum alloys EN AW 2024 and EN AW 7075

11:00AM - 11:25AM

Presented by:

Hannes Fröck, Head Of Laboratory Competence Center °Calor, University Of Rostock / Materials Science

Co-authors :

Seyed Vahid Sajadifar, Institute Of Materials Engineering, University Of Kassel,

Benjamin Milkereit, University Of Rostock

Philipp Krooß, Institute Of Materials Engineering, University Of Kassel

Thomas Niendorf, Institute Of Materials Engineering, University Of Kassel

Olaf KESSLER, Head Of The Chair Of Material Science, University Rostock

While conventional aging techniques have been employed for decades, there has been a recent surge in the interest surrounding (artificial) ageing under mechanical load, the so-called creep aging. Creep aging represents a unique combination of artificial aging and elastic or plastic stress. External stresses can significantly affect the kinetics of precipitation, including aging duration and temperature.In this study, alloys EN AW-2024 and EN AW-7075 were subjected to artificial aging, both with and without the application of mechanical stress. Tensile specimens were subjected to loads during the aging process. Subsequently, mechanical testing was conducted on one part of the samples. From other tensile specimens, samples were extracted from the measurement area after creep aging and analyzed using Differential Scanning Calorimetry (DSC).The results demonstrate that both stress-strain curves and DSC curves, along with the resulting precipitation state after creep aging, vary depending on the applied stress, artificial aging temperature, and duration. Combining artificial aging with the application of stress provides an additional avenue to optimize the mechanical properties of aluminum alloys.

Influence of a pre-aging treatment on the material properties and the subsequent heat treatment in 6xxx series aluminium alloys

11:25AM - 11:50AM

Presented by:

Patrick Ortner, Phd Student, Friedrich-Alexander-Universität Erlangen-Nürnberg

Co-authors :

Andreas Schiffl

Heinz Werner Höppel

Due to its good formability and excellent properties, the demand for aluminium alloys for technical applications is continually increasing. The primary goal for many industries is to reduce CO2 emissions, making aluminium a preferred choice due to its lightweight potential and versatility. Aluminium alloys are extensively used in the automotive sector, particularly as the industry shifts from conventional to electric mobility, where lightweight construction principles are crucial.Aside to applications in the car body as sheet materials, extruded profiles are often used for safety relevant components, such as side member, cross member or battery trays. For such applications, high strength alloys are of first choice in order to protect the passenger compartment or the battery in the event of a crash. Ensuring high strength paired with a sufficiently high ductility is a major challenge. In addition, the high degree of plastic deformation involved during manufacturing of these structural components, such as by hot-extrusion, must be taken into account. In order to meet these requirements, it is essential to understand the

precipitation sequences of hardenable Al alloys in detail and the relevant influences thereon. Depending on the alloy system in use, natural aging can have a positive or negative effect on the mechanical properties, which is often difficult to handle in the industrial process. Furthermore, different minor and major elements play a decisive role. To deal with these conditions more easily, a pre-aging treatment can be crucial.In this contribution, different alloy compositions of the 6xxx-series (from low to high alloyed) were investigated. The impact of different pre-aging treatments on the influence of the negative natural aging effect as well as the influence on the actual artificial aging was investigated. To examine the influence of the pre-aging treatment, stabilized, underaged, peak-aged and overaged conditions were analysed. In order to gain a deep insight into the precipitation sequence in the respective alloys, the early cluster formation in natural aged and stabilized condition were analysed using TEM and APT. The type of these clusters and early phases vary depending on the alloy and condition and have a decisive influence on the further precipitate formation. During further aging to peak aged or over aged condition, the previously formed clusters or early phases, which serve as nuclei in the further sequence, lead to different size distributions of the precipitates which allows in turn to tune the materials properties further. With a suitable heat treatment scheme, combining stabilization treatment with subsequent artificial aging, it is possible to set an optimised precipitation distribution in the extrusion process, which leads to improved properties.

Effect of Ag and Zn on Ultra-high Strength Al-Li Alloy

01:20PM - 01:45PM

Presented by:

Yuxing Tian, Senior Engineer, Chinalco Materials Application Research Institute

Co-authors :

Cheng Liu

Hailong Cao

Xiaobing Zheng

Wei Li

Jiaqiang Han

Using lightweight materials in aerospace equipments is a constant pursuit not only for material researcher but also for equipment designer. Over past sixty years, Al-Li alloy were used widely in aerospace field because of its high elastic modulus, high specific strength, good corrosion resistance and other advantages. Up to now, develop excellent alloy with low density and ultra-high strength is still a very important research direction. However, the difficulty is how to balance the mechanical properties and density, as well as minimizing cost as much as possible. Even in some cases, the cost reduction becomes a more critical factor for material application. International researchers had reported valuable results on high strength Al-Li alloy, including the effects of Cu, Li and micro-alloy elements on mechanical properties, precipitation sequences of T1 and δ′ phase, grain structure evolution, failure modes and so on. For the ultra-high strength Al-Li alloy, the main technical approach is to optimize the contents of Cu, Li, Mg and Ag elements, as well as using Zn to substitute for noble metal Ag in order to reduce the material cost. Recently, researchers from Chinalco Materials Application Research Institute made a valuable experimental study on developing ultra-high strength Al-Li alloy. The developed novel alloy without Ag element has an ultra-high tensile strength of above 650MPa, compressive yield strength of 600MPa, considerable fracture elongation of above 8% and low density of 2.7g/cm3 , showing its advantage for application on aircraft upper wing panel. To obtain basic high strength, the total amount of Cu and Li elements is controlled to be 5.5~5.7wt.%. Additionally, a certain amount of Zn substitute for Ag, showing the lower cost comparing with the registered alloys with Ag, such as 2195, 2065, 2055, 2071 and 2075. Certainly, grain structureoptimization also gives necessary contribution to strength, where the area proportion of recrystallization is below 10% and the density of low angle grain boundaries is not less than 150 mm/mm2 . During the experimental study, ingots were fabricated using vacuum melting furnace. Homogenized ingots were hot-rolled at 450°C to plates with thickness of 25mm. And then the plates were suffered T8 treatment to obtain final temper. By TEM observation it is found that the alloy with Zn and the alloy with Ag display the same precipitate sequence during aging process, Cu-rich cluster (GP-Ⅰ) →θ′ (GP-Ⅱ) →T1+θ′ phase, and the precipitate phase is composed of high density of T1 and small amount of θ′ phase. However, Ag and Zn have different capability for assisting T1 and θ′ phase. For peak-aged state, Ag element increases the diameters both of T1 and θ′ phase, and slightly increases the volume fraction ratio of T1 to θ′. This increases the tensile strength of the alloy with Ag higher than with Zn. But when the alloy achieves an ultra-high strength level, the strengthening effect of Ag becomes slightly, and the alloy containing Ag element loses its optimum cost performance. Inversely, moderate Zn addition shows even better balance between properties and cost. The results show that the alloy with 0.6wt.% Zn also has an ultra-high strength of 650MPa and good ductility, but further adding no obvious strengthening. Statistical date from the diameters of T1 and θ′ phase reflects its strengthening principle. That is Zn only increases θ′ phase diameter but has little influence on T1 phase diameter. So the more Zn adding can achieve an equivalent strengthening effect comparing with relatively few adding of Ag element. In future, material researcher and equipment designer would pay more attention to the balance between mechanical properties and cost. Present study displays a considerable novel alloy and also suggests the positive effect of Zn element, which has an actual meaning for developing ultra-high strength or other Al-Li alloy.

Cluster hardening in Al-Mg-Zn-(Cu) crossover alloys

01:45PM - 02:10PM

Presented by:

Philip Aster, Montanuniversitaet Leoben

Co-authors :

Phillip Dumitraschkewitz, Montanuniversitaet Leoben

Peter Johann Uggowitzer, Professor

Florian Schmid, AMAG Rolling GmbH

Stefan Pogatscher, Montanuniversitaet Leoben

Lukas Stemper, AMAG Rolling GmbH

Katharina Strobel, AMAG Rolling GmbH

Cluster hardening, i.e. the formation of clusters as the hardening phases, represents a promising approach for strengthening with a reduced loss of ductility in aluminum alloys. In this context, the effect of a typical pre-aging- and an unusual long-term aging treatment on the mechanical properties and forming behavior of Al-Mg-Zn-(Cu) alloys (5xxx/7xxx crossover alloys) is investigated. Aging is performed at temperatures which promote the formation of clusters instead of typically larger, metastable hardening phases. In the tensile test, the cluster-hardened alloys show pronounced strain-hardening properties, which we evaluate by structural analysis using atomic probe tomography (APT). The results show a pronounced aging response in combination with improved ductility compared to a conventional aging regime.

External stress on the precipitation and properties in an Al-Zn-Mg alloy

02:10PM - 02:35PM

Presented by:

Duo Zhang, Assistant Research Fellow, Institute Of Metal Research, Chinese Academy Of Sciences

Haichang Jiang, Professor, Institute Of Metal Research, Chinese Academy Of Sciences

Lijian Rong

The precipitation hardening Al-Zn-Mg alloys are widely used as structural materials in the high-speed train body due to their high strength, excellent extrusion property, and welding performance. With the rapid development of the rail transit industry in China, the demand for Al-Zn-Mg alloys with excellent properties has been increasing. As the high strength and excellent stress corrosion resistance can not be obtained simultaneously by conventional aging processes, the development and research of new aging processes are crucial. Therefore, the effects of stress-aging process on microstructure, mechanical properties, stress corrosion behavior, and the precipitation and growth behavior of precipitates of Al-Zn-Mg alloy have been studied systematically. As a result, the stress-aging process is optimized. It provides a new experimental basis and theoretical guidance for the development of Al-Zn-Mg alloy with excellent comprehensive properties.

The Application Cases of the CALPHAD Approach in Aluminum Alloys

02:55PM - 03:20PM

Presented by:

Song-Mao Liang, Materials Scientist, Computherm LLC

Co-authors :

Fan ZHANG, President, Computherm LLC

Chuan Zhang, Computherm LLC

In this presentation, we will explore how to use the CALPHAD method, a crucial element in integrated computational materials engineering (ICME), to enhance aluminum alloy development. Utilizing the simulation tool composed of Pandat software and PanAl database, we present three typical application cases in understanding the solidification and precipitation behavior of multicomponent Al alloys, including: 1. precipitation kinetics of AA7xxx alloy during heat treatment; 2. AlP-(Si) solidification sequence map associated with the morphology of eutectic (Si) in cast Al-Si alloys; 3. hot cracking susceptibility prediction of A2xxx series alloys. These examples demonstrate that the CALPHAD method has extended its applications from original phase diagram calculation to a broader field for materials design and processing optimization in Al alloys.

In-situ transformation between η1 and η12 in an AA7075 aluminum alloy

03:20PM - 03:45PM

Presented by:

Cheng Ling Tai, Ph.D Student, National Taiwan University

Co-authors :

Shu-Cheng Liang, Department Of Materials Science And Engineering, National Taiwan University, Taipei, Taiwan

Tsai-Fu Chung, Assistant Professor, Department Of Materials Science And Engineering, National Yang Ming Chiao Tung University

Jer-Ren Yang, Distinguished Professor, Department Of Materials Science And Engineering, National Taiwan University, Taipei, Taiwan

The 7xxx alloy series has been renowned for its exceptional mechanical properties owing to the presence of η' and η ($MgZn_2$) precipitates within the aluminum matrix. Within this alloy, η has manifested in 15 distinct types, each exhibiting a unique orientation relationship with the surrounding aluminum matrix. η1 phase was easily observed under over ageing condition in the present alloy, with some stacking faults inside the precipitate. A particularly intriguing discovery emerged that η1 and η12 coexisted, with some parts of them connected perfectly, implying that η12 accidentally and directly formed from η1. In addition, their orientation relationship gave rise to the formation of flat hexagonal defect chains. This intricate interplay, captured vividly in a corresponding image, not only contributed significantly to the alloy's elevated strength but also serendipitously fostered the development of a five-fold symmetry Penrose tiling pattern.

Influence of Ag on microstructure and mechanical properties of as-cast Al-33Zn-2Cu high-zinc aluminum alloy

03:45PM - 04:10PM

Presented by:

Haitao Zhang, Northeastern Universit

Co-authors :

Donghui Yang, Northeastern University

Nagaumi Hiromi, High-Performance Metal Structural Materials Research Institute

Solute clustering and early-stage precipitation in Al-Mg-Si alloys

04:10PM - 04:35PM

Presented by:

Chunan Li, PhD Student, Norwegian University Of Science And Technology

Co-authors :

Calin Daniel Marioara, Senior Scientist, SINTEF Industry

Constantinos Hatzoglou, NTNU

Sigmund J. Andersen, SINTEF Industry

Randi Holmestad, Professor, Norwegian University Of Science And Technology (NTNU)

Yanjun Li, Norwegian University Of Science And Technology

In industrial applications of age-hardenable aluminum alloys, precipitation involves solution heat treatment, pre-aging treatment, natural aging (storage at room temperature), and artificial aging. Precipitation in Al-Mg-Si alloys are well-known to be sensitive to the thermal history at early stage, the mechanism of which is not fully understood. Systematic investigation shows that the pre-aging treatment and natural aging for different amount of times can significantly influence the age-hardening response and peak-aged strength in Al-Mg-Si alloys. Combining results from advanced transmission electron microscopy (TEM) and atom probe tomography (APT), we show that precipitates formed at early stage have atomic structure with the same motif as β" precipitates, which have dominant strengthening effect at the peak-aged conditions. Different treatment can lead to precipitates with different size, number density and structure. When multi-step heat treatment is introduced, the precipitation during later step can be significantly modified the precipitation during earlier step, as compared to a single step treatment. Different treatment at early stage will alternate the size and number density of β" precipitates in later stage, which can be related to the observed difference in yield strength and uniform elongation.

Effect of Precipitations on the Static Recrystallization and Texture Evolution of High Recycled-Content Al-Mg-Si Alloys

04:35PM - 05:00PM

Presented by:

Yandong Jing, Phd Student, EPFL

Co-authors :

Elisa Cantergiani, Novelis

Seyyed Ezzatollah Moosavi

Cyril Cayron

Jonathan Friedli, Novelis

Roland Logé, EPFL

In the recycling of aluminum alloy, impurity elements and production processes can exert unpredictable effects on recrystallization and texture evolution. This study conducted in-situ electron backscatter diffraction (EBSD) heating experiments on two cold-rolled, recycled Al-Mg-Si alloys. This study utilized a stepwise heating regime, with temperatures progressively rising from 200 °C to 500 °C. The sample with slightly lower recycled content is labeled as im+, and the sample with higher recycled content is labeled as im++. The homogenization treatment after casting for im+ is four times that of im++, which leads to significant differences in the size and distribution of precipitations. During the in-situ heating, the specimen im++ exhibited faster nucleation and growth at 210 °C, while im+ showed progressive growth from 200 °C. Ultimately, the average grain size for im++ and im+ was 24.6 μm and 34.5 μm, respectively. As the main rolling texture β-fiber weakened during heating, Cube orientation emerged as the dominant recrystallization texture in both samples, with the sample from im++ producing a higher Cube texture volume fraction. The primary reason for this discrepancy lies in the differing impurity content and homogenization time in the two materials, which results in precipitates with distinct morphologies and distributions.

Effects of user-defined parameters on cluster analysis in Al-Mg-Si-Cu-Sn alloy

05:00PM - 05:25PM

Presented by:

MiYoung Lee, Korea Institute Of Industrial Technology

Co-authors :

JaeHwang Kim, Principal Researcher, Korea Institute Of Industrial Technology

MinYoung Song, Korea Institute Of Industrial Technology

DaeHan Kim, Postdoc, Korea Institute Of Industrial Technology

JiWook Park, Korea Institute Of Industrial Technology

SeokJae Lee, Jeonbuk National University

David N Seidman

Dieter Isheim, Research Associate Professor, Northwestern University

DuYoung Choi, Korea Institute Of Industrial Technology

YongChae Jung, Korea Institute Of Science And Technology

Five combinations of Dmax and Nmin were applied to determine optimum parameters for cluster analysis in Al-0.59Mg-0.58Si-0.6Cu-0.1Sn (mass%) alloy. Several types of cluster characteristics were analyzed. Changes in size, composition and atomic density with different combinations were confirmed. Based on these results, methods for determining optimum parameters were mainly discussed and proposed. It is anticipated that our proposal can contribute to achieve high-quality results of cluster analysis.

3D non-destructive grain structure characterization in metallic alloys using lab-based diffraction contrast tomography

05:25PM - 05:50PM

Presented by:

Hrishikesh Bale, Market Solutions Manager, Carl Zeiss Research Microscopy Solutions

Co-authors :

Kaushik Yanamandra, Carl Zeiss Research Microscopy Solutions

Nathan Johnson, Carl Zeiss Research Microscopy Solutions

Sandip Basu, Carl Zeiss Research Microscopy Solutions

Jette Oddershede, Xnovo Technology ApS

Jun Sun, Xnovo Technology ApS

The grain boundary characteristics are essential information to analyze grain boundary related behaviors such as preferential precipitation or intergranular cracking in polycrystalline materials. Accessing the necessary parameters to describe a grain boundary on the mesoscopic scale is beyond the reach of 2D characterization techniques and is only achievable through a 3D approach. With the capability to map the grain morphology and crystallographic orientation non-destructively in 3D, labbased diffraction contrast tomography (DCT) using X-rays provides the necessary information to analyze the crystallographic parameters describing grain boundaries on the mesoscopic scale, including grain boundary misorientation angle/axis and plane inclination. In

this work, we will present the results of using lab-based DCT to investigate the grain boundary characters in polycrystalline materials including ceramic examples, with further discussion of how the grain boundary properties are related to grain boundary behaviors such as grain boundary wetting and cracking. Results further demonstrate how this technique can be extended for 4D studies and in-situ investigations of polycrystalline materials.

09:20AM - 05:25PM

GLC 235

Deformation Behavior and Mechanical Properties (Fatigue and Fracture)

The Effect of Strain Rate on Fracture Behavior of AA6111 Alloys

09:20AM - 09:45AM

Presented by:

Danielle Zeng

Co-authors :

Daniel Freiberg, Ford Motor Company

Aluminum, traditionally perceived as a strain rate insensitive material, has recently shown an unexpected increase in fracture strain under higher test speeds. This phenomenon holds significant implications for establishing fracture criteria used in vehicle crash simulations and is of particular importance with the increased use of aluminum in automotive body structures. The fracture model, especially vital in vehicle crash simulations, relies heavily on precise and accurate inputs, with fracture strain under varying strain rates being a key parameter for precise and accurate fracture predictions.In this work a series of plane strain tests were conducted at elevated speeds to understand the mechanism(s) responsible for the observed increase in fracture strain with increasing strain rate. The experimental setup incorporated Digital Image Correlation (DIC) in conjunction with an infrared (IR) camera to simultaneously record strain and temperature data, thus capturing the material's deformation at specific rates and temperatures. The combination of these two techniques enables the relationship between fracture sensitivity and strain rate to be explored, which will shed light on the dynamics at play in this intriguing material behavior.

Necking and fracture strain measurements in plane strain tension to understand the effect of impurities on 6XXX alloys

09:45AM - 10:10AM

Presented by:

Pierre Guerin, PhD Student, C-TEC Constellium Technology Center

Co-authors :

Fanny MAS, Senior Metallurgist Engineer, Constellium C-TEC

Alexis Deschamps, SIMaP-UGA

Pierre Lhuissier, SIMaP - UGA

Frédéric De Geuser, SIMaP-UGA

Sheet formability is a key property for Aluminum alloys used for outer body panels to enable weight reduction in cars. The foreseeable increase of recycled content in the production of AA6XXX alloys results in increasing fractions of impurities that may have adverse consequences on this property. This work focuses on studying the plane strain deformation behavior in tension and compares it to uniaxial tension and bending results. Using digital image correlation on a variety of different microstructures showing different levels of bendability, we propose a procedure for determining locally both a necking and a failure criterion. The latter is compared

with bending performance to better understand the effect of impurities and processing parameters on formability for these three different loading cases.

In-plane Edge Stretch Characterization of Aluminum Sheet

10:10AM - 10:35AM

Presented by:

Christopher Brown, Engineer, Novelis

Co-authors :

Kaab Omer, Scientist, Novelis

Sarin Thokala, Lead Engineer, Novelis

David Anderson, Lead Scientist, Novelis

Automotive blanks are commonly designed to included large cutouts to allow for material flow. The deformation of these cutouts is notably different from the bulk properties of the material and has led to automotive customers experiencing unexpected splitting issues due to the edge effects of these features. Historically, this behavior has been studied with the ISO16630 hole expansion test, however, this test method is not the ideal representation of the stamping process, as it behaves closer to a hole extrusion process than a hole expansion process. Thus, this work aims to develop an in-plane hole expansion test method to better study and predict edge strain failure in aluminum alloys. The developed method uses computer vision to automate crack detection and hole expansion measurements. Results are reported for AA5182 and AA6014. The 5xxx and 6xxx materials are found to have different edge crack sensitivities, manifested by differences in stress states and failure locations. Lab results are validated with a stamping trial and show strong correlation of the failure strains for the two methods.

Microstructure and Damage Evolution in Recycled 6xxx Aluminium Alloy

10:35AM - 11:00AM

Presented by:

Yangchao Deng, PhD Student, The University Of Manchester

Co-authors :

Zhenjie Cao, PhD Students, The University Of Manchester

Joseph Robson, Univesity Of Manchester

Kun Yan, University Of Manchester

Using recycled aluminium alloys offers significant advantages due to much less energy consumption. However, impurities like iron-rich intermetallic compounds (IMCs) inevitably form and accumulate in recycled aluminium alloys, some of which are detrimental to mechanical properties. This study explored the correlation between microstructure and local damage formation, aiming to fundamentally understand the effect of increasing Fe content on recycling 6xxx (Al-Mg-Si) type alloys. The methods based on analytical SEM/EBSD and 3D X-ray micro-computed tomography (μ-XCT) were employed here to identify and track the particle-involved grain orientation changes and the local damage evolution. In the recycled IBA6111 alloy, IMC particles underwent size refinement after the thermomechanical processing route. And the alloy showed recrystallized grains with weak texture components after T4 which resulting from grain growth around IMC particles. During uniaxial tensile deformation, the grains were elongated ultimately experiencing ductile fracture with ~30% elongation. The results revealed that local damages predominately originated from particle-cracking voids, and stress/strain localization was observed around IMC particles. The thermomechanical processing influences and metallurgical failure analysis here will further be correlated with modelling work to elucidate particle effects on formability and provide insights for the impurity tolerance of sustainable wrought aluminium alloys.

Experimental determination of the forming envelope in hydroforming of AA6111-T4 tubes

11:00AM - 11:25AM

Presented by:

Yannis Korkolis, Professor, Technical University Of Dortmund - IUL

Co-authors :

Yash Daterao, Graduate Research Assistant, Ohio State University

Farhang Pourboghrat, Professor And Chair, Ohio State University

The hydroforming envelope of AA6111-T4 is established by a total of 15 proportional-loading paths in the axial feed – internal pressure space, performed on tubes of 50.8 mm external diameter and 2.8 mm thickness. The experiments are performed under pressure- and-axial-feed-control, and expand a 51 mm length of the tube into a square die with 51 mm edge and 6.35 mm radius. In every path, failure occurs before the die is completely filled. Failure in the form of bursting occurs in the 5 paths with the least axial feed. In 9 paths with higher axial feed, the axial force on the actuators is such that the testing apparatus stalls. Finally, there is 1 path in-between the two regions where either modes of failure are possible. The thickness distribution of the formed tubes is measured by sectioning. As in earlier works, the maximum thinning occurs at the regions where the flat sides, that are pressed against the die walls, meet the still curved ones, that are freely-inflating.

Effect of crystal orientation on the stretch flange formability of single-crystal Al-Mg-Si alloy sheet

11:25AM - 11:50AM

Presented by:

Taku Niino, UACJ Corporation

Co-authors :

Hidetaka Nakanishi, Maneger, UACJ Corporation

The stretch flange formability is one of the important material properties of Al-Mg-Si alloy sheets for the automotive panel, and it is considered to be affected by the texture. To clarify the effect of crystal orientation on the stretch flange formability of Al-Mg-Si alloy sheets, the hole expansion test was conducted with the single-crystal specimen. It was found that the hole expansion rates were clearly different among the crystal orientation groups. The Taylor factor, which represents the ease of slip deformation of metals, could roughly explain the difference in the hole expansion rates among the crystal orientation groups, but it could not explain that in the same orientation

group. Then, the minimum angle between tensile axis and <111> direction of the crystal was proposed. Because <111> direction tensile gives aluminum high flow stress and work hardening property, and the ductility is presumed to be extremely low. By this indicator, it was demonstrated that the hole expansion rate was shapely decreased when the tensile direction on the hole edge was equal to, or near to <111> direction on the surface of the specimen.

Texture Effects on Through-Thickness Strength Gradients in Wrought Plate

01:20PM - 01:45PM

Presented by:

Daniel Magagnosc

Co-authors :

Jeffrey Lloyd, US Army Research Laboratory

High strength aluminum alloys obtain their strength through an array of mechanisms, including solid solution strengthening, cold work, and precipitation strengthening. These mechanisms are known to produce property gradients in thick wrought parts (e.g., thermal gradients during quench and heat treatment give rise to strength gradients). An overlooked contribution to mechanical property gradients is crystallographic texture. Texture induced directionality of strength is well established. However, texture induced strengthening (or softening) also plays a role in strengthening wrought plates. Here, the mechanical properties, including Vickers hardness and tensile deformation, of several aluminum alloys are extracted through the thickness. The hardness of all investigated plates decreases through the thickness. Conflicting trends in tensile properties are found; alloys in the 5xxx and 7xxx series are found to increase in tensile strength while alloys in the 2xxx and 6xxx series decrease in strength through the thickness. In depth x-ray diffraction and electron backscatter diffraction analysis indicates that the different strength trends are a consequence of how the crystallographic texture evolves in the different alloy classes.

Effect of Thickness on the Bendability of Extruded AA6082 Alloy

01:45PM - 02:10PM

Presented by:

Jun Ma, Associate Professor, Norwegian University Of Science And Technology

Co-authors :

Chanmi Moon

Torgeir Welo

Geir Ringen

Bendability is a crucial property for evaluating mechanical performance, particularly in forming operations and crashworthiness of aluminium components and structures within automotive applications. This study explores the influence of material thickness on the bendability of extruded AA6082-T6 alloy using the VDA 238-100 test method, specifically examining local formability parameters like bend angle (α) and VDA-failure strain. Test specimens, with different thicknesses, were EDM-cut from a 6 mm extruded AA6082-T6 plate. Conducting the bending tests with the specimens in different thicknesses and in ED (extrusion direction) and TD (transverse direction), a correlation between the bending performance (such as normalized bend angle, load-displacement curve, etc.) and thickness was revealed and identified. Microstructural characterization and finite element analysis were performed to improve the understanding of the deformation behaviors, affecting factors and physical mechanisms associated with the thickness effect on the bendability of extruded AA6082-T6 alloy. The findings offer valuable insights into the material's bendability with respect to thickness and the potential optimization of bendability assessment methods for aluminium extrusions.

Effect of Hardening Rate on Bendability of Aluminum Extrusions

02:10PM - 02:35PM

Presented by:

Jacqueline Noder, Postdoctoral Fellow , The University Of British Columbia

Co-authors :

Warren J. Poole, Full Professor, The University Of British Columbia

Aluminum extrusions are attractive for automotive lightweighting when the microstructure-property relationship is well understood and leveraged in the alloy design. Variations in the microstructure and through-thickness gradients are inherent to extrusions and governed by the processing history, i.e. die design and extrusion conditions. As a result, the plasticity and fracture behavior are strongly directional and warrant careful characterization and selection of performance metrics. To this end, tensile and 3-point bend tests were performed for a series of aluminum extrusions. It is demonstrated that a larger bend angle does not necessarily correlate with a higher fracture strain. It is proposed that the work hardening behavior affects the distribution of strain on the outer surface of the bend sample.

Devolution of Stress-Strain Data in Aluminum Alloys to Identify the Debris Species from their Obstacle Strength Factors Depending on their Thermo-Mechanical Processing

02:55PM - 03:20PM

Presented by:

Shigeo SAIMOTO, Emeritus Professor, Queen's University, Kingston, Canada

Co-authors :

Kaan Inal, Professor, University Of

Bradley Diak, Professor, Queen's University, Kingston, Canada

See attachment.

Dependence of thermomechanical response on Cu content in a hardenable Al-Si-Mg alloy

03:20PM - 03:45PM

Presented by:

Seyedmehdi Hosseini, Research Fellow, BCAST, Brunel University London

Co-authors :

Chamini Mendis, Brunel University London

Isaac Chang

Zhongyun Fan, Brunel University London

In this study, we investigated the effect of Cu content on the thermomechanical response of a precipitation-hardenable Al-Si-Mg alloy produced by the casting and rolling processes. The Cu content varied at three different levels (< 1 wt.%), while the alloy maintained fixed amounts of Si and Mg. The thermomechanical process included pre-aging (PA), stretching by 4% (S), and post-aging (T6). The results were based on the yield strength (YS) and the thermomechanical response was defined as YS_PAST6 – YS_T6. The findings indicated that at low and medium levels of Cu, the YS of the samples in PA and PAS conditions remained mostly constant at 206 and 281 MPa, respectively. However, it increased from 334 (low Cu) to 351 MPa (medium Cu) when the PAST6 process was completed. At a high level of Cu content, the YS_PA and YS_PAS enhanced to 221 and 298 MPa, respectively. Nevertheless, the YS after complete PAST6 was 349 MPa, slightly lower than that of the alloy containing medium Cu level. It was observed that the thermomechanical response of the alloy is at its maximum (50 MPa) when the amount of Cu is around the middle of the defined range.

Understanding the effect of intermediate annealing on Aluminium sheet bendability through 3D microstructural characterisation

03:45PM - 04:10PM

Presented by:

Laura Gonzalez Duque, PhD Student, University Of Manchester

Co-authors :

Elisa Cantergiani, Novelis

Zeqin Liang, Senior Metallurgy Scientist, Novelis

Christian Leppin, Novelis

Joseph Robson, Univesity Of Manchester

Joao Quinta Da Fonseca, University Of Manchester

Early failure of aluminium sheets tends to occur at the surface loaded in tension during the bending manufacturing process. It has been extensively reported that strain localises close to the surface loaded in tension, producing surface roughness and shear bands that lead to the initiation of cracks. It is known that an optional intermediate annealing (IA) during the production of the sheet affects the bendability of the final product. In this work, "IA" and "No IA" microstructures were studied and compared, in an effort to explain the impact of this optional annealing step on the microstructural parameters, and subsequently how they affect the bending performance. A Laser-PFIB coupled with an Electron Backscatter Diffraction (EBSD) detector was used to acquire 3D-EBSD datasets of both microstructures. The EBSD slices collected were reconstructed and the resulting 3D microstructures were compared and studied with crystal plasticity modelling (CPM), to predict strain localisation at the sheet surface. CPM revealed that strain localised at the grain boundaries from the start of plane strain tension simulation, especially at the surface and in the "No IA" alloy. The difference in the severity of strain localisation between both alloys was attributed to the intrinsic grain features, particularly the characteristics of the superficial grains.

Leveraging Retrogression and Reaging for the Forming and Mechanical Joining of High Strength Aluminum Alloys

04:10PM - 04:35PM

Presented by:

Eric Taleff, The University Of Texas At Austin

Transforming PLC phenotypes in a 5xxx aluminum alloy by electrically assisted deformation

04:35PM - 05:00PM

Presented by:

Angelika Cerny

Co-authors :

Johannes Österreicher, Senior Scientist, Austrian Institute Of Technology
Florian Grabner, Austrian Institute Of Technology
Aurel Arnoldt, Austrian Institute Of Technology
Georg Kunschert, Austrian Institute Of Technology
Gregor Zickler

The Portevin–Le Chatelier (PLC) effect, referring to serrated stress–strain curves in tensile tests, is a well-known phenomenon in 5xxx series aluminum alloys. The occurrence of the PLC effect has a negative influence on the decorative properties of formed parts. In the past, improvements have been achieved under warm and cryogenic forming conditions. An alternative approach is the use of pulsed current.Through the variation of electrical current parameters (pulse onset, duration, period, and current density) during the forming process, this study shows promising results for improving the formability of 5xxx aluminum alloys. Compared to cryogenic and standard room temperature tensile tests, the elongation of electrically assisted tensile tests can be increased. Moreover, the phenotype of the PLC effect changes and almost disappears with electric pulsing. Differences in dislocation density were studied using electron backscattered diffraction and transmission electron microscopy. Suppressing the PLC effect by electric current pulsing has the potential to lead to enhanced applications of 5xxx series alloys in automotive and other industrial sectors.

Improvement of mechanical properties of Al-Cu-Mg alloys by heavy cold rolling and subsequent aging treatment

05:00PM - 05:25PM

Presented by:

Yuki Ishii, Assistant Professor, Toyohashi University Of Technology

Co-authors :

Junya KOBAYASHI, Lecturer, Ibaraki University

Keitaro Horikawa

KURAMOTO Shigeru, Professor, Ibaraki University

ITOH Goroh, Professor, Ibaraki University

Severe plastic deformation processing and subsequent aging treatment have been known to be effective in achieving higher strength than the conventional aging treatment in aluminum alloys. Our research group focuses on strengthening by cold rolling. The Al-Cu-Mg-based alloy sample, Al-3.9Cu-1.5Mg, Al-4.4Cu-2.9Mg, and Al-5.3Cu-2.8Mg with 0.15Cr added (mass%) were solution-treated at 480, 495 and 505℃, cold-rolled by 90% and subsequently aged at 190°C for 0.03 and 0.6 ks. The effect of cold rolling and subsequent aging treatment on mechanical properties in Al-Cu-Mg alloys was investigated. When the solution treatment temperature in the cold-rolled and aged Al-Cu-Mg alloy increased, strength increased regardless of alloy composition, but ductility showed different trends depending on the alloy composition. Strain distribution during tensile deformation and local deformation capacity was affected by alloy compositions and solution treatment temperature. Aging for cold-rolled Al-Cu-Mg alloys at various times resulted in improved ductility regardless of aging time. The uniform elongation increased as aging progressed from 0.03 ks to 0.6 ks, and local strain in the vicinity of the fracture point was concentrated at multiple locations in some specimens.

09:20AM - 05:25PM

GLC 222

Modelling and Simulations (process and products)

Development of Integrated Computational Materials Engineering (ICME) Framework to Predict Mechanical Properties of AlSi7MgMn in a Structural Component Manufactured with High-Pressure Die Casting (HPDC)

09:20AM - 09:45AM

Presented by:

Yang Li, Research Scientist, Ford Motor Company

Co-authors :

Yang Huo, Research Engineer, Ford Motor Company

Mei Li, Technical Leader, Ford Motor Company

Miao He, Postdoc, University Of Michigan

Yue Fan, Associate Professor, University Of Michigan

Xiaohua Hu, Scientist, Oak Ridge National Laboratory

High-pressure die casting (HPDC) has been embraced by the automotive industry as a promising option to produce large structural components, especially for electric vehicles. Previously HPDC process has been appliy in production of engine parts, chassis components and small structural components. However, the most recent application of HPDC on large structural castings pose tremendous challenges that are uncharted in existing studies. The inhomogeneous mechanical properties of HPDC AlSi7MgMn induced by both the rapid cooling during solidification and the postprocessing have not been studied systematically. The absence of consideration of process-induced material properties in computer aided engineering (CAE) simulations, along with the stochastic nature of HPDC components, make the design and optimization process of such structural automotive components highly challenging. To improve the efficiency of the structural design process, an Integrated Computational Materials Engineering (ICME) approach has been developed in the present study. The ICME approach features the integration of several physics-based models across different length scales and processes, namely, a) component-level HPDC process simulation, b) kinetic Monte Carlo and CALPHAD models for precipitates evolution and c) multiscale finite element simulation to predict local material properties and d) mapping procedure to assign local mechanical properties to CAE crash simulations. The design optimization via the developed ICME workflow is demonstrated on a subscale component made with HPDC AlSi7MgMn.

Multi-scale Simulation of Formation of Si-Dominated Precipitates in Heat-treated HPDC AlSi7MgMn Alloys

09:45AM - 10:10AM

Presented by:

Miao He, Postdoc, University Of Michigan

Co-authors :

Yue Fan, Associate Professor, University Of Michigan

Yang Huo, Research Engineer, Ford Motor Company

Yang Li, Research Scientist, Ford Motor Company

Bita Ghaffari, Ford Motor Company

Mei Li, Technical Leader, Ford Motor Company

In the structural design of materials in automotive industries, a challenge lies in the lack of systematic understanding of how materials microstructures and properties are dictated by manufacturing processes. In particular, unconventional phases, i.e., Si-dominated precipitates, are observed in high-pressure die casting (HPDC) AlSi7MgMn alloy through a non-standard heat treatment. A multi-scale computational framework is developed to understand the mechanisms that govern the precipitation under different heat processing conditions. In this computational framework, nucleation and early-stage growth of precipitates are investigated through vacancy-mediated atomic diffusion in kinetic Monte Carlo simulations. The vacancy migration barriers are predicted from a neural network based surrogate model, which is trained on the results from a series of atomistic simulations. The multi-scale computational framework provides essential insights into the kinetics of the precipitate nucleation process.

Modelling the atom clustering kinetics under the influence of excess vacancies during natural ageing in 6xxx alloys

10:10AM - 10:35AM

Presented by:

Xuezhou Wang, PhD Candidate, Norwegian University Of Science And Technology

Co-authors :

Chunan Li, PhD Student, Norwegian University Of Science And Technology

Yijiang Xu

Dongdong Zhao

Yanjun Li, Norwegian University Of Science And Technology

The clustering of solute atoms is of critical importance in the precipitation kinetics of age hardening Al-Mg-Si alloys. Meanwhile, excess vacancies generated by rapid quenching from solutionizing temperature play crucial roles in these kinetic processes, especially during natural ageing (NA). In this work, a numerical model has been developed to simulate the evolutions of atom clusters under the influence of excess vacancies during NA. In the model, the interplay between cluster growth and vacancy evolution has been well addressed. The growth of atom clusters is controlled by the absorption and emission of pseudo-monomers. The trapping of vacancies by solute atoms and growing clusters has been rigorously considered, and the annihilation of vacancies at grain boundaries/dislocations has been simultaneously treated. The model is applied to understand the influences of quenching mode, grain size, dislocation density, and alloy composition on the atom clustering kinetics. The simulation results are compared to the experimental measurements and show a good agreement. This model will help to reach a deeper

understanding of the impact of excess vacancies on atom clustering kinetics and to further optimize heat-treatment parameters and alloy composition for improving the mechanical properties of Al-Mg-Si alloys.

Effects of Mg/Si ratio on clustering behavior using Monte-Carlo simulation in Al-Mg-Si alloys

10:35AM - 11:00AM

Presented by:

JiWook Park, Korea Institute Of Industrial Technology

Co-authors :

DaeHan Kim, Postdoc, Korea Institute Of Industrial Technology

MiYoung Lee, Korea Institute Of Industrial Technology

JaeHwang Kim, Principal Researcher, Korea Institute Of Industrial Technology

The demand for aluminum alloys is increasing, and one representative alloy is Al-Mg-Si, known for achieving excellent mechanical properties through the age hardening. Cluster formation occurs during the age hardening. Analyzing this process using Atom Probe Tomography (APT) is possible, but it has limitations in terms of time and cost. To overcome these limitations, computer simulations offer an alternative. In this study, Monte Carlo simulation was employed among various simulation methods to predict the cluster formation behavior of Al-Mg-Si with different compositions. Subsequently, the obtained results were subjected to the maximum separation method (MSM) to derive the cluster distribution. Cluster analysis was conducted based on this distribution.

CFD Modelling of Liquid Metal Flow Through Tundish and Nose-tip Assembly for Continuous Belt Caster

11:00AM - 11:25AM

Presented by:

Matteo Galuppo, Novelis Global Research & Technology Center

Co-authors :

Shahin Ahmad, Senior Scientist, Aditya Birla Science & Technology Co. Pvt. Ltd.

Pratik Jambucha, Scientist, Aditya Birla Science And Technology Company Private Limited

Simon Barker, Principal Scientist, Novelis Molten Metal Processing Group

Saikat Adhikari, Lead Scientist, Aditya Birla Science And Technology Company Private Limited

Vanessa Li, Program Manager- Advanced Technologies, Novelis Global Research & Technology Center

Sazol Das, Product And Process Innovation Lead For Advanced Technologies, Novelis Global Research & Technology Center

Amit Gupta, Senior Lead Scientist, Aditya Birla Science And Technology Company Private Limited

Vilas Tathavadkar, Senior VP And Function Head- Technology (Metals & Mining), Aditya Birla Science And Technology Company Private Limited

Raj Gopalaswamy, Global Technology Director- New Domains, Novelis Global Research & Technology Center

The continuous belt caster is one of the greatest enablers to establish next generation aluminum processing with reduced number of processing steps along with sustainable solution for carbon footprint reduction. The high turbulence in the liquid metal flow through the tundish and nose-tip is one of the major reasons for various quality and productivity issues in the cast strips. In the present study, a detailed Computational Fluid Dynamics (CFD) model was developed to simulate the liquid melt flow through the tundish and nose tip assembly. The developed model was calibrated using the actual melt level fluctuation data from a plant at various casting speeds. The predicted melt fluctuation level was in close agreement with the actual plant value (< 5 % error). The validated model was utilized to conduct a detailed comparative study to understand the effect of feeding system design and melt temperature on flow behavior. The comparison of recirculation zones and turbulent viscosity was used to identify the optimum feeding system design. The optimization of the feeding system design along with various process optimizations led to an increase of the casting duration by ~3.4 times over a period of nine months.

Die filling studies and development of Two-wheeler Brake Discs out of novel Al-15Mg2Si- 4.5Si composite

11:25AM - 11:50AM

Presented by:

Prosenjit Das, Assistant Professor , Indian Institute Of Science Bangalore

Co-authors :

Mohamed Afraaz Sultan, Indian Institute Of Science Bangalore

Aditya Anand, Indian Institute Of Science Bangalore

In this study, a computational fluid dynamics (CFD) model has been developed to analyse the die cavity filling and solidification processes of brake discs used in commuter motorcycles. Conventional brake discs are typically composed of either steel or cast iron. However, Aluminum Matrix Composites (AMCs) with reinforcing particles, like the novel Al-15Mg2Si-4.5Si is a promising alternative due to its significantly lighter weight while retaining comparable material strength, primarily attributed to Mg2Si as the reinforcing particle. It also offers economic advantages compared to steel, owing to its lower melting point range in contrast to traditional steel and cast-iron materials. The gating system employed in die casting plays a crucial role in minimizing defects in the solidified components. Three different gating systems have been implemented uniformly across both the front and rear brake discs, with a specific emphasis on the bottom gating design. The defects such as entrained air volume, free surface defect and microporosity are discussed to find the optimum die cavity layout.

On the Effect of Flow on Dendritic Solidification in 7xxx Al alloys

01:20PM - 01:45PM

Presented by:

Thomas Flint, Lecturer, The University Of Manchester

Co-authors :

Phil Prangnell, Professor, The University Of Manchester

Pratheek Shanthra, UKEA

Solidification microstructure in metallic substrates largely determine the mechanical properties and influence the fracture toughness behavior. The growth kinetics of dendrites within 7xxx alloys

is strongly influenced by the local composition ahead of the advancing solid-liquid interface as solute species are rejected. Additionally, fluid flow around, and through, the dendrites can act to re-distribute this rejected solute and perturb the growth of dendrites. In this work we use a CALPHAD-informed multi-component, multi-phase field framework, including conservation of momentum, mass, and energy to investigate the role of melt velocity fields in the re-distribution of solute and associated changes to dendritic growth morphologies in 7xxx alloys.

Temperature-Dependent Yield Strength of Particle-Containing Aluminum Alloys

01:45PM - 02:10PM

Presented by:

Olaf Engler, Senior Scientist, Speira Research And Development

Hot tensile tests were performed to assess the temperature and strain rate dependency of the yield strength of particle-containing aluminum wrought alloys. In this class of alloys yield strength accrues from a combination of the intrinsic matrix strength of pure Al, the strength due to second-phase particles and the strength due to alloy elements in solid solution. In Mg-containing Al alloys dynamic strain ageing (DSA) adds an extra strength contribution in a certain range of temperatures and strain rates. For each of these mechanisms a suitable constitutive model was devised; the resultant yield strength predictions were compared to the experimental results of various particle-containing Al sheet alloys.For non-heat-treatable Al alloys where the effect of sub-micron sized dispersoids is predominant, the model is capable of predicting the experimental yield strength with good accuracy, including the general decrease of yield strength with increasing temperature and a rather mild strain rate sensitivity. In Mg-containing alloys the incorporation of DSA was decisive to yield adequate model predictions, especially in an intermediate temperature range where DSA is most pronounced. It is only at very high temperatures and/or low strain rates that the presumed activation of additional rate-sensitive deformation mechanisms led to a significant softening of the Mg-bearing alloys which is not covered by the present modelling approach.

Strengthening effect of single GP-zone and θ' plate in Al-Cu alloys

02:10PM - 02:35PM

Presented by:

Haiwei Zheng, PhD Candidate, Tokyo Institute Of Technology

Co-authors :

Jianbin Liu, Midea Group

Shinji Muraishi, Tokyo Institute Of Technology

Physics-based modelling of precipitation in multi-component aluminum alloys: consideration of natural ageing

02:55PM - 03:20PM

Presented by:

Somayeh Gharavian, Doctoral Researcher, Brunel University London

Co-authors :

Hamid Assadi, Brunel University London

Carla Barbatti, R&D Centre Manager, Constellium

A robust dislocation line tension model considering obstacle strength distribution for yield strength prediction of an Al–Cu–Li alloy

03:20PM - 03:45PM

Presented by:

Purnima Bharti, Research Scholar, Indian Institute Of Technology Roorkee, India

Both spatial and strength distribution of point obstacles, offering an advance approach that outperforms previous yield strength models based on a linear superposition of strengthening mechanisms.

Heterogeneous dispersoid distribution in AA6082: simulation and experimental insights

03:45PM - 04:10PM

Presented by:

Nicolás García Arango

Co-authors :

Erwin Povoden-Karadeniz, Vienna University Of Technology

The objective of this presentation is to computationally simulate the heterogeneous distribution of dispersoids within the microstructure of Mn & Fe containing Aluminum 6xxx alloys. To do so, the initial condition of the material, the element microsegregation, and the nucleation sequence of dispersoids will be considered in a CALPHAD thermodynamic framework. The computational outcome will then be compared to the experimental results obtained.

A new transformation path for the L12- Al3Zr dispersoid, triggered by Cu ternary alloying

04:10PM - 04:35PM

Presented by:

Flemming Ehlers, Associate Professor, Key Laboratory Of Light-weight Materials, Nanjing Tech University

Co-authors :

Lipeng Ding

Mingqi Zhao

Zhihong Jia

Trialimunide dispersoids, conventionally used as grain refiners in commercial Al alloys, have also been examined for decades due to their potential ability to provide hardening with high thermal stability in cast Al alloys. Of primary interest are the Al-Zr-based alloys, where the structural transformation above 450°C of the desired L12-Al3Zr phase to the brittle and more rapidly coarsening D023 phase, however, represents a central challenge. Ternary alloying (and beyond) is considered the most promising route to increasing the L12 stability range while also improving dispersoid number density and homogeneity. Promising results have been reported for Al-Cu-Zr, but without true clarification of the interplay between macroscopic material parameters (alloy composition and heat treatment) and atomistic response (Cu concentration in the dispersoid and long-term consequences). This presentation shows (Ref. 1) that the introduction of ≈16% Cu on the dispersoid Al sublattice may trigger a transformation to an additional, previously unobserved post-L12 phase (composition Al4CuZr), which is found to be an equilibrium phase in AlCu-Zr. Compared to D023, the Al4CuZr phase remains coherent with the Al matrix and may thus represent a preferred post-L12 phase. Theoretical studies indicate that the Cu influence is linked to the speed at which the L12 structural transformation proceeds.

09:20AM - 05:25PM

GLC 323 & 324

Casting and Solidification

Revealing the heterogeneous nucleation and grain growth behaviours of inoculated aluminium alloys by in-situ X-radiographic study and numerical modelling

09:20AM - 09:45AM

Presented by:

Yanjun Li, Norwegian University Of Science And Technology

Inoculation is the most effective method to refine the solidification grain structure of aluminium alloys. In this study, systematic in-situ X-ray radiographic studies on the grain nucleation and grain growth behaviors of Al-Ti-B inoculated Al-Cu alloys have been carried out, where the effect of melt convection is minimized while constant cooling rate, constant temperature gradient and nearly isothermal melt solidification conditions are achieved. The deterministic nature of the heterogeneous nucleation of aluminium grain on inoculant particles is revealed. Numerical microstructure models have been developed to simulate the nucleation and growth behavior of aluminum grains. A comparison between the experimental results and simulation results shows that the model can well address the nucleation behavior and predict the grain size of inoculated aluminum castings. The influences of the addition level of inoculant particles, the cooling rate, the temperature gradient and the solute diffusion layer on the nucleation and grain growth are discussed.

In-situ X-ray imaging and deep learning for solidification science of sustainable alloys

09:45AM - 10:10AM

Presented by:

Enzo Liotti, University Of Oxford

Co-authors :

Shun Yang

Rohit Abraham

Carlos Arteta

Andrew Zisserman

Patrick Grant, University Of Oxford

X-ray imaging has emerged as a crucial technique for investigating metal solidification and manufacturing processes, offering the ability to explore the dynamics of phase transformations with the spatio-temporal resolution inherent in industrial alloy microstructures. Over the past two decades, numerous fundamental insights have been gained into the nucleation and growth of primary and secondary phases, defect formations, morphological instability of dendritic arrays, and elemental segregation.However, the progress in X-ray imaging capabilities - fueled by continuous enhancements in detector technologies and X-ray sources - has notably outpaced advancements in data handling and analytics, giving rise to a significant 'data problem.'This study addresses this challenge by introducing deep learning approaches designed to expedite the data analysis process and amplify the volume of quantified information extracted. Two distinct case studies will be presented: firstly, an exploration of the impact of convective flow on the nucleation and growth of equiaxed dendrites in Al-Cu alloys, and secondly, a novel approach for multi-elemental mapping applied to model ternary Al-Pt-Er alloys.

In-situ X-ray Tomography of Entrained Oxides in Ca-added Al-Mg melts

10:10AM - 10:35AM

Presented by:

Sean Telford

Co-authors :

Marina Galano, Associate Professor, Department Of Materials, University Of Oxford

Keyna O'Reilly, Associate Professor, Department Of Materials, University Of Oxford

Minute (ppm) additions of group II metals (Be, Ca, Sr) eliminate melt oxidation of Al-5Mg alloy almost completely by forming a thin, flexible, protective oxide layer. Reducing oxidation helps reduce oxide entrainment, improving mechanical and casting properties, but the actual behavior of entrained oxides in microalloyed Al-5Mg melts has not been observed until now: here, we observed the behavior of entrained oxides within Al-5Mg (wt.%) melts microalloyed (0, 100 ppm, 300 ppm) with Ca using X-ray microtomography. Radiographical observations of the melt holds revealed the mechanism of deoxidation by calcium, opening novel research avenues into casting quality improvement.

Cellular Automaton Modeling of Microstructure and Porosity Formation in Aluminum Solidification Processing

10:35AM - 11:00AM

Presented by:

Michael Moodispaw, The Ohio State University

Co-authors :

Nicole Trometer, The Ohio State University

Buwei Chen, The Ohio State University

Qigui Wang, General Motors

Wayne Cai, General Motors

Alan Luo, Donald D. Glower Chair In Engineering, The Ohio State University

Microstructure and porosity formed during solidification of aluminum alloys affect the performance of aluminum solidification products such as castings, welds or additively manufactured components. A three-dimensional cellular automaton (CA) model was developed to predict the formation and evolution hydrogen porosity coupled with grain growth during solidification of Al-Si based alloys. The simulation results fully describe the concurrent nucleation and evolution of both solidification grain structure and hydrogen porosity (including the shrinkage effect), yielding the morphology of multiple grains as well as the porosity size and distribution. This model was applied to permanent mold casting and laser welding processes of aluminum alloys. These grain structure and porosity models have been validated by optical metallography and scanning electron microscopy. With relatively large domains and high computational

efficiency, CA models provide critical links between finite-element-based solidification process modeling and structural simulations of solidification products.

In Situ Monitoring of Nucleation and Growth of Al-Fe-Si Intermetallics: Inspiring Alloy Design of Next-Generation Recycling Friendly Aluminium Alloys

11:00AM - 11:25AM

Presented by:

Georges Salloum-Abou-Jaoude, Senior Innovation Engineer, Constellium C-TEC

Today's focus in the aluminium industry is promoting a circular economy, thus meeting the US and the EU's ambition of reducing greenhouse gas emissions. This means replacing primary aluminium with post-consumer scrap, which contains larger quantities of intermetallic forming impurities, particularly Fe and Si, which are detrimental to mechanical properties. We need to develop new generations of impurity-tolerant aluminium alloys enabling reduced carbon footprint through increased recycled content. To meet this objective, it is necessary to deepen our understanding of AlFeSi secondary phase nucleation and growth during aluminium alloy solidification. In this work, model 6xxx recycling-friendly alloys were manufactured and unique in situ directional solidification experiments were performed. For the first time, nucleation and growth of α-AlFeSi and β-AlFeSi intermetallics were observed in real-time in thin samples of model 6xxx alloys. We discuss the effect of chemistry modification and solidification parameters on the AlFeSi phase nucleation and growth.

Towards Diffusion By Design in Solidification: an Ab Initio Molecular Dynamics Study of Al-Mg-Si (-Fe) Melts

11:25AM - 11:50AM

Presented by:

Philippe JARRY, Technical Expert, Constellium C-TEC

Co-authors :

Noel JAKSE, Professor, INP Grenoble

Alaa FAHS, Post Doctoral Fellow, INP Grenoble

Atomistic studies of Al based melts provide insight into solute diffusivity and the corresponding atomic arrangement in the liquid phase which differ from that of the crystal. This arrangement is at the origin of the crystal liquid interfacial energy and the entropy of melting, whose ratio is the Gibbs-Thomson coefficient. Atomistic simulations are then relevant to investigate the basics of the diffusion vs capillarity trade-off governing solidification structure and morphology selection. There are two main drivers for Al alloy design from a solidification point of view. One is maximization of solute supersaturation in alloys for additive manufacturing. Another is to distribute constituent particles as finely and uniformly as possible in the solidification microstructure in a context of increasing recycled content, which can be done by selecting dendritic grain growth morphology. In both cases knowledge of the mechanisms governing solute diffusivity in the melt is essential. Now this property is governed by atomic arrangement, that is, short- and medium- range order in the liquid. The present paper aims at giving an overview of this scientific issue, with a focus on the results obtained by Ab Initio Molecular Dynamics modelling of liquid Al-Mg, Al-Si and Al-Mg-Si alloys, as well as the quaternary Al-Mg-Si-Fe system.

Development of Structural Casting with Digital Twin Technology

01:20PM - 01:45PM

Presented by:

Shouxun Ji, Professor, Brunel University London

Co-authors :

Zhichao Niu

Xixi Dong

Xiangzhen Zhu

In the present paper, we introduced the development of integrated structural castings with digital twin technology for the rear structure of high-end E-sports cars. The topological optimization, casting structural design, materials verification, melt flow and solidification, mechanical property prediction and the final verification using low pressure die casting (LPDC) for the component manufacturing are described in details for digital twin.

Parametric Study and Effect of Aluminium Melt Quality on Final Cast Product Properties

01:45PM - 02:10PM

Presented by:

Shahid Akhtar, Principal Research Scientist, Hydro Aluminium

A study in an automotive casting plant was targeted to address the problem of high rejection rate of a cylinder head casting made from an A354 alloy. Ingots from three different suppliers of an A354 alloy, A, B, and C, were analysed by reduced pressure test (RPT) and pressure filtration (PREFIL) technique. In addition, step castings with section thickness from 5 to 20 mm were produced from ingots of supplier A, B and C at constant hydrogen level (0.2 mL/100g). Hydrogen measurements during casting trials were carried out with an ALSPEK H® analyser. Simulations of the filling path were done by a commercial software package, MAGMA soft. In this paper, we present the results of the characterization from these casting trials. In order to study the influence of transfer and de-gassing on the melt quality, reduced pressure tests were also conducted along the production line. The bi-film index values changes from 389 mm to 50 mm after the final degassing operation before pouring. The effect of melt holding time on the quality of the cast product is also presented. With the in-depth analysis of metal quality, the problem of high scrap rate was significantly reduced when the ingots with highest oxide content from supplier C were replaced.

Development of Novel Casting Processes for Aluminium Industries

02:10PM - 02:35PM

Presented by:

Sanjeev Das, Associate Professor, NIT Raipur

Co-authors :

Prasenjit Biswas, Assistant Professor, OP Jindal University Raigarh

Deepak Patel

Arjun Kundu

Jagadish Nayak

Archana Mallik, Associate Professor, NIT Rourkela

The strength of aluminum (Al) alloys can be improved by adding alloying elements/various reinforcement or/and grain refinement. However, most of the processes of Al alloy, MMC making, and introducing grain refiners (GRs) are either batch type or less efficient. A novel continuous caster to produce Al-based alloys, MMCs, and add GRs during casting was designed and developed. The processes showed significant improvement in cast quality and reduction in production cost. It's well-known transforming the cast columnar grain structure into an equiaxed grain structure improves the formability and reduces the macro-segregation of the cast product. Force convection (FC) technology is one of the technologies, which shows significant refinement in grain size in cast alloy without the addition of GRs. However, introducing the FC technology with the existing metal casters like Direct Chill (DC) caster and Twin Roll Caster (TRC) is extremely challenging. Various casters and FC technologies have been designed, manufactured, and integrated to achieve high-quality cast products. Initially, the concept design was tested by a water model, followed by computer-based simulation, and the machine was manufactured. The products obtained using these technologies were subjected to various characterization techniques to evaluate their physical and mechanical properties.

Stability and Sedimentation of TiC and SiC Reinforcement Particles in Al-Mg-Si-(Cu) Alloy

02:55PM - 03:20PM

Presented by:

Abdallah Abu Amara, Doctoral Researcher, BCAST, Brunel University London

Co-authors :

Guangyu Liu

Brian McKay

The rate of sedimentation and the stability of TiC and SiC reinforcement particles in aluminium were studied. The particles were added to the aluminium melt and held for 2 hours at 720°C. Samples were taken from the melt at regular time intervals and cast in a permanent mould. The chemical compositions and microstructures of the castings were investigated. XRD analysis was also carried out. Experimental results indicate that both particle types sediment over time, showing consistency with theoretical calculations using Stoke's Law. Nevertheless, some discrepancy between the practical and theoretical results is imminent due to factors such as particles agglomerating in practice. XRD results show that with time, the TiC and SiC particles react with the aluminium matrix to form aluminium carbide (Al_4C_3), an undesirable phase due to its instability and brittle characteristics. In the case of TiC, titanium aluminide ($TiAl_3$) also forms

over time. This phase, with blocky morphology is identified in the microstructure. The main concluding point of the study is that aluminium metal matrix composites incorporating TiC or SiC particles should be processed in a short time (between 5-10minutes) to avoid the formation of undesired phases and the sedimentation of particles.

Flux-Assisted Sessile Drop Method on the Stability and Wettability of Al on TiC

03:20PM - 03:45PM

Presented by:

Ingvild Runningen, PhD, The Norwegian University Of Science And Technology

Co-authors :

Ida Westermann, Heat Of Department Of Materials Science, The Norwegian University Of Science And Technology

Geir Kvam-Langelandsvik, SINTEF Industry

Flux-assisted spreading reveals the intrinsic contact angle of systems characterized by a high affinity for oxygen, where oxide films act as a barrier preventing direct contact. The fluxing agents, capable of dissolving oxides, are crucial in establishing an oxide-free interface between the contacting phases, facilitating intrinsic wetting. In the absence of fluxing agents at the interface, spreading occurs following an extended high-temperature exposure, which is necessary to disrupt the oxide films. Thus, it influences the stability of the Al/TiC system, and the formation of Al4C3 at the interface drives the spreading. This study explores the impact of two fluxing agents, KAlF4 and K2TiF6, on the stability and wettability of the Al/TiC system. When a critical amount of KAlF4 was present at the interface, spreading proceeded within seconds, closely linked to the flux's melting point for pure aluminum and 6082. Equimolar amounts of K2TiF6 facilitated instantaneous, complete wetting in the case of pure aluminum but no wetting for 6082. If wetted, there was no detection of Al4C3 at the interface after 30 minutes at 750 ℃ and 850 ℃, respectively. Flux-assisted wetting highlights the importance of using fluxes to ease particle incorporation and dispersion when synthesizing aluminum matrix composites.

Enhancing the Efficiency of Commercial Al-Ti-B Grain Refiners

03:45PM - 04:10PM

Presented by:

Yun Wang, Senior Research Fellow, Brunel University London

Co-authors :

Jayesh Patel, Brunel University London

John Courtenay, Chairman Of MQP Ltd, MQP Ltd, UK

Zhongyun Fan, Brunel University London

Grain refinement during solidification of engineering alloys is a common practice in metal foundry industry, offering the castings a fine and equiaxed grain structure and thus considerably reduced casting defects for improved engineering performance. External addition of grain refiners was usually applied to enhance heterogeneous nucleation and achieve grain refinement. In this work, the factors affecting the refining efficiency of commercial Al-Ti-B based grain refiner for Al alloys were investigated by advanced electron microscopy of the samples obtained at various stages in the production line. The experimental results show that controlling of the salt reactions and the subsequently isothermal holding of the master alloy melt plays an important role in determining the efficiency of the final products. Suitable combination of holding temperature and period of time is essential to allow the formation of Al3Ti segregation monolayer on the surface of the synthesized TiB2, resulting in a high refining efficiency.

Microstructure and tensile properties of Stirrcast A356-MWCNT composite

04:10PM - 04:35PM

Presented by:

Prosenjit Das, Assistant Professor , Indian Institute Of Science Bangalore

Subodh Kumar, Professor, Indian Institute Of Science Bangalore

Co-authors :

Aditya Anand, Indian Institute Of Science Bangalore

The tensile properties of A356 aluminium alloy are improved by adding multi walled carbon nanotube (MWCNT). The pouring temperature is optimized by computational fluid dynamics modeling as 650°C. To avoid the agglomeration of CNTs, vortex has to be created by stirring the melt. The stirring speed and time are optimized as 600 rpm and 30 minutes, respectively. The effect of optimized stirring and addition of 0.25 wt.% CNT on the microstructure and tensile properties of gravity die cast A356 alloy are discussed. A refinement in microstructure is observed with stirring and CNT addition in terms of decrease in dendrite size (132 to 96 to 73 μm) and inter-dendritic arm spacing (11.1 to 7.6 to 4.7 μm). The addition of CNT facilitates nucleation of primary α dendrites increasing its area fraction in the microstructure from 55% to 71%. Thus, an improvement in tensile properties in the as-cast condition is obtained for virgin A356 alloy (0.2%PS = 88 MPa, UTS = 126 MPa, El = 0.91%) on mechanical stirring (0.2%PS = 107 MPa, UTS = 157 MPa, El = 1.0%) and addition of MWCNTs (0.2%PS = 117 MPa, UTS = 173 MPa, El = 1.25%). The tensile properties in the heat-treated condition will be discussed in the final manuscript.

Effect of grain morphology on the Hall Petch relationship of binary Al-Si alloys

04:35PM - 05:00PM

Presented by:

Shishir Keerti, Doctoral Researcher, Brunel University London

Co-authors :

Hari Nadendla, Brunel Centre For Advanced Solidification Technology

The study explores the Hall-Petch equation's application in metallic materials, emphasizing its correlation with grain morphology by introducing a perimeter-associated parameter. The Hall-Petch equation is widely used to relate the yield strength/hardness of metallic materials with the grain diameter, d in faceted grains structure, and SDAS in dendritic structures. In Al and Mg alloys, the morphology of grain has been observed to change without changing the SDAS, through processing and changing the composition, which raises a need to accommodate the change in morphology of grains in the Hall-Petch relationship. This study proposes a novel Hall-Petch relation , , where p' signifies the area per unit perimeter, offering a more comprehensive

representation of grain morphology changes. The proposed relation is validated through controlled solidification experiments on Al-Si binary alloys, revealing a non-linear relationship between the SDAS and p'. The generic Hall-Petch relationship outperforms conventional representations in describing hardness variations across diverse grain morphologies, such as facetted, rosette, and dendritic structures.

In-line temperature measurement in a laboratory direct chill casting plant for alloy design

05:00PM - 05:25PM

Presented by:

Andreas Weidinger, PhD. Candidate, Montanuniversity Leoben

Co-authors :

Sebastian Samberger, PhD. Candidate, Montanuniversity Leoben, Austria

Florian Schmid, AMAG Rolling GmbH

Stefan Pogatscher, Montanuniversitaet Leoben

A laboratory direct chill casting plant Indutherm VCC3000 is a valuable tool for alloy design. It allows researchers to tailor alloys on a small scale under cooling conditions comparable to those in the industry. This is important for understanding the relationship between alloy composition, microstructure and properties. It allows researchers to test the effects of different alloy compositions and processing parameters quickly and easily on the final properties of the casting. Furthermore, it can be used to produce alloys that have special process engineering requirements, such as increased cooling rates. The aim of this study is to investigate cooling rates during casting through temperature measurements taken at specific intervals. This is crucial for producing castings with fine microstructures and desirable properties. For this reason, the plant is equipped with five thermocouples (TC) to monitor the live temperature during casting. This allows new alloy compositions and processing parameters to be tested under controlled conditions.

11:50AM - 01:20PM

Lunch

01:20PM - 04:35PM

Dr Thomas H Sanders Memorial Symposium on Physical Metallurgy

GLC 225

Dr. T. H. Sanders: Understanding a New Generation of Aluminum Alloys (1974-2023)

01:20PM - 01:45PM

Presented by:

Robert Sanders, Speaker, Chongqing University/Novelis

Co-authors :

James Staley, Alcoa, Inc. - Retired

The abstract describes the career and impact of Dr. Sanders in his nearly 50 year career in aluminum research and development. It will serve as an introduction to the rest of the symposium program.

Kinetic Monte Carlo simulation of automotive 6000 natural ageing

01:45PM - 02:10PM

Presented by:

Christophe Sigli, Technical Expert, Physical Metallurgy, Constellium C-TEC

A Kinetic Monte Carlo model with a residence time algorithm has been developed in order to simulate the natural ageing strengthening kinetics of 6000 automotive alloys. The model input parameters are the solute impurity diffusion coefficient as well as the solute-solute and solute-vacancy interactions. The later are computed with an ab-initio electronic calculation (Quantum Espresso). Some interactions have been adjusted in order to better reproduce the measured evolution of yield strength with natural ageing time. At any time, the simulation predicts the ordering enthalpy due to short range order. The alloy yield strength is deduced empirically from the ordering enthalpy. The model can, for example, predict the impact of the pre-aging temperature or the impact of ambient temperature on the natural ageing strengthening kinetics as a function of alloy composition. Comparisons between simulations and measurements will be presented.

Stress corrosion cracking of 7000 series aluminum in humid air

02:10PM - 02:35PM

Presented by:

Ricky Whelchel, Speaker, Constellium

Co-authors :

Lionel Peguet, Constellium Technology Center
Timothy Warner, Constellium Technology Center
Paul Smith, Constellium Rolled Products

Controlling Crystallographic Texture in AA2195

02:35PM - 02:55PM

Presented by:

Judy Dickson

Aluminum-lithium alloys, such as AA2195, offer weight and strength advantages over traditional aerospace aluminum alloys. However, lithium containing alloys display detrimental anisotropic properties attributed to crystallographic texture development differing from what occurs in non-lithium alloys, namely, that common deformation texture components – Brass, S, and Copper – evolve differently. Prior work identified undesirable combinations of Brass, S, and Copper textures in AA2195. A combination of these components was quantified as the "Plate-Like Number." Positive values of this number had textures resembling that of non-lithium alloys. Negative values were associated with undesirable Al-Li textures. The aim of this work was to investigate methods for controlling texture development during thermomechanical processing. A lab-scale rolling study was conducted in which the rolling temperature and dwell time between rolling passes was systematically varied. Texture component analysis was then performed using x-ray diffraction. Rolling temperature was found to affect the resulting texture most significantly. The highest rolling temperature (515°C) resulted in the highest Plate-Like Number, while the effect of dwell time was inconclusive. Based on this work, use of higher processing temperatures is recommended to reduce texture related anisotropy in Al-Li products.

Thomas H. Sanders, Jr.—A Superb Materials Scientist Who Unselfishly Helped the Aluminum R&D Community

03:20PM - 03:45PM

Presented by:

Joseph Pickens, Retired, Martin Marietta R&D Laboraratory

This presentation describes the impact of Dr. Sanders on a colleague early in his career. He was instrumental in coaching and sharing his experience with industrial processing of Al-Li alloys. The symposia organized by Dr. Sanders were valuable as a forum for sharing research in an emerging area of alloy development.

Effects of Microstructure on Dynamic Tensile Spall Failure of Al 5083 Alloy

03:45PM - 04:10PM

Presented by:

Naresh Thadhani, Speaker, Georgia Tech

Co-authors :

Ricky Whelchel, Speaker, Constellium

Greg Kennedy, Georgia Institute Of Technology

Laszlo Kecskes

Cyril Williams

Dynamic compressive and tensile (spall) behavior of Al 5083 strain hardenable alloy is investigated as a function of textured grain structure due to cold rolling and highly refined equiaxed grain structure produced by equal-channel angular processing (ECAP). Symmetric plate-on-plate impact experiments were performed using the 80-mm single-stage gas gun. Rear free-surface velocity measurements using VISAR interferometry revealed velocity profiles with clear signatures of the dynamic compressive strength indicated by the Hugoniot elastic limit (HEL) and velocity pullback signature and ringing corresponding to tensile spall failure for all impacted samples. The Hugoniot Elastic Limit (HEL) and the spall strength of the rolled Al 5083-H116 plate vary as a function of longitudinal (rolling) and transverse orientations. The properties of the ECAP material are affected by the refined equiaxed microstructure and presence of intermetallic particles that can align and crack due mechanical processing. Consistent with the spall strength differences, variations in spall damage with the fracture surfaces revealing dissimilar modes of ductile and inter-granular fracture were observed from post-mortem microstructural evaluations of the recovered impacted samples. In all cases, cracked brittle inclusions near spall damage regions contribute to nucleation of voids during spall failure.

The utilization of correlated aging response curves to study the decomposition of Al-Zn-Mg-Cu alloys

04:10PM - 04:35PM

Presented by:

Justin Lamb, Moderator, Universal Alloy

Co-authors :

Alexander Malliett, Universal Alloy Corporation
Victor Dangerfield, Universal Alloy Corporation
Thomas Sanders, Georgia Tech

02:35PM - 02:55PM

Afternoon break

04:40PM - 05:30PM

GLC 225

Industrial Applications (Aerospace, Automotive and Packaging)

Wide panel fracture toughness testing of aluminum lithium and conventional aluminum alloys

04:40PM - 05:05PM

Presented by:

Jonathan Beckman, Gulfstream Aerospace

Co-authors :

Nathan Coffee, Gulfstream Aerospace

Fracture toughness properties are a key factor in many aerospace designs. For materials with a high toughness, wide panels are required to fully characterize the plane stress fracture toughness behavior. However, most industry data are based on testing performed using 16-inch or 30-inch wide panels. A number of aluminum lithium options have been released in the last 10 to 15 years that appear to show good promise for low density options with high toughness. Similarly, advances have been made in conventional alloys with improved toughness. In an attempt to optimize properties for use in new designs, plane stress fracture toughness testing was performed with middle tension panels up to 60 inches wide. This testing characterized the K values, R-curves and fracture mode for 8 different aluminum alloys: 2024, 2524, 2624, 2029, 2074, 2198, 2199 and 5028. The effect of panel temper, width, thickness and stretch percentage was also investigated. This presentation will show the results of this testing and discuss the hypotheses and conclusions reached thus far.

Dissimilar friction stir welding and post-weld heat treatment of Ti-6Al-4V and AA7075 producing joints of unprecedented strength

05:05PM - 05:30PM

Presented by:

Georg Kunschert, Austrian Institute Of Technology

Co-authors :

Johannes Österreicher, Senior Scientist, Austrian Institute Of Technology

Christian Pfeiffer, Stirtec GmbH

Thomas Weinberger, Stirtec GmbH

Karl Radlmayr, Voestalpine Metal Forming GmbH

Werner Suppan, Voestalpine Metal Forming GmbH

Figure 1: Weld set up. Dissimilar joining of Ti and Al alloys is considered difficult due to possible formation of brittle intermetallics, leading to inferior joint strength. Friction stir welding (FSW) is an advanced joining method with the potential to drastically reduce or avoid the formation of intermetallic phases because melting is avoided. We friction stir welded Ti-6Al-4V and EN AW-7075 sheets in a butt configuration and analyzed the effects of post weld heat treatments on the mechanical properties. We achieved tensile strengths of 441 MPa in the as-welded condition and 505 MPa after heat treatment, significantly surpassing strength values reported in earlier studies. Microscopic investigations showed no evidence of formation of brittle intermetallic phases and

ductile fracture was observed. Our results show that FSW is a very promising candidate for future aerospace applications requiring dissimilar joining of Ti and Al alloys.

Day 3, Jun 25, 2024

09:30AM - 11:10AM

GLC 233

Emerging Markets and Applications

Microstructure analysis of cold rolled aluminium foil for battery current collector applications

09:30AM - 09:55AM

Presented by:

Joacim Hagström, Research Leader, Swerim AB

Aluminium foil for automotive battery current collector applications is thin, 12 μm, and the development towards thinner foils is ongoing. There are strong demands on the foil properties and to fulfil them and develop them further requires understanding of the thermo-mechanical processes during fabrication. The material needs to be essentially free from defects, and production must be cost efficient. Material properties need to be stable and not change significantly with time. Detailed characterization of the microstructure in thin cold rolled foil is difficult since the large cold reduction creates nano-size grains and sub grains, and the dislocation density is high. TEM can be used for characterization but it is difficult to get texture information and statistically sound results on grains and dislocation density. New methods have been developed for EBSD characterization in the SEM during the last decade which makes it possible to resolve the fine microstructures found in thin foils. TKD, transmission Kikuchi electron diffraction is one method with the power to resolve nanometre size grains and the pattern matching or dictionary indexing technique is another one. This paper describes the techniques and compares them to other established techniques, i.e. TEM and XRD.

AlSiTiB Alloys as Anodes for Aluminum Batteries

09:55AM - 10:20AM

Presented by:

Federico Bertasi

Co-authors :

Arianna Pavesi, Material Specialist, Brembo S.p.A

Giorgio Valota

Mary Angel Abello

Marta Daga

Andrea Bonfanti

The development of alternative to Lithium batteries requires the investigation of new electrodes and electrolytes. This is particularly true in the case of non-aqueous Aluminum batteries which typically include a pure Aluminum anode that: a) suffers of poor cycling stability and low coulombic efficiency; b) is subjected to dendrite growth; c) undergoes corrosion phenomena upon cycling; and d) shows poor compatibility toward chloroaluminate electrolytes.In this regard, the development of Aluminum alloys anodes is a challenging task that is barely investigated in the field of Aluminum batteries and requires experience in both battery electrochemistry and Aluminum metallurgy and casting. In this scenario, the work investigates the synthesis and characterization of Aluminum alloys, comprising Si, Ti and B as alloying elements, as anodes for

Aluminum batteries. Deposition/stripping measurements, impedance spectroscopy, metallography, EDXS, XRD and SKP techniques unveil the complex interplay between the alloy microstructure and the obtained electrochemical performance. Full-battery cycling and post-mortem battery failure analyses are also performed. Remarkable improvements in the: a) oxidation/reduction currents and overvoltages; and b) interfacial stability with the electrolyte; are demonstrated with respect to conventional pure Aluminum anode. Ultimately, results prove that the investigation of Aluminum alloys can be crucial for future Aluminum batteries development.

Aluminum Foil Anodes for Solid-State Batteries

10:20AM - 10:45AM

Presented by:

Matthew McDowell

Aluminum foil anodes alloy with lithium and can exhibit high theoretical charge storage capacity to enable rechargeable batteries with improved energy density, and aluminum is low cost and widely manufactured as foils. However, such materials have long shown poor reversibility in liquid electrolytes. Longstanding issues include excessive solid-electrolyte interphase (SEI) formation and lithium trapping that reduces Coulombic efficiency. Here, we show that aluminum foil-based anodes with engineered microstructures and without pre-lithiation exhibit promising cycling stability within solid-state batteries. Full cells with dense, 30-μm AlxIny foil anodes exhibit hundreds of stable cycles with commercially relevant areal capacities and high current densities (6.5 mA-cm 2), markedly outperforming identical electrodes in liquid cells while avoiding short circuits common with lithium electrodes in solid-state batteries. The solid-state battery architecture is important for minimizing SEI formation, and the multiphase Al-In microstructure enables improved rate behavior and enhanced reversibility due to the networked Li-In phase, which can support fast lithium transport. Further efforts towards optimizing the interface, stack pressure, and work on other compositions is described. This work suggests that metallurgical design of dense aluminum foil anodes could be a pathway to high-performance solid-state batteries.

Alloy Development for High Performance Aluminum-air Battery Anode

10:45AM - 11:10AM

Presented by:

Saikat Adhikari, Lead Scientist, Aditya Birla Science And Technology Company Private Limited

Co-authors :

Shreyas Khot, Manager- Hindalco Innovation Center, Hindalco Industries Limited

Sumit Gahlyan, Assistant General Manager, Hindalco Industries Limited

Gautam Wagle, Assistant Vice President, Hindalco Industries Limited

Adam Weismann, Phinergy Inc

Ilya Yakupov, Phinergy Inc

Aluminum air batteries have been extensively studied for applications in power stations, electrical vehicles, and energy storage systems. High purity Aluminum alloys (>99.99%) are typically used for achieving high energy densities and low corrosion rates. In this work Al-Mg alloys are investigated for achieving high energy densities using commercial grade P0202/P0303 pure

Aluminum. Effect of solutionizing heat treatment on intermetallics within the matrix was studied. The developed P0202 based alloy along with optimization in the casting and heat treatment process was able to deliver up to 7.5% higher energy densities as compared to conventionally used base alloy made from high purity Aluminum alloys.

09:50AM - 12:20PM

GLC 225

Industrial Applications (Aerospace, Automotive and Packaging)

Improving Dimensional Accuracy of Aluminum Extrusion by Inline Calibration

09:50AM - 12:20PM

Presented by:

Torgeir Welo

Co-authors :

Jun Ma, Associate Professor, Norwegian University Of Science And Technology

Ingebrigt Killingberg

In this paper, a new mechanical calibration method with its experimental setup and tooling is presented for improving the dimensional accuracy of extruded aluminum profiles. The method employs the combination of transversal stretching and local bending of cross-sectional members, while minimizing elastic springback to assure high dimensional accuracy. The process capability of the method is experimentally investigated for extrusions with different gap-opening of open U-shapes and twists in the longitudinal direction. Finite element analysis is performed to reproduce the calibration process and provide insights into deformation behavior and governing mechanisms. The results show that the as-extruded aluminum profile can effectively be calibrated with the proposed method, even when initial variations fall well outside the standard industrial tolerance limits of extrusions. It is concluded that the method provides good process capability for correcting gap openings, thus presenting opportunities for advanced inline integration in high-volume manufacturing.

Aluminium Scandium alloy development for hydrogen storage valve

09:50AM - 12:20PM

Presented by:

Francisco García-Moreno

Co-authors :

Tillmann R. Neu, Scientist, Helmholtz-Zentrum Berlin

Paul H. Kamm

For the purpose of the application for an on-tank valve (OTV), various Al alloy series were tested, to which different contents of up to 0.3 % Sc and Zr were added. The hardening curves were plotted for different temperatures and correlated with the corresponding mechanical tests. The alloys were characterized by hardness measurements, tensile tests and corrosion tests. By characterizing the materials, transferring them to simulation models and developing design guidelines, the foundations are laid for technology transfer to other applications of these materials.

Precipitation evolution during long-time ageing in 2xxx alloys: a high-throughput methodology

09:50AM - 12:20PM

Presented by:

Thomas Perrin, SIMaP-UGA

Co-authors :

Pierre Heugue, Material & Process Specialist, Safran Transmission Systems

Alexis Deschamps, SIMaP-UGA

Arthur Després, SIMaP-UGA

Frédéric De Geuser, SIMaP-UGA

Aluminum alloys for the aerospace industry need to be able to withstand thermal aging during duty. Knowledge of the evolution of mechanical properties is essential to predict the end of life of those products. High-throughput characterizations of the microstructural and mechanical properties of samples aged in a temperature gradient for up to 10,000h were carried out on two 2XXX series alloys using SAXS/WAXS and hardness. Models can then be fitted to correlate the microstructural parameters and the mechanical properties. TEM observations were also conducted to validate size distribution and identify potential phase transformations on specific positions in the gradient samples.

Coarse Grain Controlled High-Toughness AA6xxx Extrusion Alloy

09:50AM - 12:20PM

Presented by:

MANU SAXENA, General Manager - Extrusion Technical, Hindalco Industries Limited, Renukoot

Co-authors :

Sumit Gahlyan, Assistant General Manager, Hindalco Industries Limited

AA6xxx alloys are used for various automotive and industrial machinery applications where microstructural characteristics are critical to have acceptable final properties. The demand for high strength alloys in AA6xxx is desirable for light weighting automotive applications. Additionally, there is a requirement of control on Abnormal Grain Growth (AGG) in these alloys, industrially termed as Peripheral Coarse Grain (PCG) restricted to the extent of 1 to 5 % of extrusion profile Circumscribing Circle Diameter (CCD). In this study, development of high strength alloy is presented where process parameter controls and compositional engineering was used to obtain a high toughness extrusion alloy. Additionally, the PCG levels obtained here were well within the limits nearing to zero.

Manufacturing of bright-rolled aluminum suitable for decorative elements in the automotive industry

09:50AM - 12:20PM

Presented by:

Anita Gründlinger, Product Engineer, AMAG Rolling GmbH

Co-authors :

Peter Johann Uggowitzer, Professor

Josef Berneder

This work addresses the manufacturing of bright-rolled 5xxx aluminum alloys, which may be utilized for producing sophisticated design elements in the automotive industry due to their outstanding surface properties as well as excellent processability. Apart from investigations on the microstructure and mechanical properties in temper H2X, addressing the demand for a sufficient formability and paving the way for complex geometries, gloss measurements on brightened and anodized material are carried out. Additionally, phase studies combined with thermodynamic simulations are performed, dealing with the impact of precipitates on the appearance.

Low temperature interrupted quenching improves formability without compromising natural ageing stability and paint bake strength of an Al-Mg-Si alloy

09:50AM - 12:20PM

Presented by:

Jyoti Ranjan Sahoo, Research Scholar, Indian Institute Of Technology Roorkee, India

Low-temperature IQ treatment (80 oC_1h) leads to a higher uniform elongation and fracture strains along different strain paths (uniaxial, plane strain, and biaxial) without affecting natural aging stability.

09:50AM - 04:40PM

GLC 323 & 324

Casting and Solidification

Scandium in the additive manufacturing of Al2618-TiB2 composites

09:50AM - 10:15AM

Presented by:

Xiaoming Wang, Purdue University

Scandium (0.1wt%) is added to Al2618 that is reinforced with in-situ TiB2 particles for additive manufacturing (AM). Significant improvement in both strength and ductility comparing with its wrought matrix alloy is accomplished for the AM products attributed to both grain refinement of the alloy matrix and the ubiquitous dispersion of reinforcing particles at both micro and nano levels. Sc is mainly associated with the particles, homogenizing their dispersion by offering coherent interfacial bounding with the aluminum matrix.

Effect of Li on the structure formation of AlMg5Si2Mn-type casting alloy

10:15AM - 10:40AM

Presented by:

Kostiantyn Mykhalenkov, Researcher, University Rostock

Co-authors :

Viktoriya BOYKO, Researcher, University Rostock

Armin SRINGER, Researcher, University Rostock

Olaf KESSLER, Head Of The Chair Of Material Science, University Rostock

The authors present results of microstructural studies of AlMg5Si2Mn-type casting alloys with Li addition on a broad scale. Li addition leads to the depression of eutectic melting temperature down to 587.2°C at 2.0 wt.% Li, which is a common effect of eutectic modification. The complex addition of Li and AlTi5B1 resulted in a eutectic melting temperature close to the equilibrium eutectic temperature for the Al-Mg-Si system (596.2°C). Li addition does not affect a-Al grain size but changes the morphology of eutectic colonies from petal-like to fibrous. Observation of TiB2 particles inside the primary Mg2Si crystals gives direct experimental confirmation of nucleation of the primary phase on the surface of TiB2 in the alloy after adding Li and AlTi5B1. The cooling of the alloys in mould cavity resulted in the formation of fine precipitates detected close to dislocations, and the precipitate density is proportional to the dislocation density. The most apparent supposition is that the mechanism responsible for their formation is heterogeneous nucleation in the stress field of dislocations. Hardness tests showed that adding 2.0 wt.% of Li is very effective, increasing hardness up to 113 HV0.2, nearly double that of commercial AlMg5Si2Mn high-pressure die-casting alloy.

Eutectic evolution in near-eutectic Sr-modfied Al-Si alloys: The impact of electromagnetic stirring

10:40AM - 11:05AM

Presented by:

Keiji Shiga, Researcher, National Institute Of Advanced Industrial Science And Technology (AIST)

Co-authors :

Yuichiro Murakami, National Institute Of Advanced Industrial Science And Technology (AIST)

Hiroshi Harada, Nagoya University

Naoki Omura, National Institute Of Advanced Industrial Science And Technology (AIST)

Near-eutectic Al-11 wt.% Si alloys containing 0.02 wt.% Sr were solidified in the presence of electromagnetic stirring, and the effect of stirring on the eutectic evolution was elucidated. In the absence of stirring, the alloys exhibited fibrous modified eutectic phases, while those solidified with stirring exhibited spherical eutectic grains containing acicular unmodified Si phases. Two distinct eutectic morphologies were observed within the spherical eutectic grains: acicular in the outer parts and fibrous in the central regions. Optical images of the quenched microstructure revealed that spherical eutectic grains evolved ahead of the eutectic growth front. The application of melt stirring hindered the eutectic modification effect induced by the addition of Sr, as evidenced by thermal analysis, which indicated that the application of electromagnetic stirring lowered the eutectic depression temperature.

Efficiency of in-situ synthesis grain refiner during boron treatment in 1XXX Al alloy

11:05AM - 11:30AM

Presented by:

JIAN QIN, Weiqiao Lightweight Research Center At Soochow

Co-authors :

MEIXU Cheng

YI LI

HIROMI NAGAUMI

3C products require excellent surface quality, high strength, and especially electronic conductivity of Al extrusions. Transition impurity elements in Al alloys have a significant effect on electrical conductivity. To fulfill the requirements of 3C products, these elements are usually removed by B treatment. Herein, a novel approach was proposed to refine the grain size by in-situ synthesis of XB2 particles formed via B treatment. The conductivity of 1060 alloy was improved by boron treatment, which was close to pure Al. Besides that, we found XB2 particles formed in boron treatment effectively refine the grain size of 1060 alloy. Agglomeration of XB2 refiners was barely observed. Effect of boron addition, molten temperature and reaction time on grain refinement was examined. The optimized in-situ synthesis grain refiner parameters were given. The refining mechanism of borides was also elucidated. (Ti,V,Cr,Zr)B2 can act as nucleation sites owing to the several nanometer-thick Al3Ti layers on its surface, which are coherent with the alpha-Al matrix. Unlike TiB2, (Ti,V,Cr,Zr)B2 has no orientation relationship with either the alpha-Al nor Al3Ti layer. Present study may provide a method to reuse impurity elements and guide the development of a superior grain refiner.

Microstructural Evolution, Mechanical and Corrosion Properties of Highly Recycled Aluminium Alloys

11:30AM - 11:55AM

Presented by:

Hirenkumar Kotadia, Senior Lecturer , LJMU

Microstructural Evolution, Mechanical and Corrosion Properties of Highly Recycled Aluminium Alloys

Influence of Ti on microstructure of high-strength Al-Mg-Si-Cu extrusion alloy

11:55AM - 12:20PM

Presented by:

Pavel Shurkin, Research Fellow, Brunel University London

Co-authors :

Geoff Scamans, Head Of Industrial Research, BCAST, Brunel University London

Carla Barbatti, R&D Centre Manager, Constellium

Tungky Subroto, Lead Research Metallurgist, Constellium University Technology Centre, Brunel University London

Nilam Barekar, Lead R&D Metallurgist , Constellium University Technology Centre, Brunel University London

The addition of Ti within an Al-Ti-B rod to refine the primary Al grains is a routine procedure during the casting of AA6xxx alloys, enabling the production of high-density cast billets. In the case of alloys containing some peritectic elements, an excessive grain refiner is necessary to overcome the so-called "poisoning effect." However, there is always a maximum specification limit for Ti content, which might be exceeded when utilizing post-consumer scrap encountered multiple grain-refining cycles. This study sheds light on the microstructure evolution after DC casting, homogenization, and large-scale extrusion of a high-strength Al-Mg-Si-Cu extrusion alloy doped with 0.1 wt% of Ti, in comparison with a reference alloy. Optical and scanning electron microscopy was used to investigate the grain structure, the distribution of elements among second phases, their size, morphology, and population. Additional microstructure features, such as undissolved Al_3Ti crystals and primary $(Al, Si)_3(Ti, Zr)$ phases, were observed. The Al_3Ti crystals were found uncrushed after extrusion which, however, did not influence the efficiency of dispersoids as grain pinning agents. The age-hardening response was hardly affected by Ti, as evidenced by measurements of hardness and electrical conductivity measurements.

Revealing the dynamics and mechanisms of Fe-rich intermetallic compound refinement for Fe-tolerant alloy recirculation

01:50PM - 02:15PM

Presented by:

Shikang Feng, University Of Oxford

Co-authors :

Patrick Grant, University Of Oxford

Enzo Liotti, University Of Oxford

In engineering Al alloys, second-phase intermetallic compounds (IMCs) that form during casting control critically alloy mechanical properties, corrosion performance and recyclability, despite their relatively low volume fraction (typically < 5 vol.%). Due to the ubiquity of Fe in alloy feedstock, especially as the recycled fraction increases, Fe-rich IMCs form during solidification, generally in coarse (typically 50 μm to several millimetres), anisotropic morphologies. These IMCs, such as θ-$Al_{13}Fe_4$, α- and β-AlFeSi cannot be fully re-dissolved during downstream heat treatment, and can cause severe stress localisation and undermine alloy tensile ductility and toughness. These aspects hinder high-value upcycling of increasingly abundant post-consumer Al resources. Therefore, understanding Fe-rich IMCs has remained an active area of research, with a particular interest in refining their size as a means to render them more mechanically benign. Nonetheless, there remains opportunity for deepening the understanding of how to manipulate IMC formation through composition and solidification changes. We use in situ X-ray radiography, complemented with post-solidification electron backscattered diffraction (EBSD) and X-ray computed tomography (XCT), to investigate systematically the formation of $Al_{13}Fe_4$ that is found in a wide range of commercial Al alloys, using a model hypereutectic Al-Fe alloy. First, we show with a large real-time imaging dataset how IMC number density and formation rate can be effectively enhanced by inoculant additions and control of solidification conditions. Then, using a large post-solidification crystallographic dataset, we reveal reproducible IMC-inoculant orientation relationships, despite low crystal symmetry. We show a strong link between the formation of IMCs on inoculants and a twinning-induced IMC pseudo-symmetry. Finally, a strategy to explore effective IMC refiners for high Fe-containing commercial alloys is proposed, aiming to better exploit low-carbon, recycled Al and ultimately to lead to greater alloy recirculation.

Up-scaling melt conditioning treatments for Low Pressure Die Casting

02:15PM - 02:40PM

Presented by:

Jaime Lazaro-Nebreda, Research Fellow, Brunel University London

Co-authors :

Erdem Karakulak, Research Fellow, BCAST, Brunel University London

Jayesh Patel, Brunel University London

Hari Nadendla, Brunel Centre For Advanced Solidification Technology

Geoff Scamans, Head Of Industrial Research, BCAST, Brunel University London

Zhongyun Fan, Brunel University London

This study examines upscaling melt conditioning treatments developed at BCAST from laboratory to semi-industrial scale for Low Pressure Die Casting. Melt cleanliness monitoring and X-ray inspection demonstrated both macro-porosity control and a reduced rejection rate. Grain size, porosity level and mechanical properties were assessed on over 100 castings with good correlations between them. These upscaling activities are the first step towards implementing these novel processes in industry.

Extraction and characterization of intermetallic particles extracted from DC cast AA8021

02:40PM - 03:05PM

Presented by:

Sarah George, Senior Lecturer, University Of Cape Town

Co-authors :

Tshepo Maluleka

Gerard Leteba

The constituent intermetallic particles (IMPs) that form during the direct chill (DC) casting of aluminium alloys are critical features responsible for property development during downstream processing. The structural characterization of these IMPs and the mapping of their evolution during homogenization, in terms of phase identification, structure and composition is poorly understood, although important, as the starting structure of the IMPs underpins the evolving structure during homogenisation as well as the microstructure and property development in the downstream process, such as hot and cold rolling. Here, we report the characterization of IMPs extracted from DC cast AA8021 using transmission electron microscopy (TEM) and scanning (STEM) to investigate the local structure and elemental distribution within individual particles. We find that the as-extracted IMPs coexist in complex crystalline mixtures of elongated, rod-like, near-spherical, irregular, and cuboidal geometries. High-angle annular dark field imaging (HAADF) in a scanning transmission electron microscope (HAADF-STEM) with energy dispersive spectroscopy (EDS) analysis reveals homogeneous distribution of different elements within the IMPs, with Al-enrichment on the surface. The results highlight the importance of assessing the geometrical formation, elemental distributions, and phase identification of these IMPs. The high-level characterisation information will inform alloy, homogenisation or processing parameters for final properties.

Investigation of Solidification Behavior and Quality of Continuous Cast Al-Mg2Si Composite Sheet with Varying Thickness

03:05PM - 03:30PM

Presented by:

Dheeraj Saini, Ph.D. Student, Indian Institute Of Technology Roorkee, India

Co-authors :

Pradeep Jha, Professor, IIT Roorkee

The present work investigates the effect of varying sheet thickness on the quality of Al-Mg2Si composite sheets fabricated using twin-roll continuous casting. The study involved numerical investigation and experimental studies. The numerical model was validated against the experimentally measured eutectic interlamellar spacing. A coupled three-dimensional fluid flow and heat transfer model was developed to investigate the solid fraction variation in the melt pool. Experimental studies involved the fabrication of 3 mm, 4 mm and 5 mm thick composite sheets based on the insights gained from numerical investigation. Results show that the thicker sheets cool down more slowly, posing a risk of incomplete solidification during rolling, which could disrupt continuous production. Therefore, with increasing sheet thickness, a lesser pouring temperature is required for the successful continuous operation. Fabrication of 3mm, 4mm, and 5 mm thickness composite sheets requires an inlet temperature of 831 K, 831 K - 826 K and 826 K, respectively. Furthermore, thicker sheets may increase porosity and centerline segregation due to more significant volume shrinkage.

Effect of nozzle tip shape on periodic surface pattern of Al-3%Si-1%Fe alloy twin-roll cast strips.

03:50PM - 04:15PM

Presented by:

Seina Kurotatsu, Student, Tokyo Denki University

Co-authors :

Yohei Harada

Shinji Kumai

The vertical-type high-speed twin-roll casting is expected to realize a highly productive upgrade recycling of aluminum alloys. However, strips fabricated by this method have periodic surface pattern, which adversely affect mechanical properties and appearance quality. The surface patterns are thought to be caused by the vibration of the molten metal in the gap at the contact point between the nozzle tip and roll surface. In the present study, the effect of the nozzle shape on the surface patterns of Al-3%Si-1%Fe alloy. Normal nozzle with the nozzle tip parallel to the casting direction and bent tip nozzle with the nozzle tip toward the roll center were prepared. Furthermore, microstructural observation and composition analysis on the surface and in the cross-section of the strips were performed, and the influence of the nozzle tip shape was considered. Normal nozzle formed a periodic surface pattern. However, bent tip nozzle formed no periodic pattern on the strip surface and the entire surface was un-shiny. The cooling rate of the strip with the bent tip nozzle was lower than that with the normal nozzle. As a result, the surface is roughened by Al-Fe-Si intermetallic compound particles and Si enriched areas, and the entire surface is considered to be un-shiny.

Novel Direct Chilled- Rotor Stator Device Technique for Synthesis of Al-12.6 Si Alloy and Eutectic Silicon Modification

04:15PM - 04:40PM

Presented by:

Prasenjit Biswas, Assistant Professor, OP Jindal University Raigarh

The primary objective of this study is to establish a casting methodology for eutectic Al-Si alloy, focusing on the modification of eutectic Si without the incorporation of external modifiers. Traditional casting techniques typically involve the use of rare earth materials such as Strontium or other substances like Na, Ca, Sb, which serve as modifiers. However, these modifiers not only escalate the overall production cost but also contribute to the formation of numerous casting defects. In this investigation, the Al-12.6 alloy was subjected to casting using a direct chill caster, wherein a innovative Rotor Stator Device was employed for achieving temperature homogenization. The implementation of this device resulted in a modified final cast structure, which was subsequently compared with that of conventionally cast samples. The study aimed to assess the efficacy of this novel approach in achieving eutectic Si modification without resorting to external modifiers, thus offering potential cost savings and minimizing casting defects.

09:50AM - 05:05PM

Corrosion, Surface Treatments and Environment Sensitive Fracture

GLC 235

Measurement of Coating Protection from Environment Assisted Cracking

09:50AM - 10:15AM

Presented by:

Victoria Avance, Senior Materials Engineer And Project Manager, Luna Labs

Co-authors :

Rebecca Marshall, Luna Labs

Alexander Lilly, NAWCAD

Steven Kopitzke, NAWCAD

Fritz Friedersdorf, Senior Technical Fellow, Luna Labs

Environmentally assisted cracking (EAC) of high strength aluminum alloys in corrosive atmospheres presents significant maintenance and safety issues for aircraft and other lightweight structures. Corrosion inhibiting coatings are the primary means of protecting these structures from atmospheric corrosion in harsh environments. Generally, standard test methods for evaluating performance of corrosion inhibiting coatings do not incorporate a stressed substrate, and significant risk is assumed if these tests are used to infer protection from EAC. A test system and method have been developed to assess corrosion inhibiting coatings and their capacity to protect structures from EAC initiation in corrosive atmospheres. It is well known that EAC initiation and propagation are influenced by the interactions of load, environment, and alloy properties.These factors were considered in producing a method to quantify resistance to crack initiation provided by protective coatings using an EAC susceptible high strength aluminum alloy (AA7075-T651) fracture sample. Accurate assessment of coating performance will reduce the risk associated with introduction of new environmentally compliant coatings. A corrosive environment, smooth-notch double cantilever beam fracture sample, static loading mechanism, and continuous monitoring system are employed to measure cracking throughout an atmospheric corrosion test. Results demonstrate a strong dependence of the EAC resistance on inhibited primer type.

Evaluation of the Suitability of SCC-Tests for Screening 7xxx Automotive Sheet Materials

10:15AM - 10:40AM

Presented by:

Dietrich Wieser, Consultant, Aluminium Deutschland E.V.

To evaluate the suitability of different laboratory tests for determining the stress corrosion cracking (SCC) resistance of thin 7xxx series sheet, five laboratory corrosion tests have been performed on six different 7xxx series alloys. Three alloys containing Cu and three alloys with low Cu-content have been selected, with each of the two groups including an alloy representing a material with high resistance, an alloy with limited resistance and an alloy with high sensitivity against SCC. The results of the laboratory tests have been evaluated by comparing with those from a 2-year truck exposure and a 4.5-year seacoast environment exposure.All tests performed on the extremely SCC-sensitive and on the highly SCC-resistant materials show a very good conformity with the results from field testing. But materials with limited resistance to SCC – which have a moderate but still existing sensitivity to SCC - show a higher correlation of the results when tensile loaded specimens are tested (independent if loaded with constant strain or with constant stress).

EFFECT OF GRAIN SIZE ON THE IGC AND SCC RESISTANCE OF 7075 ALLOY

10:40AM - 11:05AM

Presented by:

Ganesh Bhaskaran, Global Roadmap Leader, Novelis Inc

Co-authors :

Preet Singh, Professor, Georgia Institute Of Technology

Yudie Yuan, Principal Scientist, Novelis

The effect of grain size on the stress corrosion cracking (SCC) resistance of 7075-T6 (Novelis Advanz s701) alloy is investigated in this work. Two distinct processing methods (cold work and recovery anneal) were used to make materials with different grain sizes. The samples were subjected to SCC test in ASTMD 1384 +1% H_2O_2 solution using a slow strain rate test. The fractographs showed that in smaller grain material brittle intergranular fracture was dominant while in the coarse grain material, ductile fracture was dominant. Focused ion beam (FIB) cross sections lift-out adjacent to the crack tip clearly showed that the crack propagation was along the corroded grain boundaries in smaller grain material. In coarse grain material, the fracture originated from the pitting corrosion sites and propagated in transgranular mode. The improved SCC resistance of the coarse grain material was attributed to discontinuous coverage of precipitates along the grain boundaries. By proper processing measures, we can control or even improve the SCC resistance of the 7075 – T6.

Stress corrosion cracking of high strength Al-Zn-Mg-Cu alloy with Mn-rich dispersoid and T phase

11:05AM - 11:30AM

Presented by:

Jianwei Tang, Post-doc, Kyushu University

Co-authors :

Yafei Wang, Kyushu University

Hiro Fujihara, Assistant Professor, Kyushu University

Kazuyuki SHIMIZU, Associate Professor, Tottori University

Kyosuke HIRAYAMA, Assistant Professor, Kyoto University

Hiroyuki Toda, Professor, Kyushu University

T phase and Mn-rich dispersoid were introduced into high strength Al-Zn-Mg-Cu alloy to suppress stress corrosion cracking (SCC). 4D X-ray microtomography observations of the SCC process demonstrated the evidently inhibited crack initiation and propagation behaviors due to the T phase and enhanced corrosion resistance induced by Mn-rich dispersoid. A synergy of T phase and Mn-rich dispersoid leaded to a superior comprehensive mechanical property with relatively high strength (up to 750 MPa) and large elongation (up to 10.2%). This work is anticipated to promote an effective strategy for mitigating the SCC by considering both anodic dissolution and hydrogen embrittlement (HE).

Effect of zinc to magnesium ratio on the SCC resistance of high solute 7xxx alloys in a humid environment

11:30AM - 11:55AM

Presented by:

Ganesh Bhaskaran, Global Roadmap Leader, Novelis Inc

Co-authors :

Preet Singh, Professor, Georgia Institute Of Technology

Yudie Yuan, Principal Scientist, Novelis

XIAOXIANG YU, Senior Scientist, Novelis

The effect of the Zn to Mg ratio on the environmental cracking susceptibility of the high solute 7xxx series alloy was studied. In a high-humidity environment, the alloy composition had a direct effect on the days to failure. The alloy composition appears to influence the grain boundary microstructure specifically along the precipitate free zone. Fracture surface examination confirmed the crack propagated along the grain boundary leading to the brittle fracture features such as cleavage-like morphology. Under tested conditions, surface oxidation was the anodic reaction, and no sign of localized pitting or IGC was observed in high-solute alloys. Density functional theory (DFT) calculations were used to identify the causation behind the correlation and to validate the experimental observations. The results implied that hydrogen-enhanced decohesion (HEDE) appears to be the operating mechanism under these tested conditions

Hydrogen-tolerant ultra-high-strength aluminum alloy

11:55AM - 12:20PM

Presented by:

Hiroyuki Toda, Professor, Kyushu University

Co-authors :

Yafei Wang, Kyushu University

Jianwei Tang, Post-doc, Kyushu University

Hiro Fujihara, Assistant Professor, Kyushu University

Nozomu ADACHI

Yoshikazu Todaka

Hydrogen causes quasi-cleavage or intergranular fracture (QCF/IGF) in solid metals, which is vital especially for ultrastrong alloys. We introduce a new approach to ameliorate hydrogen embrittlement of ultrastrong Al alloys by incorporating potent hydrogen traps into an ultra-fine-grained matrix. The nanoprecipitates that survive severe plastic deformation prove non-trivial and exploitable for hydrogen trapping. Alloys with and without such precipitates exhibit markedly contrasting mechanical properties, as meticulously validated by three-dimensional observations. This study may inspire innovative design techniques for H-tolerant ultrastrong alloys.

Hydrogen-induced nanovoid and intergranular cracking in a novel Al-Zn-Mg-Cu alloy

02:15PM - 02:40PM

Presented by:

Kazuyuki SHIMIZU, Associate Professor, Tottori University

Co-authors :

Hiroyuki Toda, Professor, Kyushu University

Motomichi Koyama, Associate Professor, Tohoku University

Kyosuke HIRAYAMA, Assistant Professor, Kyoto University

Masayuki Uesugi, Senior Researcher, Japan Synchrotron Radiation Research Institute

Akihisa Takeuchi, Senior Researcher, Japan Synchrotron Radiation Research Institute

T-phase-precipitated Al-Zn-Mg-Cu alloys have been posited as aluminum alloys that exhibit elevated resistance to hydrogen embrittlement and superior strength. The preferential precipitation of the T phase, denoted as Mg32(Al, Zn)49, rather than the conventional η phase, MgZn2, is achieved through careful manipulation of the Mg content and the control of aging conditions. The T phase, with its capability to sequester hydrogen within its confines, can be precipitated on the order of a few nanometers. Notably, in T-phase-precipitated alloys devoid of trace Zr, mitigation of hydrogen-induced quasi-cleavage fracture is apparent; however, conspicuous intergranular fracture manifestations are discernible on the fracture surface. We postulate that while the precipitate phase within the grain interior comprises the T phase, η phase precipitation occurs at the grain boundary. Consequently, it is hypothesized that the presence of hydrogen attenuates the decohesion energy between the interface of η phase and the grain boundary, culminating in interfacial debonding and the consequent formation of interfacial voids. This investigation is undertaken to elucidate the underpinnings of intergranular fracture, shedding light on the intricate interplay between precipitate phases and hydrogen embrittlement.

3D analysis of hydrogen embrittlement mechanism in Aluminium alloy by 3D-TEM observation

02:40PM - 03:05PM

Presented by:

Kyosuke HIRAYAMA, Assistant Professor, Kyoto University

Co-authors :

Miharu DOI, Kyoto University

Hiroyuki Toda, Professor, Kyushu University

Hiro Fujihara, Assistant Professor, Kyushu University

Kazuyuki SHIMIZU, Associate Professor, Tottori University

Previously, we have shown from first-principles calculations that hydrogen concentration at the interface between the aged precipitate particles and aluminium parent phase, causes semi-spontaneous interfacial debonding. We have proposed from indirect experimental results that this debonding of the precipitate interface is the mechanism of hydrogen-induced quasi-cleavage fracture. In order to investigation the mechanism of quasi-cleavage fracture due to hydrogen

embrittlement of Al-Zn-Mg alloys, 3D observation just below the fracture surface was performed by 3D-TEM. As a result, changes in precipitate morphology and damage were observed just below the fracture surface.

Simulating crack tip H-controlled crack growth kinetics in Al-alloys using a coupled chemo-mechanical phase field damage model

03:05PM - 03:30PM

Presented by:

Cameron Grant, PhD Student, The University Of Manchester

Co-authors :

Phil Prangnell, Professor, The University Of Manchester

Tim Burnett, Professor, University Of Manchester

Pratheek Shanthra, UKEA

Sharan Roongta, Post-Doctorate, Max Planck Insitut Für Eisenforschung Gmbh

Environmentally Induced Cracking (EIC) of 7xxx series aluminium alloys involves interactions between multiple physical phenomena, which ultimately influence the in-service life of critical components. In this work, we present a new model to study hydrogen (H) -assisted intergranular fracture, which is implemented in the Düsseldorf Advanced Material Simulation Kit (DAMASK). It includes the coupling of crack tip H generation and transport, crystal plasticity, and trapping of H at dislocations, grain boundaries (GB), and attraction to the crack tip stress field, to predict crack propagation at the microstructural length scale. When applying the model to study EIC in 7xxx series aluminium alloys, the implementation of local H production at the crack tip and passivation of the crack wake has provided novel insight into the kinetics and crack driving forces for microstructurally short cracks, exposed to a humid environment. Importantly, while simulating realistic grain structures, the model produces consistent predictions with the crack velocities measured in experimental 4-point-bend EAC performance tests.

The Influence of Partial Recrystallisation on Hydrogen-Environmentally Induced Cracking (H-EIC) of AA7085 in Humid Air

03:50PM - 04:15PM

Presented by:

Juhi Srivastava, PhD, The University Of Manchester

Co-authors :

Phil Prangnell, Professor, The University Of Manchester

Tim Burnett, Professor, University Of Manchester

The effect of partial recrystallized grain structures on the Hydrogen (H) -Environmentally Induced Cracking (H-EIC) behavior of AA7085 has been systematically investigated in thick plates, re-processed by hot rolling within the range of 300–470 °C to generate different levels of recrystallization. In-situ optical monitoring was employed with four-point bend tests, performed in warm-humid air (50% RH & 70 °C), to study the H-EIC initiation and short-to-long crack transition behavior. Increasing the fraction of recrystallised grains from, near zero (2%) to ~ 20% is shown to lead to a more erratic short crack behavior, and tortuous long crack path, which reduces the overall crack propagation velocity, but with higher levels of recrystallization (i.e. 40%) the long crack growth rates increased again. These findings reinforce the significant influence of grain structure on the H-EIC behaviour of 7xxx Alloys..

Hydrogen embrittlement resistance of Al-Zn-Mg-Cu alloy processed by surface severe plastic deformation

04:15PM - 04:40PM

Presented by:

Toshiaki Manaka, Associate Professor, National Institute Of Technolgy(KOSEN), Niihama College

Co-authors :

Kento Okimoto, Advanced Course Student, National Institute Of Technolgy(KOSEN), Niihama College

Al-Zn-Mg-Cu alloys show high strength but high susceptibility to hydrogen embrittlement (HE). Over-aging is effective to prevent HE, however, the strength decreases due to coarsening of precipitates in grain interior. In this study, surface severe plastic deformation, sliding friction treatment (SFT) was applied to Al-Zn-Mg-Cu alloy in order to achieve both high strength and high-resistance to HE. After solution treatment, SFT was performed on the specimen surface and followed by aging at 120 oC for 24h. SFT resulted in grain refinement and increasing of hardness near the surface. HE sensitivity was evaluated by slow strain rate tensile test in humid air (HA) and dry nitrogen gas (DNG). The specimens in peak-aged and over-aged conditions were also used. In the peak-aged specimen, elongation in HA was smaller than that in DNG due to hydrogen embrittlement. The over-aged specimen showed almost same elongation in the two environments but the strength decreased compared to the peak-aged specimen. The specimen processed by SFT and aging showed almost the same strength of the peak-aged specimen without degradation of ductility in HA.

Hydrothermal pretreatment of aluminum for automotive applications

04:40PM - 05:05PM

Presented by:

John Hill, Technical Leader- Adhesives, Pretreatments & Mechanical Joining , Ford
Jichao Li, Surface Treatment And Corrosion, Constellium

This work investigated the hydrothermal pretreatment on aluminum alloys to improve adhesive joining performance. The results show the formation of a pseudo-boehmite layer on the Al substrate that can inhibit the corrosion and improve the bonding durability. Several alloys in the form of sheet and extrusion that are commonly used in automotive industry were pretreated, characterized, and tested. The hydrothermal pretreatment appears to be robust to a wide range of process parameters such as temperature and contact time. Furthermore, this pretreatment is environmentally friendly and chemical-free.

Effects of Steam Source Amount on AlO(OH) Film Formation on an Aluminum Alloy by the Steam Coating Process

05:05PM - 05:30PM

Presented by:

Kensuke Kurihara, Doctoral Course, Shibaura Institute Of Technology

Co-authors :

Keita Suzuki

Ai Serizawa

Al alloys are used in various applications, including structural materials for transportation equipment, because of their lightweight and high specific strength. Al has a relatively high corrosion resistance due to the spontaneous formation of a thin oxide film in the air. However, when considering industrial use of Al alloys, their corrosion resistance should be improved more effectively by surface treatment. The steam coating process is a novel surface treatment method to improve corrosion resistance by forming a dense hydroxide film (AlO(OH) film) on the Al alloy's surface through a chemical reaction between the high-pressure, middle-temperature steam and the Al alloy in an autoclave. One of the advantages of this method is that it uses only pure water, resulting in the low environmental impact. On the other hand, it is still unclear what chemical reaction occurs between steam and Al in the process. In particular, the surface states of the Al alloys during the steam coating process should be clarified. In this study, weinvestigated the relationship between the AlO(OH) film thickness and the steam quantity during the steam coating process, where it can be measured quantitatively by varying the amount of ultrapure water introduced as steam source in the autoclave. The film thickness significantly increased when the amount of introduced ultrapure water changed from 80% to 100% of the saturated vapor density. In comparison, no significant change in film thickness was observed when the amount is above 100%. It is considered that the thickness of the adsorbed water layer on the Al alloy surface increased as the amount of ultrapure water increased, and then the thickness of the AlO(OH) film was increased by the accelerated dissolution of Al ions. This shows the reaction of AlO(OH) film formation in the steam coating process occurs in the adsorbed water layer involving a high concentration of Al ions and hydroxy groups formed on the Al alloy surface.

Microstructural Effects of Aluminium Extrusions on Anodizing Quality

05:30PM - 05:55PM

Presented by:

Akshay Deshpande, Deputy Engineer, Hindalco Industries Ltd

Co-authors :

Sumit Gahlyan, Assistant General Manager, Hindalco Industries Limited

Gautam Wagle, Assistant Vice President, Hindalco Industries Limited

MANU SAXENA, General Manager - Extrusion Technical, Hindalco Industries Limited, Renukoot

Eduardo Albuquerque, Hindalco Industries Limited

Aluminium extrusions are anodized in order to improve surface hardness, corrosion resistance and for cosmetic appearance. These anodized components also find usage in automobile applications where significant friction is expected. Due to high surface hardness, these parts can withstand wear, abrasion and have a long life. While the surface hardness is critical, surface aesthetics and anodic layer thickness also important considerations for the customer. The color or shade of the anodized product is dependent on anodizing parameters and microstructural

features. In this study, when microstructures of the samples having different shades were analyzed, key differences were found. It indicates that the presence of coarse dispersoids and their number density has a significant effect on the resulting anodic layer thickness and the color shade generated.

Analysis of transition of oxide layers formed at high temperatures on Al-Mg alloys.

05:55PM - 06:20PM

Presented by:

Hiroki Yoshida, Research & Development Center Marketing & Technology Division, UACJ Corporation

Co-authors :

Satoru Honda, Research & Development Center Marketing & Technology Division, UACJ Corporation

Yoshihiko Kyo, Research & Development Center Marketing & Technology Division, UACJ Corporation

Tadashi Minoda, Research & Development Center Marketing & Technology Division, UACJ Corporation

Oxide layers on Al-1Mg alloys formed by heat treatment at 550 ℃ and sputtered thin oxide films on Au mirror were analyzed with Fourier transform infrared spectroscopy (FT-IR). There are three states in the oxide layer on Al-1Mg: amorphous Al-Mg mixed oxide, amorphous Mg oxide, and crystalline Mg oxide, which were generated in this order with increasing the heat treatment time.

Influence of internal and external hydrogen on stress corrosion cracking behavior in Al-Zn-Mg alloy

01:50PM - 02:15PM

Presented by:

Hiro Fujihara, Assistant Professor, Kyushu University

Co-authors :

Hiroyuki Toda, Professor, Kyushu University

Ken-ich Ebihara, Japan Atomic Energy Agency

Daiki Shiozawa, Associate Professor, Kobe University

Masayuki Uesugi, Senior Researcher, Japan Synchrotron Radiation Research Institute

Akihisa Takeuchi, Senior Researcher, Japan Synchrotron Radiation Research Institute

Al-Zn-Mg alloys have high strength but high sensitivity to hydrogen embrittlement and stress corrosion cracking (SCC). A recent study reported the peculiar behavior that the $MgZn_2$ precipitate interface debond due to hydrogen accumulation. This report led us to believe that SCC could be understood in terms of this debonding behavior. In the present study, local SCC behavior by both of local hydrogen accumulation in the specimen and hydrogen enrichment due to local corrosion around specimen surface was analyzed via multi-modal three-dimensional (3D) image-based simulation. 3D microstructure, corrosion and fracture behavior in the tensile test were visualized by X-ray imaging techniques. In the experimental result of the in-situ tensile test, external hydrogen enhanced hydrogen embrittlement and SCC. Corrosion behavior on surface causes hydrogen-enrichment around surface, resulting enhanced crack initiation. Growth of cracks initiated in early deformation stage was accelerated particularly. These cracks mainly

contributed to fracture. Based on the results of experiment and image-based simulation, the influence of internal and external hydrogen on SCC will be discussed.

09:50AM - 05:55PM

GLC 236

Microstructure Design; Alloying and Heat Treatments

Effect of impurities on recrystallization behavior of hot-rolled Al-1mass%Mn alloys

09:50AM - 10:15AM

Presented by:

Ken-ichi IKEDA, Associate Professor, Hokkaido University

Co-authors :

Kazuha YAMASE

Seiichiro Ii, Principal Researcher , National Institute For Materials Science

Seiji MIURA

In this study, the effects of impurity elements and hot rolling temperature on microstructure formation during heat treatment of hot-rolled Al-Mn alloys were investigated by SEM-EBSD analysis and BSE observations. It was found that the distributions of precipitates and crystallized particles differ depending on the amount of impurity elements, which affects the growth behavior and shape of the recrystallized grains.

Precipitation hardening in Al-Fe-Zr alloys

10:15AM - 10:40AM

Presented by:

Dmitry Eskin, Speaker, Co-organizer, BCAST, Brunel University London

Role of intermediate quenching and dispersoids in controlling planar anisotropy in AA6016-T4 sheets

10:40AM - 11:05AM

Presented by:

Atish Ray, Lead Scientist, Novelis Inc.

Co-authors :

Minju Kang, Novelis Inc.

John Ho, Novelis Inc.

Deep drawability of AA6016 alloy sheets are limited during stamping operation due to high in-plane anisotropy, and lower average r values. In this work we demonstrate improvements to r values by either adjusting the rolling process variables or by adjusting the chemical composition of the alloy. Mechanisms to control Cube texture in annealed aluminum sheets will be presented, and impact of various rolling texture components on r-value will be discussed.

Effects of cooling late on microstructure on Al-Mg-Mn alloys in twin roll casting process

11:05AM - 11:30AM

Presented by:

Hyoungwook Kim, Director/Principal Researcher, Korea Institute Of Materials Science

Co-authors :

Yong-Hee Jo

Yun-Soo Lee

Won-Kyeong Kim

Al-Mg-Mn alloy sheets with different Mg and Mn contents were fabricated by twin roll casting and rolling process and the microstructure and tensile properties of the sheets was investigated. The twin roll cast Al-Mg-Mn alloy sheets had a fine dendrite size and very fine precipitates due to high cooling rate during the casting process. The density of fine Al6Mn precipitates of the annealed sheets increased with increasing Mn and Mg content so that large number of fine Al6Mn precipitates inhibited recrystallization and grain growth in Al-Mg-Mn. The strength of Al-Mg-Mn alloy sheets increased with increasing annealing temperature due to additional precipitation of fine Al6Mn precipitates at elevated temperature. The nano-size precipitates and fine grain size improved tensile and yield strength of the Al-Mg-Mn sheets. Al-Mg-Mn sheets fabricated by twin roll casting and rolling have a superior strength to conventional Al-Mg-Mn alloy sheets due to fine Al6Mn precipitate in Al matrix.

Effect of Indium on the nucleation and precipitation behaviors of α-Al(Mn, Fe) Si dispersoids

11:30AM - 11:55AM

Presented by:

Zhen Li

Co-authors :

JIAN QIN, Weiqiao Lightweight Research Center At Soochow

Hiromi NAGAUMI

Wrought Al-Mg-Si alloys are extensively utilized in the transportation and aerospace sectors due to their exceptional specific strength, machinability, and resistance to corrosion. Retarding dynamic recrystallization process during hot deformation has consistently posed a challenge. The introduction of α-Al(Mn, Cr, Fe) Si dispersoids, formed through homogenization heat-treatment, has demonstrated effectiveness in regulating recrystallization and preventing abnormal grain growth. This study explores the impact of Indium on the nucleation and precipitation of α-Al(Mn, Cr, Fe) Si dispersoids. Experimental findings reveal that an Indium-rich phase precipitates with increasing heat-treatment temperatures. Additionally, these In-rich phases, alongside metastable Mg2Si, were identified as nucleation sites for α-Al(Mn, Cr, Fe) Si dispersoids. The addition of Indium to 6xxx aluminum alloys fosters the nucleation of α-Al(Mn, Cr, Fe) Si dispersoids.

Microstructural Control of DC-Cast 6082 Alloy Through Chemical Modification

11:55AM - 12:20PM

Presented by:

Erdem Karakulak, Research Fellow, BCAST, Brunel University London

Co-authors :

K. M. Sree MANU

Chamini Mendis, Brunel University London

Jayesh Patel, Brunel University London

Zhongyun Fan, Brunel University London

In this study billets of a commercial Al-Mg-Si alloy were cast using direct chill casting with and without addition of rare earth elements (RE) and grain refiner. RE addition changed grain morphology of billets from rosette-like to dendritic which enabled a reduction in secondary dendritic arm spacing. This reduction decreased the average size and increased the number density of the secondary phase particles. Homogenized and non-homogenized billets were extruded. Tensile tests of artificially aged profiles showed that all three variations of the studied alloy have similar mechanical properties with and without homogenization treatment.

Simultaneous improvement of strength and ductility of ultrafine-grained Al-Cu-Mg alloys with aging treatment

01:50PM - 02:15PM

Presented by:

Pengcheng Ma, Ph.D. Student, Graduate School Of Engineering Science Yokohama National University

Co-authors :

Shoichi HIROSAWA, Professor, Graduate School Of Engineering Science Yokohama National University

Zenji Horita

Al-Cu-Mg alloys with three different compositions (Al-4Cu-1.5Mg, Al-4Cu-3Mg and Al-5Cu-3Mg in mass%) were subjected to high-pressure torsion (HPT), and then aged at 423 K. The strength of the three alloys was significantly increased from 380-388 MPa to 734-773 MPa after HPT process because average grain sizes were refined from 62mm to 190-220 nm. By the subsequent aging treatment, furthermore, the strength was further increased to 798-802 MPa with increased elongation to fracture from 12.1% to 14.6% and from 7.1% to 8.5% in Al-4Cu-1.5Mg and Al-4Cu-3Mg alloys, respectively. Such a simultaneous improvement of strength and ductility was attributed to the coupled effects of precipitation hardening by nanoscale precipitates and softening by increased grain sizes and reduced dislocation densities.

Effect of heat treatment on microstructure and tensile behavior in cast Al-Si-Mg alloy

02:15PM - 02:40PM

Presented by:

Toko Tokunaga, Assistant Professor, Nagoya Institute Of Technology

Co-authors :

Reiji Hirono, Nagoya Institute Of Technology

Tatsuya Ako, Toyota Motor Corporation

Masakura Tejima

Koji Hagihara, Nagoya Institute Of Technology

Al-Si-Mg alloys have been practically used by controlling their mechanical properties with heat treatment, i.e., solution treatment and aging. Recently, to mitigate environmental issues, there is a strong need for simplification or reduction of heat treatment. To simplify or to reduce the heat treatment for Al-Si-Mg alloys, it is necessary to clarify the key factor achieving their mechanical properties, and to find other factors complement the properties. In this study, we investigate the relationship between the microstructure and mechanical properties in Al-Si-Mg alloys treated with variety of heat treatment. From the microstructure observation, it was found that after the solution treatment, annihilation of the Mg segregation and spheroidizing of Si particles occurred. The solution-treated samples exhibited higher elongation, and the samples without solution treatment exhibited higher strength. Fracture surface observation revealed that the fracture of the samples without solution treatment initiated at the grain boundary in between the Al grains, while in the solution-treated samples, the fracture starts at the Si particles. It was demonstrated that spheroidizing of Si particles suppressed the stress concentration, and annihilation of Mg segregation improves the grain boundary strength, and those are the main reasons for the higher elongation achieved with the solution-treated samples.

BENDABILITY OF Al-Mg-Zn-(Cu) CROSSOVER ALLOYS

02:40PM - 03:05PM

Presented by:

Sebastian Samberger, PhD. Candidate, Montanuniversity Leoben, Austria

Co-authors :

Irmgard Weißensteiner, Montanuniversität Leoben

Lukas Stemper, AMAG Rolling GmbH

Ramona Tosone, AMAG Rolling GmbH

Peter Johann Uggowitzer, Professor

Stefan Pogatscher, Montanuniversitaet Leoben

The demand for sustainable solutions in the aluminum industry has never been more critical, as the world faces an upcoming increase in aluminum scrap. The introduction of the crossover alloying concept emerges as a promising strategy to mitigate the upcoming surplus by redefining the material properties of aluminum alloys. Among these alloys, the 5/7-crossover alloy (a crossover between 5xxx and 7xxx alloys) has proven as an interesting candidate, effectively addressing the long standing challenge of the strength-ductility trade-off in aluminum alloys. These alloys exhibit a range of advantageous properties that position them as a promising choice for the next generation of sustainable materials. Bendability is a critical property in various applications, including automotive manufacturing, aerospace, and construction industries.

Understanding the factors that impact bendability in these alloys is of utter interest to their successful implementation in diverse engineering contexts. In this study the composition and microstructure of 5/7-crossover alloys is investigated, examining how variations in alloying elements and heat treatment processes influence their mechanical behavior. The findings highlight the potential of 5/7-crossover alloys to contribute to the countering of an upcoming scrap increase. By successfully balancing strength and ductility, these alloys open new ways for lightweight and durable applications.

Al Mg Si Fe crossover alloys

03:05PM - 03:30PM

Presented by:

Bernhard Trink

Co-authors :

Irmgard Weibensteiner, Leibniz-Institute For Materials Engineering

Peter Johann Uggowitzer, Professor

Katharina Strobel, AMAG Rolling GmbH

Stefan Pogatscher, Montanuniversitaet Leoben

The Role of GP Zone Formation Temperature, Time and Composition on Faceting in Al-Ag Alloys

03:50PM - 04:15PM

Presented by:

Gary Shiflet, Reynolds Professor Emeritus , University Of Virginia

Co-authors :

Kenji Matsuda, Prof., University Of Toyama

The Al-Ag GP zone, considered to be a truncated octahedron, has matrix facets of {111} and {100} planes at its interface. During ICAA 12 in 2010 the authors presented experimental results that partly confirmed Guinier-Preston (GP) zone {111} and {100} facet findings of Alexander et al. (1). However, some questions were raised concerning facet percentages remaining constant during aging at a constant temperature (2). The morphology and faceting of Guinier-Preston (GP) zones in three Al-Ag alloys of Al-3.8, 15, 30 wt/o Ag were investigated by high resolution transmission electron microscopy (HRTEM). The percentage of faceting along the interphase boundary was found to decrease with increasing aging temperature similar to results shown in ref. 1, thus further confirming that facets are dominant at lower aging temperatures and smaller diameter GP zones. Contrary to this report, current results show that facet percent does not remain constant with increasing GP zone size. Silver content of the alloy is also important and found to alter facet percentage.

Evolution of Precipitates during Aging of an AA2618 Alloy

04:15PM - 04:40PM

Presented by:

ASHIM MUKHOPADHYAY, Advisor, Hindalco Industries Limited

Co-authors :

Rajdeep Sarkar, Scientist F, Defence Metallurgical Research Laboratory

Partha Ghosal, Scientist G, Defence Metallurgical Research Laboratory

The evolution of precipitates that occurred during natural and artificial aging of an AA2618 alloy has been studied using a combination of conventional transmission electron microscopy, high resolution transmission electron microscopy, electron energy-loss spectroscopy and X-ray energy dispersive spectroscopy. The results describe for the first time the basis of formation of Guinier-Preston-Bagaryatsky zones and precipitates belonging to S (Al2CuMg) phase family during natural aging, and formation of precipitates on {220}Al matrix planes [in addition to the well known S phase on {420}Al matrix planes] during artificial aging.

Microstructural Evolution During Pre-ageing of Al-Cu Alloys

04:40PM - 05:05PM

Presented by:

Yun Wang, Senior Research Fellow, Brunel University London

Co-authors :

Zaidao Li, Constellium

Shihao Wang, SuperSTEM, UK

Chamini Mendis, Brunel University London

Zhongyun Fan, Brunel University London

Thermo-mechanical process is effective to enhancement of mechanical performance of age-hardenable Al-Mg-Si-Cu 6000 series alloys. The interplay between ageing and plastic deformation plays a key role in determining microstructure and final mechanical properties. In this work, an Al-4%Cu binary model alloy was thermo-mechanically processed, focusing on microstructural evaluation during pre-ageing prior to deformation and its impact on the subsequent plastic deformation and ageing processes. The experimental results show that GP zone or q ", rather than q ' precipitates, appearing in the pre-aged alloys is favorable to achieve the maximum improvement in hardness during deformation. Final ageing was thereafter applied to allow further precipitation strengthening to realize the optimal combination of strength and ductility.

Competition between dynamic precipitation and dynamic dissolution in 7xxx alloys studied by in situ SAXS

05:05PM - 05:30PM

Presented by:

Guillaume Crowin, PhD Student, SIMaP-UGA

Co-authors :

Frédéric De Geuser, SIMaP-UGA

Arthur Després, SIMaP-UGA

Alexis Deschamps, SIMaP-UGA

Due to their high mechanical properties coupled with a low density, age-hardening aluminium alloys are attractive to replace steel in the context of weight reduction in the automotive industry. However, these alloys have a very limited formability at room temperature, making more difficult the use of them for structural parts. A way to avoid this problem is to use plastic deformation during warm forming to both increase the formability and increase precipitation kinetics. During dynamic precipitation, when straining and precipitation occur simultaneously, the interactions between plastic deformation and precipitates are complex. The object of this work is to study dynamic precipitation in a 7xxx alloy at moderate temperatures lower than 100°C for various initial precipitation states. A heating tensile test device compatible with in situ small-angle X-ray scattering measurements (SAXS) allows to follow the precipitation kinetics during the deformation. It is observed that in a supersaturated state, plastic deformation accelerates significantly the growth of precipitates thanks to the formation of excess vacancies during the deformation which accelerate the solute diffusion. In the case of pre-existing precipitates stable at the deformation temperature, deformation promotes dissolution of the smallest precipitates sheared by the dislocations.

09:50AM - 05:55PM

GLC 222

Advanced Characterization and Testing

Atom-Probe Tomography for Atomic-Scale Characterization of Aluminum Alloys

09:50AM - 10:15AM

Presented by:

Dieter Isheim, Research Associate Professor, Northwestern University

Atom-probe tomography (APT) is a high-resolution microanalytical imaging technique especially suited for the characterization of nanostructured metals and alloys: APT generates an atom-by-atom three-dimensional reconstruction of a specimen volume with a field-of view several 100 nm to 1 micrometer, subnanometer spatial resolution, single-atom detection, and an analytical resolution on the order of 10 atomic ppm, with the same detection efficiency for all elements across the entire periodic table. The atom-by-atom 3D reconstruction can be visualized with the aid of a computer workstation and microstructural parameters and local compositions derived with a broad variety of 3D computational analysis tools. Example applications include nano-scale precipitation and solute clustering, core-shell precipitates, concentration gradients across matrix/precipitate interfaces, surface layers and coatings, and grain boundary segregation. APT requires the samples to be prepared into the shape of a sharp tip which can be achieved by eletropolishing of bulk materials or focused-ion beam / scanning electrom microscopy for targeted preparation of specific microstructural features. Cryogenic workflows for working with alloys that undergo rapid changes due to high diffusivity at room temperature are available today. We will discuss fundamentals of the method and applications to aluminum alloys.

Solute Clustering in a High-strength Al-Mg-Si-Cu Alloy

10:15AM - 10:40AM

Presented by:

Gregory Thompson, Professor , University Of Alabama

Co-authors :

David Tweddle , University Of Alabama

Drew Johnson , University Of Alabama

Monica Kapoor, Novelis

Sean Mileski , Novelis

John Carsley, Novelis

The early stage of atomic clustering is critically important in identifying how solutes partition towards the precipitation pathways that form strengthening phases. Using atom probe tomography (APT), a difference in clustering behavior was characterized in natural and artificially aged states that revealed the formation of Si-rich clusters that did not readily grow into Guinier-Preston zones and β'' precipitates, the primary strengthening phase for an Al-Mg-Si alloy. However, if the alloy was pre-aged followed immediately by artificial aging, a high density of β'' precipitates formed, and yielded a higher strength. Cu was found in all strengthening particles approximately 1 nm or larger and is deemed essential for the faster precipitation kinetics to enable the growth of β'' precipitates. In addition, pre-aging followed by an extended secondary natural aging treatment for tens of days followed by subsequent artificial aging revealed a modestly lower yield strength than the direct pre-age with immediate artificial aging. This drop in strength is linked to the formation of less-beneficial Si-rich clusters that evolve over the extended natural aged period. Finally, this talk will address how specific atom probe specimen preparation methods can accelerate clustering, which can bias outcomes.

Investigating the influence of pre-ageing and deformation on nanostructural evolution in high-strength Aluminium 6XXX using Atom Probe Tomography

10:40AM - 11:05AM

Presented by:

Anthony Akinwale, PhD Student, University Of Oxford

Co-authors :

James Famelton, Research Fellow, Brunel University London

Carla Barbatti, R&D Centre Manager, Constellium

Paul Bagot, University Of Oxford

Michael Moody, University Of Oxford

A commercial Aluminium 6XXX alloy has been pre-aged, deformed, and final aged and Atom Probe Tomography (APT) has been used for microstructural characterisation across multiple stages of this process. A study of the influence of natural ageing as well as the impact of deformation on the composition, size distribution, number density, and morphology of clusters and precipitates will be presented. The new insights provide a better understanding of the full precipitation sequence in this alloy and help to explain the tensile properties observed.

Role of naturally aged solute clusters in the nucleation of precipitates during artificial ageing

11:05AM - 11:30AM

Presented by:

James Famelton, Research Fellow, Brunel University London

Co-authors :

Ceri Williams, Innoval

Carla Barbatti, R&D Centre Manager, Constellium

Paul Bagot, University Of Oxford

Michael Moody, University Of Oxford

Atom probe tomography and differential scanning calorimetry have been applied to two 6xxx series alloys to demonstrate that solute clusters formed during natural ageing and pre-ageing largely dissolve during artificial ageing, while solute clusters and small precipitates formed with little natural ageing do not dissolve. However, solute clusters are still found in artificially aged samples with prior natural ageing. These small features are seen act as nucleation sites for larger strengthening precipitates. The addition of Cu to the investigated alloy increases the number density of solute clusters which are found after artificial ageing and hence the number density of nucleation sites, the overall precipitate number density and yield strength.

Correlative DSC and (S)TEM analysis of GP-zone formation and precipitation in an Al-Mg-Si alloy

11:30AM - 11:55AM

Presented by:

Randi Holmestad, Professor, Norwegian University Of Science And Technology (NTNU)

Co-authors :

Christoph Hell, PhD, NTNU

Ruben Bjorge, Research Scientist, SINTEF Industry

Benjamin Milkereit, University Of Rostock

Hannes Fröck

Jonas Frafjord

This study presents a comprehensive investigation into the process of Guinier–Preston (GP) zone formation and subsequent precipitation in an Al-Mg-Si (AA6082) alloy, employing a correlative approach that combines Differential Scanning Calorimetry (DSC) and (Scanning) Transmission Electron Microscopy ((S)TEM). For this, the alloy's thermal behavior and microstructural evolution from various initial stages were systematically characterized. The effect of a changed initial vacancy concentration and a clustered microstructure after natural aging were compared to directly aging, i.e. from a supersaturated solid solution. DSC analysis was conducted to discern the alloy's thermal transitions, and providing insights into the nucleation and growth kinetics of GP-zones and precipitates. The acquired calorimetric data were correlated with STEM observations to establish a direct link between the alloy's thermal history and the resulting emerging phases. The STEM analysis allowed for a high-resolution examination of GP-zones and a structural model could be derived. The correlative study sheds light on the intricate interplay between thermal treatment parameters and the resultant onset of precipitation in the Al-Mg Si alloy.

Quench Sensitivity After Solution Heat Treatment of a High Strength 6xxx-series Al Alloy

09:50AM - 05:55PM

Presented by:

Alexandru Techeres

Co-authors :

Tudor Piroteala, Lead Engineer, Novelis Inc.

Rajeev Kamat, Novelis

Thomas Dorin, Deakin University

This study examines the quench sensitivity of a high-strength 6xxx-series aluminum alloy characterized by elevated solute levels, focusing on the impact of quench processing after solution heat treatment on their metallurgical evolution and in-service performance. The study addresses the challenge of forming coarse second-phase particles during quenching, which can

significantly compromise mechanical properties such as strength, plasticity, and toughness. We used differential scanning calorimetry (DSC), scanning electron microscopy (SEM), and transmission electron microscopy (TEM), to elucidate the critical cooling rates that balance microstructural integrity with optimal mechanical performance, offering insights into heat treatment optimization for these widely used alloys.

Microstructure evolution and strain-rate sensitivity of tensile properties in a rapidly solidified AA5182 Al-Mg alloy via thin-strip continuous casting

01:50PM - 02:15PM

Presented by:

Shengze Yin, Post-Doc Fellow, Queen's University, Kingston, Canada

Co-authors :

Hesam Pouraliakbar, Queen's University

Andrew Howells, CASTechnology

Mark Gallerneault, Queen's University

Vahid Fallah, Queen's University

This study reports the phase evolution and its impact on the thermal and oxidation behavior of a rapidly solidified AA5182 Al-Mg alloy strip fabricated using a novel thin-strip (TS) continuous casting technique developed by Hazelett-CASTechnology®. The microstructural analysis revealed a thru-thickness gradient microstructure of distinct types, morphology, and fractions of non-equilibrium Al-Mn-Fe intermetallic and Al-Mg eutectic phases. The rapid solidification experienced in TS casting effectively mitigated the formation of phases, particularly with the Al-Mg (β-Al3Mg2) eutectic, being nearly absent from the near-surface regions (i.e., where the highest cooling rate is experienced). The total fraction of formed phases was considerably lower than that in the slowly cooled direct-chill (DC) counterpart. The solute macrosegregation also showed an inverse Mg segregation profile towards the strip surface primarily due to a higher degree of matrix supersaturation closer to the strip surface. Modeling of solidification successfully predicted the influence of cooling rate on the fractions of the non-equilibrium eutectic phase (i.e., TS vs. DC), agreeing well with the experimental data obtained from image analysis. Heat treating the samples over a wide range of temperatures (i.e., 150-600°C) revealed unexpected improvements in oxidation resistance as well as excellent thermal stability. When exposed to atmospheric oxygen up to 600°C, no surface oxidation was observed in the TS sample, owing to the unique isolated morphology of the eutectic phases and the absence of coarse intergranular β-phase. Additionally, the heat-treated TS coupons exhibited significant thermal stability throughout the temperature range of 150-600°C. The TS sample, particularly, showed an anomalous hardness increase attributed to the formation of transient GP-zones and β''-phase in the range of 200-250°C, followed by the transformation to β'/β-phase colonies. Moreover, this study investigates the strain-rate triggered Portevin-Le Chatelier (PLC) effect and fracture behavior of TS AA5182 alloy in comparison with those of direct chill (DC) counterparts. Higher cooling rates obtained via TS casting, suppression of the phase formation, and significant matrix solute supersaturation beyond the equilibrium level, impact the interaction dynamics of mobile dislocations and solute atoms. This in turn affects the evolution of typical stress fluctuations in Al-Mg alloys, referred to as the PLC effect, occurring in specific strain rate-temperature domains, i.e., with type and

characteristics dependent upon the microstructure. Tensile testing performed at 10-4-10-1 s-1 range demonstrated a strain-rate dependent PLC effect, also aligning with the ductility trend in both negative (10-4-10-3 s-1) and positive (10-3-10-1 s-1) strain-rate sensitivity domains for the samples. The elongation-to-failure behavior in both samples demonstrated similar trends by SRS change in both domains. The characteristics of PLC bands, as well as the magnitude of stress fluctuations, were shown to evolve with strain rate, facilitating distinct fracture mechanisms. The transformation of Type-B+C bands to Type-A+B bands was observed in the TS samples, whereas the DC samples predominantly exhibited Type-A+B bands across the 10-4-10-3 s-1 range of strain rates. This suggests that the rate sensitivity of the TS sample was considerably higher than the DC sample, which can be attributed to the higher concentration of interacting solute atoms. In particular, the fracture mechanisms associated with the TS sample exhibited a higher rate sensitivity thus a narrower range of deformation rates for optimum ductility. Fracture analysis revealed fully ductile fractures in both TS and DC samples across all strain rates. However, a small fraction of quasi-cleavage fracture was observed in the DC sample, which can be attributed to the presence of coarser particles acting as stress concentrators. Also, the fracture surfaces exhibited a trade-off between dimple formation and slipping mechanisms, with the fraction of slipped material initially increasing and then decreasing at higher strain rates, where the dominance of the dimple-rupture mechanism became apparent. Controlling the deformation rate to favor predominantly Type-B serrations and ensuring their stability with minimal fluctuations was shown to postpone necking and prevent material failure. The significance of rate sensitivity in alloys with reduced microsegregation is emphasized, suggesting the need for further exploration of mechanical properties. The research findings have practical implications for improving the properties of sheet Al-Mg alloys.

The S-phase formation in a high-purity Al-Cu-Mg alloy monitored by truncation during heating-up

02:15PM - 02:40PM

Presented by:

Torsten Staab, Senior Rescher, Julius-Maximilians Universität Würzburg

Co-authors :

Dominik Boras, PhD-Student, Julius-Maximilians Universität Würzburg

Bernd Rellinghaus, Director Of DCN, Technische Universität Dresden

We present a novel attempt to combine in-situ and ex-situ measurements for aluminum alloys. For this research we have chosen an Al-1.7Cu-1.3Mg (at.%) alloy, which has been cast from high purity elements (5N5 Al, 4N Cu and 4N Mg). DSC serves as a basic method, which is employed to determine different precipitation states towards the final S-phase formation: before the formation starts, at the maximum of the exothermal peak, after the end of the exothermal reaction. By an abrupt truncation of the heating ramp (5 K/min), i.e. cooling quickly to room temperature, the current sample state is frozen-in for a defined temperature. After truncation all samples have been measured without further preparation by X-ray diffraction (XRD), positron annihilation lifetime spectroscopy (PALS). By this treatment we could correlate exactly different sample states, which is impossible by conventional experiments, i.e. heating to a defined temperature and holding for a certain time. This open new possibilities to investigate defined and comparable sample states by methods, which require extensive sample preparation, like TEM or 3DAP, and in-situ methods like DSC or XRD / EXAFS at synchrotron beam lines. First results by TEM will be presented.

Impact of recycled contents in 6xxx Series Aluminum Alloys: Studying and modeling precipitation

02:40PM - 03:05PM

Presented by:

Seyyed Ezzatollah Moosavi

Co-authors :

Zeqin Liang, Senior Metallurgy Scientist, Novelis

Cyril Cayron

Jonathan Friedli, Novelis

Roland Logé, EPFL

Recrystallization in Wrought Aluminum Alloys - A Critical Evaluation of Characterization Methods

03:05PM - 03:30PM

Presented by:

Moritz Theissing, TU Graz

Co-authors :

Georg Falkinger

Stefan Mitsche

Recrystallization has a major influence on the final microstructure and thus on the properties of almost all wrought aluminum alloys. The study of recrystallization is challenging because of the interplay of different mechanisms at the microscale such as phase transformations. Therefore, the selection of the appropriate characterization method is not straightforward. Each research question requires a thoughtful decision to address the problem. In this work, we test and evaluate different characterization techniques, such as hardness measurements, in-situ and ex-situ EBSD and light microscopy for various studies related to recrystallization. We present their advantages and disadvantages and point out limitations that may not be obvious.

Deformation-induced symmetrical tilt boundary in layer-structured Al-Cu eutectic alloy

03:50PM - 04:15PM

Presented by:

Daisuke Egusa, Assistant Professor, The Univesity Of Tokyo

Co-authors :

Tusyoshi Mayama

Koji Hagihara, Nagoya Institute Of Technology

Eiji Abe

We have investigated symmetrical tilt boundaries spontaneously introduced by compressing layer-structured Al-Cu eutectic alloys, based on scanning electron microscopy (SEM), transmission electron microscopy (TEM), scanning transmission electron microscopy (STEM) and crystal plasticity (CP) analysis. SEM observations show sine-wave-like bending of a layered structure consisting of soft Al and hard Al2Cu phases and sharp symmetric tilt boundaries appeared only in the Al layers at the corner of the waves. TEM/STEM observations revealed that the tilt-boundaries consist of a single variant of dislocations, the feature of which is similar to the kink boundary that normally occurs in anisotropic crystals such as hexagonal close-packed. CP analysis indicated that differences in plastic deformation capacity between the Al and Al2Cu layers cause selective activation of slip systems in soft Al layers, which induces rotational deformation accompanied by the spontaneous formation of kink boundaries.

Dislocation-Grain Boundary Interactions Studied using in-situ High-Resolution EBSD (HR-EBSD) in FCC Metals

04:15PM - 04:40PM

Presented by:

Yang Su, Post-doc, Georgia Tech

Co-authors :

Josh Kacher, Speaker, Georgia Tech

To understand how grain boundary characteristics affect the strength of polycrystalline face centered cubic (FCC) metals, high-resolution electron backscatter diffraction (HR-EBSD) analysis was conducted at ~50 grain boundaries in high purity aluminum, high purity nickel, and stainless steel 316L during in situ tensile deformation. Stress evolution near each grain boundary will be presented and discussed in terms of grain boundary types and geometrical metrics, including m', residual Burgers vector, strain energy density, and grain boundary coherency.

Improving the Reproducibility of Characterization and Quantification of Precipitates through Automated Image Processing and Digital Representation of Processing Steps

04:40PM - 05:05PM

Presented by:

Birgit Skrotzki, Head Of Division, BAM Bundesanstalt Für Materialforschung Und -prüfung

The strength of age-hardenable aluminum alloys is based on the controlled formation of nm-sized precipitates, which represent obstacles to dislocation movement. Transmission electron microscopy (TEM) is generally used to identify precipitate types and orientations and to determine their size. This geometric quantification (e.g., length, diameter) is often performed by manual image analysis, which is very time-consuming and sometimes poses reproducibility problems. The present work aims at the digital representation of this characterization method by proposing an automatable digital approach. Based on DF-TEM images of different precipitation states of alloy EN AW-2618A, a modularizable digital workflow is described for the quantitative analysis of precipitate dimensions. The integration of this workflow into a data pipeline concept is also presented. The semantic structuring of data allows data to be shared and reused for other applications and purposes, which enables interoperability.

Investigation of nanostructural precipitate evolution in aluminum alloys

05:05PM - 05:30PM

Presented by:

Moritz Theissing, TU Graz

Co-authors :

Evelin Fisslthaler

Martina Dienstleder

Werner Grogger

One of the key challenges in alloy development is the quest for a deeper understanding of fundamental processes happening on the micro- and nanoscale, triggered either by minuscule changes of composition or by different types of treatments.Material scientists have used high-resolution scanning transmission electron microscopy (HR-STEM) for many years to visualize the inner structure of these complex materials and to map their chemical composition by electron energy-loss spectroscopy (EELS) and energy dispersive x-ray spectroscopy (EDXS). However, in recent years, methods for chemical analysis on an atom-by-atom basis have significantly advanced, especially in terms of sensitivity. In parallel, new systems for in situ investigations within TEMs have emerged, featuring stable MEMS-based sample platforms that are capable of delivering a variety of different well-defined stimuli during high-resolution investigations.In this study, we use atomic resolution STEM imaging and powerful localized chemical analysis to illustrate the structure, composition and evolution of precipitates in various aluminum alloys. We will track temperature-triggered growth processes with nanoscale resolution during in situ heating experiments and capture and describe the changes of the system during different stages of precipitate formation using fast EDXS and EELS techniques to track the chemical composition.

01:50PM - 05:55PM

GLC 233

Additive Manufacturing and Joining

Effect of clearance between components and brazing pressurization on the brazeability of flat joints

01:50PM - 02:15PM

Presented by:

Kazuya Funatsu, Nippon Light Metal Company, Ltd.

Co-authors :

Kenta Suzuki

Aluminum-furnace brazing using noncorrosive fluxes under flowing nitrogen gas is a conventional and useful joining technique. The conventional brazing method could be further popularized by reducing the large number of defects formed in flat-area brazing joints. To improve the flat-joint brazeability with a noncorrosive flux and flowing nitrogen gas, we investigated the effect of intercomponent clearance and pressurization during the brazing process. The brazeability was evaluated on tee joints formed by a horizontal A3003/A4343 sheet specimen and a vertical A3003 plate specimen. To control the clearance between the horizontal sheet and vertical plate and the pressure during the brazing process, the tee-joint samples were fixed in a stainless steel jig. The jointing area ratio increased with increasing clearance under both nonpressure and pressure conditions. The jointing area ratio reached 99% under the pressure condition but decreased when the clearance was excessive and was lower under the nonpressure condition than under the pressure condition. The voids in the brazing area were filled with flux. In the tee joined specimens with clearance, the brazing filler metal should enter the interface from the surrounding area under capillary action, because the amount of brazing filler metal is insufficient before brazing. Meanwhile, the flux is presumably discharged from the joint interface area. Therefore, the number of voids at the joint interface can be reduced by properly controlling the clearance.

Dissimilar laser brazing of aluminum alloy and galvannealed steel using dual beam

02:15PM - 02:40PM

Presented by:

Tomo Ogura, Osaka University

Co-authors :

Reiko Wakazono, Osaka University

Shotaro Yamashita, Osaka University

Kazuyoshi Saida, Osaka University

The purpose of this study was to improve the brazing performance and strength of dissimilar metal joints by performing dual laser brazing with a preheated beam. It was found that the dual beam greatly improved the wettability, thereby increasing the strength of the joint. Simulation models for single-beam and dual-beam laser brazing were constructed, and the wetting and spreading behavior of molten brazing filler metal was investigated by varying the laser output. Both simulation and experimental results show that as the laser output increases, the wetting

width increases and the bead toe angle decreases, making it possible to qualitatively predict the wetting and spreading behavior.

Microstructural characterisation of Al/Cu joints welded using hybrid metal extrusion & bonding

02:40PM - 03:05PM

Presented by:

Randi Holmestad, Professor, Norwegian University Of Science And Technology (NTNU)

Co-authors :

Elisabeth Thronsen, SINTEF

Jørgen Sørhaug, NTNU

Øystein Grong, NTNU

Per Erik Vullum, SINTEF

Tina Bergh, NTNU

Advances in joining processes for aluminum (Al) and copper (Cu) are sought after to facilitate an adoption of Al alloys in electrical applications. Aluminum's chemical affinity to Cu causes the joining and lifetime of Al/Cu joints to be vulnerable to formation of various brittle intermetallic compounds (IMCs), which can reduce the structural integrity and increase the electrical resistance of the welds. In this study we evaluate the novel joining process hybrid metal extrusion & bonding (HYB) for butt welding Al and Cu plates, as HYB already has successfully joined Al and Cu in a multi-material joining process. The HYB method is based on continuous extrusion of an Al filler material to take up the space in the weld groove, and to consolidate the plates to be joined. At the same time, a rotating steel tool is plastically deforming the sidewall of at least one of the base materials. To mimic real life electrical applications, Al/Cu joints have been artificially aged at different temperatures and the weld structures have been examined using scanning and transmission electron microscopy. The non-heat-treated sample's interface is observed with a < 200 nm thick and continuous IMC fine-grained layer between the filler material and the Cu base material. Electron diffraction analysis and energy dispersive spectroscopy indicate the presence of Al_2Cu and Al_4Cu_9. Specimens annealed at 200°C for up to 1000 hours were also examined using TEM. The results show that the IMP layers use longer time to reach a critical thickness of ~2 μm compared to alternative joining processes, and that a third layer believed to be AlCu is emerging in-between the pre-existent layers. In conclusion, the HYB method shows a significant performance advantage compared with other joining techniques, and the slow IMC growth is promising for a potential functional performance.

Interfacial elemental distribution of air atmosphere diffusion-bonded Al-Mg-Si alloy with surface treatment

03:05PM - 03:30PM

Presented by:

Dipin Kumar R, Indian Institute Of Technology Delhi, India

Co-authors :

Aravindan S, Indian Institute Of Technology Delhi

Diffusion bonding of AA6082 in an air atmosphere furnace is successfully demonstrated in this paper. The process considerably reduces the equipment-related cost and cycle time associated with vacuum diffusion bonding. The stable oxide layer that readily forms on the Al surface hinders the atomic dispersion at the interface. Ga treatment at the faying surface prevents reoxidation by isolating the surface and facilitates bonding in the air atmosphere. The diffusion bonding was carried out at a temperature of 550°C for a dwell time of 75 minutes. Microstructural analysis was carried out using FESEM with EDS, and elemental distribution was analyzed using EPMA with WDS. The EDS and EPMA analysis show a comparatively high mass % of Mg, O, and Al at the interface indicating the formation of Al2MgO4 at the interface. The formation of Al2MgO4 and the pressure applied disrupt the continuous oxide layer, facilitate atomic diffusion, and result in void closure. The joint formation mechanism and elemental diffusion behavior at the interface are elucidated.

Engineering defects-free equiaxed grains containing microstructure in Arc-wire DED additive manufacturing of Al-5Mg alloy

03:50PM - 04:15PM

Presented by:

Sherin Thampi, Resear Scholar, Indian Institute Of Technology, Madras

Co-authors :

Hariharan K, Associate Professor, Indian Institute Of Technology Madras

Murugaiyan Amirthalingam, Associate Professor, Institute Of Technology Madras

Gautam Wagle, Assistant Vice President, Hindalco Industries Limited

Al-5Mg alloys are increasingly used for various automotive applications due to their high thermal conductivity, strength-to-weight ratio, corrosion resistance, and weldability. Al-5Mg (Al-5356) is also increasingly used as a filler wire for welding of high-strength aluminium (6xxx and 7xxx) alloys. Arc wire directed energy deposition, also known as wire arc additive manufacturing (WAAM), is attractive to produce large-volume components due to its high deposition rate. Careful selection of WAAM process parameters can reduce gas porosity, hot cracks and anisotropic mechanical properties, which are major issues during the WAAM of Al-5Mg alloys. In this work, an unique WAAM process methodology was developed to print Al-5Mg components using the short-circuiting metal transfer mode. The process parameters are optimized by correlating the mean current and travel speed with the deposition geometry. Multi-layer thin-walled depositions of Al-5Mg WAAM were made using the developed parameters. Microstructural analysis revealed the presence of equiaxed microstructures throughout the cross-section of the printed samples. The dynamic correction and arc length correction during short circuit metal transfer resulted in low heat input and shallow temperature gradient, resulting in an equiaxed microstructure. A detailed mechanical properties evaluation was carried out to ascertain the isotropic characteristics of the WAAM parts made by the developed procedure

The role of inter-pass idle time on the defects and microstructure formation in the wire-arc additive manufacturing of AA 4043 alloy components

04:15PM - 04:40PM

Presented by:

Tilak Kumar JV, Postdoctoral Researcher, Indian Institute Of Technology, Madras

Co-authors :

Sumit Gahlyan, Assistant General Manager, Hindalco Industries Limited

Gautam Wagle, Assistant Vice President, Hindalco Industries Limited

Murugaiyan Amirthalingam, Associate Professor, Institute Of Technology Madras

The interlayer cooling time in gas metal arc-based wire-arc additive manufacturing (GMA-WAAM) is an important process parameter which can affect the thermal gradient and cooling rates of the solidifying melt pools. Aluminium alloys are highly susceptible for hot cracking and anisotropic mechanical properties due to the excessive heat input in the GMA-WAAM process. Excessive heat input can also significantly impact the geometric integrity of the build. This study aims to analyze the impact of inter layer cooling time during the deposition of ER 4043 filler wire over AA 6061 base plates on the microstructure, mechanical properties, and geometrical features of the build. GMA-WAAM parameters were optimized by considering the geometry of the beads produced in short-circuiting and short-circuiting with pulse modes. Short-circuiting mode was used to build multilayer thin walls as the beads produced in this mode exhibited better geometric shape parameters than in other modes. Three thin walls were built with 30s, 60s and 90s interlayer cooling times. The difference in the tensile strengths and Vickers hardness observed in the thin walls built with 60s and 90s interlayer cooling times is insignificant. The magnitude of anisotropy observed in the mechanical behavior in both these walls is also minimal.

Investigating the wire deposition of TiC-inoculated AA7075 using L-DED and the influence of post-processing heat treatment.

04:40PM - 05:05PM

Presented by:

Michael Benoit, Professor, Department Of Mechatronics & Mechanical Engineering, University Of Waterloo

Co-authors :

Taha Waqar, Student, University Of Waterloo

Emma Pugsley, Liburdi Automation

Mark Easton, RMIT University

A fundamental issue for additive manufacturing (AM) of AA7075 is its tendency to crack during solidification, due to its relatively large solidification range and the columnar grain structure characteristic of AM processes. In this study, the printability of laser directed energy deposition (L-DED) of AA7075 weld wire feedstock enhanced with TiC nanoparticles is investigated. It is found that the combination of high laser power along with low travel speed and low wire feed speed results in the reduction of lack of fusion and porosity within the prints. Microstructure analysis shows that the presence of TiC nanoparticles results in grain refinement, with fine equiaxed grains observed within the melt pool leading to the elimination of cracking. The effect of traditional heat treatments in comparison to direct aging is also studied. The microhardness of the build is found to be higher in prints undergoing T6 heat treatments in contrast to directly aged samples.

Mechanical Behavior of Additively Manufactured vs. Wrought 7050-based High Strength Al Alloy

05:05PM - 05:30PM

Presented by:

Rupesh Rajendran, Georgia Tech

Co-authors :

Preet Singh, Professor, Georgia Institute Of Technology

High strength 7xxx aluminum alloys are widely used in aerospace applications due to high strength to weight ratio, good fatigue, and corrosion properties. Metal Additive manufacturing (AM) of high strength aluminum alloys can provide additional benefits – high design freedom, increased efficiency and part performance. However, the AM of high strength Al alloy has been particularly challenging due to hot tearing and solidification defects associated with their columnar microstructure. This is exacerbated by a high % of alloying elements like Zn. Recent developments in inoculation and addition of in-situ reactive constituents have proven to mitigate the defects while improving printability. This often results in complex microstructures compared to equivalent wrought alloys. This study compares and contrasts the microstructure of AM 7050 alloy fabricated using Laser Powder Bed Fusion (LPBF) process vs. equivalent wrought (WR) 7050 alloy and shows how differences in microstructure relates to the differences observed in mechanical behavior.

Selective Laser Melting parameter optimization in new high strength Al-alloys

05:30PM - 05:55PM

Presented by:

Mikel Rodriguez-Arbaizar, University Of Applied Sciences And Arts Western Switzerland

Co-authors :

Efrain Carreno-Morelli, Head Of Powder Technology And Advanced Materials, University Of Applied Sciences And Arts Western Switzerland

Ludovic Meylan, University Of Applied Sciences And Arts Western Switzerland

Mathilde Rossier, University Of Applied Sciences And Arts Western Switzerland

Navid Sohrabi, Metallurgy Scientist, Novelis Switzerland SA

Philippe Boichat, Novelis Switzerland SA

The influence of laser parameters (energy density, hatch spacing and scanning strategy) was studied on two new high strength aluminum alloys for selective laser melting (SLM). These alloys contain Iron and low amount of Silicon compared to standard SLM Al grades using Mg and Si as alloying elements. The energy densities and scan strategies were adapted to improve pores morphology and distribution which enabled to obtain samples with relative densities higher than 99.5% and Yield strengths higher than 350 MPa. Besides, the optimized parameters also minimized the presence and size of hot tearing cracks. Nevertheless, it was not possible to completely avoid their appearance in the case of the studied alloys which have a wide solidification interval. The printed samples were characterized by optical microscopy and tensile strength tests. Besides, twin cantilevers were printed with supports to assess the influence of the different parameters on geometrical distortion due to residual stresses.

02:20PM - 05:35PM

Deformation Behavior and Mechanical Properties (Fatigue and Fracture)

GLC 225

Compression response of Al-Mg system alloy processed by severe-plastic deformation under dynamic loading

02:20PM - 02:45PM

Presented by:

Tao Yamaguchi, Student, Kobe University

Co-authors :

Alok Singh, National Institute For Materials Science

Koichi Tsuchiya, National Institute For Materials Science

Toshiji Mukai, Kobe University

Assessment of dynamic deformation behavior of structural materials is essential to design materials for structural components of transportation vehicles. This study focuses on Al-Mg system alloys strengthened by severe plastic deformation. Quasi-static compression tests were conducted at strain rates ranging 1×10-3 s-1 ~ 1×10-1 s-1. Dynamic compression tests were also carried out at strain rates ranging 1.6×103 ~ 1.4×104 s-1 with a split-Hopkinson pressure bar (SHPB) apparatus specially designed for precise impact compression tests at around 104 s-1. Negative strain rate sensitivity of flow stress was exhibited in the quasi-static strain rate range, which was attributed to the Portevin Le-Chatelier effect by magnesium solute. In contrast, strong positive strain rate sensitivity was observed in the high strain rate range. Estimated activation volume indicates a transition of the rate-controlling mechanism of dislocations from thermal activation process to viscous drag of phonons in the high strain rate range. Furthermore, the viscous drag component of flow stress may decrease with increasing dislocation density due to severe plastic deformation.

Single-Crystal Micropillar Compression Tests for Understanding Strain-Rate Dependent Strength of Additive-Manufactured Al-Fe alloy

02:45PM - 03:10PM

Presented by:

Dasom Kim, Designated Assistant Professor, Nagoya University

Co-authors :

Akihiro Choshi, Nagoya University

Naoki Takata, Nagoya University

Tsubasa Aoki, Nagoya University

Makoto Kobashi, Nagoya University

In this study, a single-crystal micropillar compression test was performed to fundamentally understand the strain-rate dependent strength of the Al-2.5Fe (wt%) binary alloy manufactured by laser power bed fusion (L-PBF) process. The L-PBF processed Al-2.5Fe alloy has a unique microstructure in which the solidified melt-pools were stacked with a building direction. Whereas large needle-like Al13Fe4 phases with a length of above 100 μm were formed in slowly-solidified

Al-2.5Fe alloy prepared as a comparative sample, nano-sized metastable Al6Fe phase were homogeneously distributed in the L-PBF processed Al-2.5Fe alloy due to the rapid solidification rate (non-equilibrium solidification). As a result of the single-crystal micropillar compression test, it was found that the L-PBF processed Al-2.5Fe alloy exhibited negative strain rate sensitivity (decrease in 0.2% proof stress with an increase of initial strain rate). This amorous strain-rate dependent strength of L-PBF processed Al-2.5Fe alloy would be caused by dynamic precipitation.

A Specific Aluminum Laminate Composite with Very High Impact Toughness

03:10PM - 03:35PM

Presented by:

Haiou Jin, Research Scientist, Natural Resources Canada

A specific aluminum laminate composite, consisting of soft AA3052 and strong AA5083 alloys with very high bonding strength, has been developed. The mechanical properties and impact toughness were evaluated by tensile, Charpy, and ballistic testing. It has been found (1) the tensile strength is simply the combination of monolithic AA3052 and AA5083 according to rule-of-mixture, and (2) the impact toughness in the arrester orientation is significantly higher than the monolithic alloys. The conventional de-bonding between adjacent layers was not observed in the impact and ballistic testing; instead, a very strong in-plane shear deformation occurred in the thin and soft AA3052 layers, leading to high flexural strength, strong energy absorption ability, and consequently unique impact behaviors. The Charpy impact energy is triple that of AA5083, and in ballistic testing the 10.2mm composite is hard to be perforated by 7.62mm M80 NATO bullet.

Creep and creep-rupture behavior of an additively manufactured Al-Ce-Ni-Mn-Zr alloy

03:55PM - 04:20PM

Presented by:

Jovid Rakhmonov, Staff Scientist, Oak Ridge National Laboratory

Co-authors :

Sumit Bahl, Oak Ridge National Laboratory

Alex Plotkowski, Oak Ridge National Laboratory

Obaidullah RAHMAN, Oak Ridge National Laboratory

Curtis Frederick, Carl Zeiss

Amir ZIABARI

David DUNAND, Northwestern University

Amit Shyam, Oak Ridge National Laboratory

The creep resistance and creep-rupture behavior of an additively manufactured Al-Ce-Ni-Mn-Zr alloy at 300, 350, and 400 °C were investigated. The creep results obtained in both tension and compression over a wide range of stresses were then related to the microstructural and three-dimensional X-ray computed tomography observations of the alloys before and after the creep to (i) determine the controlling creep and cavitation (void formation) mechanisms, and (ii) reveal the main microstructural constituents that control creep and cavitation behavior. The high volume fraction of fine, coarsening-resistant precipitates formed on solidification provides excellent creep resistance to Al-Ce-Ni-Mn-Zr alloy in the 300-400 °C temperature range. Cavitation (diffusion-controlled void formation) activates upon the accumulation of an infinite plastic strain in an α-Al matrix during creep, initiating a tertiary creep. The extent of cavitation is highly dependent on the applied stress level and the heterogeneity of the microstructure. The fine-grained, heat-affected zones adjacent to melt pool boundaries create favorable conditions for both nucleation and growth of cavities through a combination of enhanced diffusion and localization of plastic strain, and yet the cavity growth rate remains coupled to the matrix tensile creep rate, consistent with constrained cavity growth mechanism.

Effects of precipitate microstructures on creep properties of AA2618 forged aluminum alloy

04:20PM - 04:45PM

Presented by:

Naohiro KOISO, KOBE STEEL, LTD.

Co-authors :

Tomoya NAKANO, Graduate School Of Engineering Science Yokohama National University

Mitsuhiro OOTAKI, Graduate School Of Engineering Science Yokohama National University

Shoichi HIROSAWA, Professor, Graduate School Of Engineering Science Yokohama National University

Fatigue Behavior at Elevated Temperature of Alloy EN AW-2618A

04:45PM - 05:10PM

Presented by:

Birgit Skrotzki, Head Of Division, BAM Bundesanstalt Für Materialforschung Und -prüfung

The influence of test temperature and frequency on the fatigue life of the alloy EN AW-2618A (2618A) was characterized. The overaged condition (T61 followed by 1000 h/230 °C) was investigated in load-controlled tests with a stress ratio of R = -1 and two test frequencies (0.2 Hz, 20 Hz) at room temperature and at 230°C, respectively. An increase in the test temperature reduces fatigue life, whereby this effect is more pronounced at lower stress amplitudes. Decreasing the test frequency in tests at high temperatures further reduces the service life.

Effect of Corrosion on Fatigue Behavior of Anodized Cast AlSi8Mg-T6 Alloy

05:10PM - 05:35PM

Presented by:

Arianna Pavesi, Material Specialist, Brembo S.p.A

Co-authors :

Mary Angel Abello

Marta Daga

Silvia Barella

Fabrizio D'Errico

Federico Bertasi

The work aims at unveiling the influence of corrosion on fatigue performance of anodized, cast AlSi8Mg-T6 alloy. At this regard a set of anodized specimens has been obtained and exposed to neutral salt spray (NSS) atmosphere for 480 and 1000 hours. After exposure to NSS, tensile and fatigue tests are carried out and compared with non-anodized and anodized specimens to elucidate the effect of corrosion on mechanical performance. Additionally, electrochemical noise measurements, computed tomography and fracture surface analyses are performed to assess the effect of anodic layer integrity and pitting on mechanical results.It is demonstrated that, as corrosion proceeds (i.e., as the time in NSS chamber increases), corrosion pits increase in dimension and concentration, becoming the dominant fatigue crack nucleation mechanism.

Day 4, Jun 26, 2024

08:00AM - 08:45AM **GLC 236**	Keynote speaker - Day 3
08:50AM - 09:30AM **GLC 236**	Plenary Speaker- Day 3
09:30AM - 09:50AM	*Break*

09:50AM - 02:40PM

GLC 235

Industrial Applications (Aerospace, Automotive and Packaging)

Deformation Behavior of Aluminum Strip under Edgewise Press Bending

09:50AM - 10:15AM

Presented by:

Osamu HASEGAWA, Professor, Tokyo Mtropolitan College Of Technology

Edgewise (in-plane) bending of the strip is a very difficult processing. In this research, we developed a process as a method of the edgewise bending of aluminum strips by press bending, applying wing-type dies. The strip used has cross-section of 20x2, and bending radius of R0 = 20 mm. We investigated the influence of the mechanical properties of material and the processing conditions on press bendability. We found that A1070-O material exhibits relatively good bending workability, and the deformation was obtained by significant shear deformation. On the other hand, under the bending with the harder materials such as A1070-H, we observed several irregular deformation.

Influence of ingot preheating and hot rolling on texture and formability of AA6016 automotive sheet material

10:15AM - 10:40AM

Presented by:

Angela Thum, Technology Automotive Products & Transport , AMAG Rolling GmbH

Co-authors :

Georg Falkinger

Stefan Mitsche

Stefan Pogatscher, Montanuniversitaet Leoben

High demands regarding formability exist for AA6016 sheet material for automotive applications. Formability is often characterized by the anisotropy of the sheet in terms of plastic strain ratio (r-value) and by the ability to allow flat hems without surface cracks. It is shown that the thermal history of the hot band i.e. ingot preheating and hot rolling procedure are crucial for the final properties of the sheet. Three hot bands with varying size of pure Si and Mg_2Si precipitates were industrial produced by AMAG. The production steps after hot rolling were similar. The final sheet material produced from the three hot band variants showed equal strength and elongation, but r-value and hemming behaviour were different.

Texture evolution during hot and cold rolling of the foil stock alloy AA8079

10:40AM - 11:05AM

Presented by:

Erik Santora, Product Engineer, AMAG Rolling GmbH

Co-authors :

Irmgard Weißensteiner, Montanuniversität Leoben

Stefan Pogatscher, Montanuniversitaet Leoben

Jürgen Hirsch, Owner, Aluminium Consulting

Recovery and recrystallization effects were investigated in aluminum alloy AA8079, which was hot-rolled under different conditions resulting in different cube texture fractions after hot/cold-rolling and an inter-annealing treatment. After hot rolling, a deformed and fully recovered and/or partially recrystallized microstructure was observed, revealing the related effects of texture evolution and orientation stability with their specific local variations in the microstructure. Finally, a strong influence of the hot-rolled microstructure on the cube texture development during cold-rolling and inter-annealing, and thus on the resulting earing performance, was found.

Effect of the inter-annealing conditions on the resulting softening characteristics of AA8079 foil

11:05AM - 11:30AM

Presented by:

Erik Santora, Product Engineer, AMAG Rolling GmbH

Co-authors :

Matthias Hofinger

The effect of the inter-annealing conditions on the microchemistry evolution, i.e. the dispersoid volume or the elements in solute solution, and the resulting softening behavior of AA8079 foil was the subject of the recent work. Depending on the maximum temperature, the solutes are precipitated or later re-dissolved, which strongly influences the softening behavior of the final foil. In general, a high inter-annealing temperature increases the solute content and thus shifts the recrystallization temperature of the foil during a final annealing to higher temperatures.

Development of high strength aluminum alloy for hot stamping and its forming technology

11:30AM - 11:55AM

Presented by:

Hao Wu

Co-authors :

Qi Zhang

Mingdong Huang

Cheng Liu

There are two main aspects for the light-weighting: to design lighter and stronger alloys, and to modify the body component structure. The limited formability is one of the major challenges for using high strength aluminum alloy sheets in automotive industry. The solution Heat treatment, Forming, and in-die Quenching (HFQ) process is an advanced technology to make complex-shape components instead of traditional stamping forming. This technology of the steel has been applied in the car body components since 1984 and the usage is continuously increasing these years. However, the thickness reduction potential of the steel is limited and there are increasing research on aluminum alloys. In recent years, the HFQ has been successfully applied in 5xxx and 6xxx Al alloys but less in forming high strength 2xxx and 7xxx alloys. This research mainly studied on the development of a high strength aluminum alloy for hot stamping and its application performance, as well as the hot stamping process simulation, the CAE simulation and trial production for structural components. The effect of alloy elements on the essential properties of high strength 7xxx Al alloys suitable for hot stamping has been studied, including the main alloy elements (Zn, Mg and Cu), the minor elements (Cr, Mn and Zr) and the impurities (Fe and Si). This study complected industry trials for various thickness of high strength aluminum plates and carried out the influence of solution treatment, quenching and ageing on mechanical properties and microstructure. Meanwhile, the hot stamping heat treatment, forming and in-die quenching (HFQ) process has been developed though processing parameters modification.The high temperature constitutive model was built according to the parameters acquired from experimental data, such as high temperature rheology parameter, high temperature friction index, heat exchange index and high temperature FLC. The mold for hot stamping was developed based on component hot stamping process simulation and the component structure was modified. According to the numerical modeling and experiments, the aluminum hot stamping components has been successfully processed.The shape, precision and mechanical properties have been tested as bases for real application. Based on the research, the project group has successfully developed 7xxx high strength Al alloy for hot stamping, which shows outstanding short-time solution treatment behaviour, low quenching sensitivity, good thermal formability and excellent backing hardening performance. The alloy shows higher lightening effect and lower production costs. The B pillar component was been developed by this hot stamping technology. Compared with high strength steel, the Al component has achieved a weight reduction of 40% with a cost of only 2.1 times that of steel parts. The technology can help increase the application of Al alloys on vehicle lightening and aerospace area. The technology further reduce the component weight by controllable costs, which is of profound significance.

Effect of the grain boundary microstructure on S.C.C. resistance of high strength 7000 series aluminum alloy extruded materials

11:55AM - 12:20PM

Presented by:

Tomoo Yoshida, Department Maneger, AISIN KEIKINZOKU Co,.Ltd

It is known that 7000 series aluminum extrusions have high strength and relatively good extrusion productivity. Therefore, it is applied to structural members for automobiles, etc., where vehicle weight is expected to increase due to increased battery capacity, in order to reduce component weight.The 7000 series aluminum alloys characteristically occur to stress corrosion cracking, although both high strength and no stress corrosion cracking is an important key point. We have systematically controlled Mg and Zn as main components and clarified the relationship between strength and precipitates in our previous research. In this study, we focused on the relationship between microstructure and stress corrosion cracking resistance on the alloys that have different ratios of Zn/Mg, and their results are reported.

Effects of Zinc addition on aging precipitation and corrosion of A6063 alloy

01:50PM - 02:15PM

Presented by:

Masahiro ARAKI, Section Chief, YKK AP Inc.

Co-authors :

Yasutaka KURODA, Graduate Student, Virginia Polytechnic Institute And State University

Tsutomu MORI, Section Manager, YKK AP Inc

This study evaluated the effect of Zinc in Al-Mg-Si alloy extrusions on the aging properties, corrosion resistance, and surface treatment quality of the materials. Commercial AA6063 alloy with 0.2% Zn exhibited almost the same aging properties as AA6063. The material cooling rate after extrusion was slow, the alloys with 0.2% Zn tended to have lower tensile strength and coarser precipitates. A small amount of Zn in 6063 alloy does not form compounds by itself, but when the cooling rate from the solution annealing temperature is slow, it affects the precipitation morphology and degrades mechanical properties and surface treatment performance.

Revolutionizing Aluminum Alloys: AMAG's Path to Unrestricted Innovation with AMAG CrossAlloy®

02:15PM - 02:40PM

Presented by:

Florian Schmid, AMAG Rolling GmbH

Co-authors :

Lukas Stemper, AMAG Rolling GmbH

Ramona Tosone, AMAG Rolling GmbH

09:50AM - 03:30PM

GLC 233

Modelling and Simulations (process and products)

In- & post-process simulations to obtain cost-effective fatigue driven Scalmalloy parts by laser powder bed fusion

09:50AM - 10:15AM

Presented by:

Akash Sonawane, Metallic Materials Scientist , Central R&T, Airbus SAS

Co-authors :

Frank Palm, Senior Expert Metallic Materials & Processes, Airbus Defence And Space GmbH

Vasily Ploshikhin, Airbus Endowed Chair For Integrative Simulation And Engineering Of Materials And Processes, Bremen Center For Computational Materials Science, University Of Bremen, Bremen, Germany

Mohammad S. Mohebbi

Standard-Scalmalloy® (Al-4.5Mg-0.75Sc-0.35Zr-0.45Mn) produced via laser powder bed fusion (L-PBF) has proved to be a game changer due to its bimodal microstructure combined with nano Al3(Sc,Zr) precipitates giving high mechanical properties along with good ductility [1]. In addition to these exceptional static strength properties, D. Schimbäck et al [2] fabricated Scalmalloy® with high fatigue properties by controlling melt puddle dynamics. Despite these advantages (static & fatigue), the implementation of 3D-printed Scalmalloy for aerospace application is challenged due to the time / cost associated with the laser powder bed fusion and post processing, for example : As-built : low built rates ~30cm3/hr, porosity due to keyhole melting, lack-of-fusion microstructure imperfections, evaporation of volatile elements like Magnesium.Post built - heat treatment (HT) at 325°C for 4hr or alternatively Argon medium based hot isostatic pressing (HIP) heat treatment (at 325°C for 4hr [3]) This lack of in-depth understanding of the root causes of low built rates, keyhole porosity formation is an impediment for designing Scalmalloy® engineering parts for safety-critical applications in aerospace, mainly fatigue driven. The approach proposed in this study aims to identify the high built rate conditions for Scalmalloy® by understanding the underlying melt pool dynamics using multiphysics simulations coupled with thermodynamics. First, the solidification path of the Scalmalloy is calculated relying on the Scheil-Gulliver assumption taking into account the solute trapping that is representative of high cooling rates of L-PBF. Second, the intrinsic material properties like thermal conductivity, dynamic viscosity, surface tensions, evaporation enthalpy are computed using Thermocalc® as a function of temperature. Finally, a multi phase Volume of fluid (VoF) framework is proposed, taking inputs from thermodynamics, for computationally deriving correlations between process-induced melt pool physics and LPBF process parameters. The model links process parameters to temperature-time profile, solidification conditions and identifies conditions that cause lack-of-fusion defects, melt- and solidification-induced voids, as well keyhole porosity formation. The modelling approach coupled with the single/multi track experimental results, provide guidelines to identify process parameter options that might increase the built rates by a factor of 3 (~90cm3/hr) while maintaining the material quality. Similarly to tackle the expensive and time consuming post processing, an innovative accelerated liquid-medium heat treatment (LHT) is also proposed. This is done via post process precipitation simulation that deals with identifying the HT parameters that try to predict how to maintain the Al3(Sc, Zr) precipitates

density and size distribution while shortening the HT sequence tremendously by a factor > 10 (i.e. 15 min. instead of 240 min). This involves use of thermo-metallurgical precipitation model and strengthening model to estimate the corresponding increase in static mechanical properties post LHT. The outcomes of the LHT simulations can in principle be transferred (further developed) to other interesting Aluminium alloys fabricated by LPBF, thereby reducing the post fabrication efforts. References : A.B. Spierings, K. Dawson, T. Heeling, P.J. Uggowitzer, R. Schäublin, F. Palm, K. Wegener, Microstructural features of Sc- and Zr-modified Al-Mg alloys processed by selective laser melting, Mater. Des. 115 (2017) 52–63,D. Schimbäck, P. Mair, L. Kaserer, An improved process scan strategy to obtain high-performance fatigue properties for Scalmalloy, Materials & Design 224 (2022) 111410Rosso, M. et al., Liquid hot isostatic pressing process to improve properties of thixoformed parts. Materials Science and Technology, ISSN 0267-0836, vol. 18(2), (2000), p. 16-20

Aluminum Laser Powder Bed Fusion Printing and Processing Optimization using ICMD® SaaS Platform

10:15AM - 10:40AM

Presented by:

Kerem Taskin, Senior Client Solutions Engineer, QuesTek Innovations LLC

Co-authors :

Tanner Kirk, QuesTek Innovations LLC

Commonly utilized aluminum alloys in Additive Manufacturing (AM) were initially developed to be processed via conventional manufacturing paths such as casting or forging. These alloys were adapted for AM applications due to their relative weldability, increasing the likelihood of crack-free printability. Due to the rapid solidification and remelting that occurs during the AM process, these alloys exhibit widely different microstructures and properties compared to their cast and wrought forms. Furthermore, heat treatment of AM-built alloys based on the traditional manufacturing standards yields sub-optimal properties. As a result, novel aluminum alloys are being developed that capitalize on the unique features of the AM process. Additionally, thermal processing of legacy alloys produced via AM are now being optimized to tailor microstructures and increase the performance of the materials. ICMD® utilizes a combination of physics-based models, thermodynamic and kinetic databases, and CALPHAD (CAlculation of PHase Diagrams) methods to digitally predict material microstructures and properties. This presentation will focus on the application of ICMD®, a novel SaaS offering, to assess hot cracking susceptibility and create printability maps for laser powder bed fusion (LPBF) AM of aluminum alloys.

Analytical prediction of texture of multi-phase material in laser powder bed fusion

10:40AM - 11:05AM

Presented by:

Wei Huang

Laser powder bed fusion (LPBF) has been broadly employed in metal additive manufacturing to create geometrically complex parts, where heat transfer and its resulting temperature distribution significantly influence the parts' materials microstructure and the materials properties. In determining material properties, crystallographic orientations play one of the critical roles among all microstructure representations due to the influence on anisotropy, void growth, coalescence behaviors, etc. This paper first developed a physics-based analytical model to predict the multi-phase materials texture related to the 3D temperature distribution in LPBF, considering heat transfer boundary conditions, heat input using point-moving heat source solution, and heat loss due to heat conduction, convection, and radiation. The superposition principle was used to obtain temperature distribution based on linear heat input and linear heat loss solutions. Then, by utilizing temperature distribution, the texture grown on a substrate with random grain orientations was analytically acquired, taking into account the columnar-to-equiaxed transition (CET). The correlation between texture and process parameters has been effectively established using CET models and the second law of thermodynamics. Ti-6Al-4V was selected to demonstrate the capability of the analytical models in a multi-phase situation. With applied advanced thermal models, the accuracy of the texture prediction is evaluated based on the comparison to experimental data from literature and past analytical model results and shows higher accuracy achieved. In this work, there is no involvement of any finite element iterations. This study not only offers a quick and precise way of analyzing texture prediction in multi-phase mode for metallic materials but also lays the groundwork for future research on microstructure-affected or texture-affected materials' properties, both in academic and industrial settings. The accuracy and reliability of the results delivered through this approach make it a valuable tool for further research and development.

Disassembling DSC curves with HEXRD and mean-field simulations

11:05AM - 11:30AM

Presented by:

Robert Kahlenberg

Co-authors :

Georg Falkinger

Roman Schuster

Bernhard Miesenberger

Nicolás García Arango

Emad Maawad

Benjamin Milkereit, University Of Rostock

Ernst Kozeschnik

Differential scanning calorimetry (DSC) is a frequently used method to study precipitation reactions in aluminum alloys. However, the measured specific excess heat capacity (excess cp) reflects the sum of the reaction heat of all transformation reactions and that complicates the interpretation of reaction peaks. This is especially true for continuous heating experiments, where multiple opposing reactions overlap (endothermic dissolution & exothermic precipitation). In this work, we show that by combining DSC and high energy x-ray diffraction (HEXRD) data with mean-field modeling approaches of varying complexity, it is possible to significantly improve our understanding of the later stages in the precipitation sequence of different aluminum alloys.

Deformation of thick aluminum plates accounting for through-thickness variations in texture

11:30AM - 11:55AM

Presented by:

Jeffrey Lloyd, US Army Research Laboratory

Co-authors :

Daniel Magagnosc

In this work plate-scale microstructure characterization is used to instantiate anisotropic metal plasticity models that account for through-thickness gradients in texture and strength.

Modeling the Effect of Alloy Composition on Intergranular Corrosion in 6xxx Alloys

01:50PM - 02:15PM

Presented by:

Eystein Vada, Laboratory Engineer, Hydro Aluminium

Co-authors :

Ole Runar Myhr, Principal Research Scientist, Hydro Aluminium

Malgorzata Chojak Halseid, Principal Research Scientist, Hydro Aluminium

Trond Furu, Research Manager, Hydro Aluminium

A model for predicting Intergranular Corrosion (IGC) susceptibility in 6xxx series aluminum alloys is presented. The model calculates the long-range diffusion of elements from the grain interior to the grain boundary during non-isothermal heat treatments and calculates the intergranular precipitation assuming a collector plate mechanism. The concentration of elements in the Solute Concentrated Layer (SCL) and in the adjacent Solute Depleted Layer (SDL) is updated at each time step of the simulation based on the numerical diffusion model. The predicted concentrations in the SCL and SDL are converted to a corresponding overall corrosion potential for the solid solution. Similarly, the corrosion potential of the intergranular particles was estimated for the various relevant phases. The differences in corrosion potential between the SCL and SDL, as well as between the particles and the SCL were used to predict an overall index for the relative IGC susceptibility. The index was used for ranking alloys with various Si/Mg ratio and Cu-levels and compared with experimental literature data. The overall result show good correlation between simulations and measurements.

Modeling the microstructure evolution during hot-rolling of industrial Al-Mg-Si alloys

02:15PM - 02:40PM

Presented by:

Georg Falkinger

Co-authors :

Vitesh Shah

Ramona Tosone, AMAG Rolling GmbH

Stefan Pogatscher, Montanuniversitaet Leoben

Hot-rolling considerably changes the microstructure of Al-Mg-Si alloys. The temperature, rolling reduction and rolling speed affect the grain size and crystallographic texture but also the formation of stable second phases such as Mg2Si, pure Si or the Q-phase. We use a three-dimensional Finite-Element model of the full hot-rolling schedule in conjunction with microstructure models (mean-field and full-field), to study the effect of process parameters on the cross-section distribution of grain size, texture and fraction of stable phases. We present industrial use cases and discuss the technological relevance of individual physical mechanisms and their interactions

Stored energy effect on static recrystallisation kinetics of aluminium alloy AA6082 during heating

02:40PM - 03:05PM

Presented by:

Talina Terrazas Monje, PhD Candidate, Graz University Of Technology. Christian Doppler Laboratory For Design Of High-performance Alloys By Thermomechanical Processing

Co-authors :

Ricardo Buzolin, Institute Of Materials Science, Joining And Forming, TU Graz, Kopernikusgasse 24/I, 8010 Graz, Austria. Christian Doppler Laboratory For Design Of High-Performance Alloys By Thermomechanical Processing, Kopernikusgasse 24/I, 8010 Graz, Austria

Florian Brumbauer, Institute For Material Physics, TU Graz, Petersgasse 16/IV, 8010 Graz, Austria

Wolfgang Sprengel, Institute For Material Physics, TU Graz, Petersgasse 16/IV, 8010 Graz, Austria

Annika Hämmerle, Neuman Aluminium Industries, Werkstraße 1, 3182 Marktl, Austria

Cecilia Poletti, Institute Of Materials Science, Joining And Forming, TU Graz, Kopernikusgasse 24/I, 8010 Graz, Austria. Christian Doppler Laboratory For Design Of High-Performance Alloys By Thermomechanical Processing, Kopernikusgasse 24/I, 8010 Graz, Austria

Impact extrusion causes high strain and temperature gradients within formed components, conditioning their microstructure evolution during subsequent heat treatments. Although many studies have described the isothermal recrystallisation of aluminium alloys, the concurrent static restoration phenomena (i.e., recovery and recrystallisation) may behave differently during heating. In this work, we studied the effect of the stored energy from deformation (dependent on strain, strain rate and deformation temperature) on static recrystallisation during heating. Therefore, we cold-deformed an AA6082 alloy emulating the impact extrusion process. Even at room temperature, we observed a positive strain rate sensitivity. Then, we heated the material at different rates to identify the mechanisms triggering recrystallisation. Also, we described the observed microstructure evolution during plastic deformation and heat treatments using physics-based models. In these models, grain-boundary fractions, misorientation distributions, grain sizes, subgrain sizes, and three dislocation densities describe the microstructure. Our models predicted that the start temperature of recrystallisation increases with increasing heating rate, and it is independent of the strain, in agreement with experimental results. We found that the deformation rate plays no role in recrystallisation kinetics, and we demonstrated the competing role of recovery during restoration.

Role of non-ideal orientations in texture evolution after high-temperature extrusion of Aluminum alloys

03:05PM - 03:30PM

Presented by:

Warren J. Poole, Full Professor, The University Of British Columbia

Co-authors :

Ali Khajezade, Postdoctoral Research Fellow, The University Of British Columbia

Matthias Militzer, Full Professor, The University Of British Columbia

The characteristics of the deformed state after high temperature extrusion determine the subsequent evolution of texture and the resulting anisotropic mechanical behavior of the extrudate. EBSD analyses on high-temperature axisymmetric extrusions of 3003 aluminum alloy show that while the deformed state consists only of ~2% non-ideal orientations, with respect to the extrusion direction (ED), the recrystallized state has ~41% of non-ideal orientations. This suggests that the ~2% minority of non-ideal orientations in the deformed state significantly affects the recrystallized texture. In this study, the role of non-ideal orientations on the evolution of the microstructure after high-temperature extrusion of aluminum alloys has been studied. Five different strategies for the location of the non-ideal orientations in the deformed microstructures were examined using large scale phase field simulations. The results of the simulations show that the non-ideal orientations and their spatial position play a noticeable role in the evolution of the microstructure mainly by impacting the fraction of < 111>||ED. The results were rationalized based on the role of the non-ideal orientations on the stability of the band structures in the deformed state.

Microchemistry dependent flow behaviour of secondary aluminum

03:50PM - 04:15PM

Presented by:

Sharan Roongta, Post-Doctorate, Max Planck Insitut Für Eisenforschung Gmbh

Co-authors :

Markus Apel

Janin Eiken

Franz Roters

Aluminum is used extensively in automotive production due to its light weight and good corrosion resistance properties. However, the production of primary aluminum contributes negatively to the goal of carbon neutrality as envisioned for a sustainable future. Therefore, reusability of materials has become an important research topic for academia and industry alike. Using impure and recycled secondary aluminum can lead to a reduction of 0.7 metric tons of CO2 per vehicle.The hope is to produce aluminum alloys using recycled aluminum that has comparable properties to the alloys produced using primary aluminum.In this work, we aim to develop a digital twin to model the wide variety and composition of scrap content present in secondary aluminum.This approach increases the speed for exploration of the effect of varying proportion of scrap on the overall macroscopic material properties without having to perform extensive experiments.Using computer simulations to predict the composition-microstructure-property relationships is also in the spirit of an Integrated Computational Materials Engineering (ICME) approach.The model is implemented in the Düsseldorf Advanced Material Simulation Kit (DAMASK), an open source, multi-physics crystal plasticity (CP) software, with the capability and flexibility to perform and analyze complex multi-field simulations.The work involves the coupling of DAMASK with the MICRostructure Evolution Simulation Software (MICRESS).MICRESS performs Calphad-coupled solidifcation simulations for the recycled aluminum alloys with impurity elements.The resultant microstructure is fed into DAMASK to predict the material mechanical properties using a microchemistry dependent dislocation density based CP model.

The effect of crystallographic texture on strain localization at weld seams in Al-Mg-Si porthole die extrusions

04:15PM - 04:40PM

Presented by:

Andrew Zang, PhD Candidate, The University Of British Columbia

Co-authors :

Jean-François Béland, National Research Council Canada

Yu Wang

Nick Parson

Warren J. Poole, Full Professor, The University Of British Columbia

In this study, the connection between crystallographic texture and the local mechanical response at the weld seam for porthole die extruded AA6082 strip was investigated. First, electron backscatter diffraction (EBSD) was conducted to quantify the crystallographic texture near the weld seam of the extrudate. Next, regions with similar textures were separated, and orientation distribution functions (ODFs) were calculated using MTEX. Then the ODFs for each region were used as inputs for polycrystal plasticity simulation using the visco-plastic self-consistent (VPSC) code. Barlat YLD2004-18p yield surfaces were fitted to the VPSC results for each region. Finally, finite element modelling (FEM) was conducted, with the yield surfaces assigned to regions meshed corresponding to the texture regions observed in EBSD. The results of the distribution of strain near the weld seam were compared to experimentally collected digital image correlation (DIC) strain maps. A qualitative match was found between the two results, indicating that the crystallographic texture has a significant effect on local mechanical properties.

Microstructural effects on the micro-mechanical properties of recycled 6xxx Aluminium alloys

04:40PM - 05:05PM

Presented by:

Zhenjie Cao, PhD Students, The University Of Manchester

Co-authors :

Yangchao Deng, PhD Student, The University Of Manchester

Pratheek Shanthra, UKEA

Joseph Robson, Univesity Of Manchester

These are critical times for recycled aluminium alloys research with continuously increasing demand for lighter and more cost-effective solutions in the vehicles, particularly to both reduce greenhouse gas emissions and increase the range of future electric vehicles. However, some impurity elements are inevitably introduced during the recycling process of recycled aluminium alloys, which frequently form intermetallic compound particles (IMCs) that affect the forming properties of recycled aluminium alloys. How to reduce the effect of stress concentration caused by IMCs has emerged as a critical point in improving the forming properties of aluminium alloys. A combination of experiments and simulations has been employed in this study to investigate the heterogeneous material response induced by IMCs. The advanced crystal plasticity finite element method, DAMASK, coupled with experimental data, has been utilized to model the deformation process of recycled aluminium alloys under varying loading conditions. Our research has formulated a series of 3D synthetic models incorporating IMCs. Through the examination of the volume fraction and IMCs distribution within the synthetic models, it has been observed that fluctuations in IMC volume fraction exert a more pronounced influence on the overall heterogeneous response, while the distribution of IMCs plays a more substantial role in localized heterogeneous response.

09:50AM - 05:55PM

GLC 323 & 324

Additive Manufacturing and Joining

Controlling interfacial reaction between Al and carbon fibers during laser powder bed fusion by Ti alloying and TiC coating

09:50AM - 10:15AM

Presented by:

Asuka Suzuki, Nagoya University

Co-authors :

Tsubasa Aoki, Nagoya University

Naoki Takata, Nagoya University

Makoto Kobashi, Nagoya University

Masaki Kato, Aichi Center For Industry And Science Technology

Controlling microstructure of Al-Fe-Ti alloys using peritectic reaction in laser powder bed fusion process

10:15AM - 10:40AM

Presented by:

Naoki Takata, Nagoya University

Co-authors :

Takanobu Miyawaki, Nagoya University

Asuka Suzuki, Nagoya University

Makoto Kobashi, Nagoya University

Masaki Kato, Aichi Center For Industry And Science Technology

Characterization of porosities and melt pool dimensions in Fe-contaminated hypo- and hyper-eutectic Al-Si alloys produced with laser powder bed fusion

10:40AM - 11:05AM

Presented by:

Layla Shams Tisha, Research Scientist, Leibniz-Institute For Materials Engineering, University Of Bremen, Germany

Co-authors :

Daniel Knoop, Leibniz-Institute For Materials Engineering

Nils Ellendt, Leibniz-Institute For Materials Engineering University Of Bremen

Anastasiya Tönjes, Leibniz-Institute For Materials Engineering University Of Bremen

Heterogeneous plastic strain in an Al-Mn-Ni-Cu-Zr alloy designed for L-PBF

11:05AM - 11:30AM

Presented by:

Alexis Deschamps, SIMaP-UGA

Aluminum alloys designed for additive manufacturing often exhibit highly heterogeneous microstructures. A bimodal grain size distribution is observed with submicron equiaxed grains at the bottom of the melt pool and coarser columnar grains in the melt pool interior. Microstructural heterogeneities also develop at the intragranular scale (a large proportion of intermetallics with differences in size and morphology) down to the atomic scale (solid solution variations and nanoprecipitation) depending on the region of interest. This heterogeneity translates in a complex mechanical behavior, whether in monotonic loading or during strain path reversal. Here, the plastic behavior of a newly developed Al-4Mn-3Ni-2Cu-1Zr alloy has been studied. Using micro-digital image correlation, we show that an extended elastic-plastic transition takes place controlled by the relative strength and work hardening rate of the different regions. Additionally, studying the Bauschinger effect allows to evidence the role of the different contributions to plastic incompatibility at different scales and the resulting build-up of internal stresses.

Zr-Ti modified high strength Al-Mg aluminum alloy with heterogeneous microstructure specifically developed for laser powder bed fusion process

11:30AM - 11:55AM

Presented by:

SaravanaKumar Murugesan, Research Assistant, KKS/ RWTH Aachen University

Aluminum-Magnesium alloys, renowned for their lightweight properties, are an exciting class of alloys for additive manufacturing (AM), where further weight reduction is possible. In laser powder bed fusion (LPBF), given the extreme process conditions in terms of heating and cooling rates, high strength Aluminum alloys are prone to hot cracks and other defects. A Zr-Ti modified Al-Mg alloy was developed in this study for LPBF, using a partially pre-alloyed powder blend approach, and it exhibits clusters of columnar and equiaxed grain regions, demonstrating good processability in LPBF. Two master alloys of Al-Mg-Zr and Al-Mg-Ti were atomized, which then were blended with elemental Al and Mg to achieve the targeted composition and produced by LBPF. The AM specific microstructure and the deformation behavior of the as-built and direct-aged alloy were studied by multiscale microstructure characterization (OM, SEM, EBSD, EDX, TEM) and tensile testing. The effect of LPBF specific microstructure and heat treatment on the precipitation and mechanical behavior of the developed alloy is discussed. The developed alloy has a unique smooth strain hardening behavior in aged condition in contrast to similar class of high strength Aluminum alloys and is a good candidate for lightweight aerospace and automotive applications.

Direct natural and artificial aging of LPBF Al10Si0.3Mg

11:55AM - 12:20PM

Presented by:

Rabea Steuer

Co-authors :

Benjamin Milkereit, University Of Rostock

Olaf KESSLER, Head Of The Chair Of Material Science, University Rostock

The present study gives insight in direct aging of an Al10Si0.3Mg alloy additively manufactured by laser powder-bed fusion (LPBF). Therefore, the aging behavior of the as built LPBF condition without additional "solution annealing + quenching" is analyzed via hardness testing and differential scanning calorimetry (DSC) measurements. In particular the natural aging as well as artificial aging after relatively short (few days) and prolonged natural aging (few weeks & months) after the LPBF are considered. Compared to classically cast variants of this alloy type, high hardness levels are achieved. Though, natural aging from intermediate storage causes a pronounced negative effect: Remarkably not only that the hardening potential for subsequent artificial aging is substantially reduced but also natural aging itself caused an unexpected reduction of the hardness instead the commonly occurring hardness increase from clustering. The findings should sensitize the LPBF community to manage the process logistics in order to lately achieve the desired strength level for the part in service.

Grain refinement in extruded 6000 series aluminum alloy using additively manufactured billet

01:50PM - 02:15PM

Presented by:

Shogo Oda, YKK AP Inc.

Co-authors :

Shun-Ichiro TANAKA, Tohoku University ?SIC

Akihiko CHIBA, Tohoku University NICHe

A new approach to the design of aluminum alloys for additive manufacturing

02:15PM - 02:40PM

Presented by:

Chengbo Zhu, Research Fellow, Brunel University London

Co-authors :

Dmitry Eskin, Speaker, Co-organizer, BCAST, Brunel University London

Alloy design for additive manufacturing of a 6xxx aluminum alloy for ultra-high and medium strength applications

02:40PM - 03:30PM

Presented by:

Navid Sohrabi, Metallurgy Scientist, Novelis Switzerland SA

6xxx alloys are widely used in different industries, such as automotive and aerospace industries. However, one of the main limitations of this group of aluminum alloys is high hot cracking susceptibility. Therefore, processing 6xxx alloys with laser powder-bed fusion (LPBF) technology and fabricating parts without cracking is challenging. Using crack susceptibility models in the literature [1,2], we could develop an alloy based on Al-Si-Mg that is hot crack resistant. Since 6xxx alloys are precipitation-hardened, we tuned the mechanical properties of this alloy by applying different heat treatments to use it for high-strength and medium-strength applications.

ABD®-M420; a new high strength / temperature aluminium alloy for additive manufacturing

03:50PM - 04:15PM

Presented by:

Fateme Amirkhanlu, PhD Student, Brunel University London

Co-authors :

Hari Nadendla, Brunel Centre For Advanced Solidification Technology

This study aimed to investigate and develop a new high strength / temperature aluminium alloy suitable for laser powder bed fusion (LPBF) process while taking into consideration industrial scale production constraints. The alloy needed to be processable at large-scale AM platforms and have a high production rate and low cost. ABD®-M420 is an Al-Fe-Mn base alloy suitable for high temperature performance applications was successfully developed at an industrial scale throughout this investigation. The use of Alloy by Design (ABD®) software and EIGA process allowed for the creation of the alloy with desired properties, and the Renishaw 500S AM machine produced specimens with over 99.95% optical density. ABD®-M420 achieves the best combination of properties at different temperatures by employing both dispersoids and precipitates strengthening strategies. In as build state, tensile results indicate 262 MPa yield strength and 21.7 elongation at room temperature tensile testing and 220, 213, 172 MPa yield strength and 17.8, 11,7, 5.2 % elongation at 200℃, 250℃ and 300℃, respectively. For room temperature performance, T5 heat treatment increases strength of ABD®-M420 while for high temperature applications, optimal performance is achieved without the need for T5 heat treatment.

Influence of Oxide Film on Eutectic Melting between Aluminum and Silicon

04:15PM - 04:40PM

Presented by:

Ryo Tomori, Japan / UACJ Corporation

Co-authors :

Taichi Suzuki

For automotive heat exchanger materials, Al-Si alloy filler material and aluminum alloy with silicon powder coating is used to join the materials by brazing. In the materials, molten filler is generated by eutectic melting between aluminum and silicon during brazing. However, its behavior is not clear because it is phenomenon between solid/solid interface and hard to observe in details. Here, we show that oxide film on aluminum surface makes melting start temperature higher in the eutectic melting between aluminum and silicon. We found eutectic melting occurred almost just at eutectic temperature in the case that oxide film on aluminum surface was removed. On the other hand, in the case that oxide film remained, eutectic melting only occurred at 5 K or more higher than eutectic temperature. We consider that oxide film inhibits aluminum-silicon contact around eutectic temperature, but when they are superheated, critical radius of liquid

phase nucleation becomes smaller and liquid phase can be generated for example at oxide film gap. From above results, in the situation where aluminum and other metal elements were in contact through oxide film, the melting behavior becomes different from Al-Si alloy filler material.

Friction Stir Welding and Metal inert Gas Welding; A comparative study for Al6061 joint strength in as-rolled, T6 and B4C reinforced composites

04:40PM - 05:05PM

Presented by:

Shahid Akhtar, Principal Research Scientist, Hydro Aluminium

Ragnhild Elizabeth Aune, Prof., NTNU

Co-authors :

Mahmood Khan, Researcher, Department Of Materials Science And Engineering, Norwegian University Of Science And Technology, Trondheim, Norway

Aufa Tahir, Student, FUUAST

Muhammad Abdul Basit, Asst. Prof, IST

Baris Avar, Bülent Ecevit University

Al6061 is widely used for structural applications in the aerospace industry. the strength of this alloy in T6 thermal condition is excellent. Joining these thermally treated structural members remains challenging. Friction Stir Welding (FSW) is among the emerging joining techniques of welding to explore various industrial solutions. In the present study, a comparative effort is carried out to compare the as-rolled Al6061 and thermally treated (T6) Al6061 sheets that were welded via metal inert gas (MIG) welding and FSW. in the FSW a set of Al6061 sheets were reinforced with B4C particles. The addition of B4C resulted in optimum balance in mechanical properties in both thermal conditions. Process related defect tendency of welding effects the joints efficiency. MIG has better weldment microstructure compared to tool friction related defect. Control of FSW parameters can result in better, defect-free and cost-effective welded joints.

Studying the influence of welding parameters and post-weld heat treatments on refill friction stir spot welded AA7050 via SAXS

05:05PM - 05:30PM

Presented by:

Susanne Henninger, Helmholtz-Center Hereon

Co-authors :

Niklaas Becker

Peter Staron

Rupesh Chafle

Benjamin Klusemann

Martin Müller

Age-hardenable alloys of the 7xxx series are often used in structural components in aerospace and automotive industry. Their excellent mechanical properties are achieved via precipitation hardening. Hardening GP-zones, η' and η-precipitates are formed through thermal ageing

processes. Solid-state joining processes like Refill Friction Stir Spot Welding (refill FSSW) are especially interesting for alloys that are difficult to weld, such as AA7xxx alloys. The rotating tools in refill FSSW introduce severe plastic deformation, frictional heat and high heating and cooling rates, which lead to severe microstructural changes. Small Angle X-ray Scattering (SAXS) was used to study the precipitation kinetics in detail. In this work, 2D SAXS mapping was used to determine precipitate size and volume fraction of AA7050 refill FSSW samples. The influence of welding parameters as well as post-weld heat treatments on the precipitation kinetics was studied. Additionally, the influence of the temperature cycles on the precipitates in AA7050 was analyzed in-situ using a modified dilatometer. Additionally, the precipitation kinetics were modelled using the commercial PandatTM software. The goal of this work is to get a better understanding of precipitation kinetics occurring during thermo-mechanical processing via modelling and experiments.

A Recrystallisation Model for Additive Friction Stir-Deposited (AFS-D) Alloy

05:30PM - 05:55PM

Presented by:

Sumit Gahlyan, Assistant General Manager, Hindalco Industries Limited

Co-authors :

Shavi Agrawal, Research Scholar, Indian Institute Of Science, Bangalore

Additive Friction Stir-Deposition (AFS-D) is a novel solid-state metal-deposition technique wherein feedstock typically in form of rods is fed into a hollow rotating tool. Frictional heat generated from contact of moving feedstock to substrate lead to plasticisation of metal for layer-by-layer deposition. An AA6061 alloy is printed through AFS-D, and later subjected to annealing heat treatments. During the heat treatment procedure, the fragmented grains of the as-printed condition underwent grain coarsening. As-printed and heat-treated samples are characterized through EBSD analysis to study the grain growth phenomenon. A model based on substructure, boundary characteristics and dispersoids distribution is used to describe the recrystallisation and grain growth phenomenon. The model closely follows the observed results. Based on the analysis it is concluded that consideration of substructure size distribution is critical for closer prediction of results rather than the median or mean values. The model described here could be extended to microstructures obtained through AFS-D or severe plastic deformation techniques for wider adoption in aerospace, industrial and automotive applications.

09:50AM - 06:25PM

GLC 236

Microstructure Design; Alloying and Heat Treatments

Revisiting Heterogenous η-Phase Grain Boundary Precipitation in 7xxx Al alloys

09:50AM - 10:15AM

Presented by:

Phil Prangnell, Professor, The University Of Manchester

Co-authors :

Yichao Yao, Student, University Of Manchester

Pratheek Shanthra, UKEA

Matthew Curd, Research Associate, University Of Manchester

Thomas Flint, Lecturer, The University Of Manchester

Tim Burnett, Professor, University Of Manchester

The fracture toughness and stress corrosion cracking resistance of thick-plate 7xxx series aluminium alloys are strongly affected by the distribution and composition of η-phase precipitates that nucleate heterogeneously on their grain boundaries (GBs). Here, we exploit novel intergranular fracture and advanced EM analysis methods, supported by CALPHAD-coupled Phase field models, to examine the effect of composition and quench rate on the morphology, distribution, and composition of precipitates nucleated on grain boundaries in thick plates with T76 tempers. This work has revealed that the precipitates that form, and the sensitivity of their distribution and morphology to cooling rate, is much more complex than previously realised.

Microstructure evolution and kinetic analysis of precipitation process in an Al-Zn-Mg alloy

10:15AM - 10:40AM

Presented by:

Mami Narita, Assistant Professor, Nagoya Institute Of Technology

Co-authors :

Hideo Yoshida, ESD Laboratory

In order to investigate the two-step aging behavior of an Al-6 mass %Zn-0.75 mass %Mg alloy (AA7003 without Zr, Fe, Si), kinetic analysis of precipitation process using Yamamoto's equation was carried out. All aging processes at 16 ℃ to 200 ℃ were described as the sum of three precipitation reactions: spherical, plate-like, and rod-like precipitates, regardless of the holding time at room temperature (RT). These results agreed with the observation of TEM microstructures. Based on the activation energy of diffusion calculated from the rate equation, it was suggested that the formation rate of precipitate is related to the diffusion of magnesium and zinc atoms. The comparison between electrical resistivity (ER) and Vickers hardness (HV) changes at 160 ℃ aging showed that the change of HV was faster than that of ER when the long holding time at RT was long. On the other hand, change in ER became faster than that of HV when the long holding time at RT was short. The reason why the change of HV was faster than that of ER was considered to be that the formation of clusters and GP zones contributing HV was faster than the precipitation of metastable and stable phases.

Geometrical analysis of η-MgZn2/Al interphase boundary

10:40AM - 11:05AM

Presented by:

Seiichiro Ii, Principal Researcher , National Institute For Materials Science

Co-authors :

Toru Hara, Group Leader, National Institute For Materials Science

p.p1 {margin: 0.0px 0.0px 0.0px 0.0px; font: 9.0px Helvetica} span.s1 {font: 6.0px Helvetica} span.s2 {font: 6.5px Helvetica} To understand the reason why the MgZn2 (η) phase has various orientation relationships for aluminum matrix in 7XXX Al-Zn-Mg(-Cu) alloys, we have analyzed the geometry of the η/Al matrix heterointerface by near coincidence site (NCS) modeling and the misfit strain. Among the 15 orientation relationships (ORs), the interfaces of η1, η2, η3, and Al matrix are analyzed to validate the efficiency of NCS analysis. The tendency of the NCS density on each plane was consistent with the experimentally observed morphology that precipitate is often observed on the plane with the highest density of NCS. This suggests the effectiveness of the NCS analysis. Furthermore, the parameter based on the misfit strain at the η/Al interface was evaluated as well, and the coherency of the interface was discussed quantitatively. The geometrical analysis explained the experimental results well, but the issue was also clarified for accurate analysis.

TEM observation of Al-7%Si-Mg alloys in T6 condition

11:05AM - 11:30AM

Presented by:

Taiki Tsuchiya, Assistant Prof., University Of Toyama

Co-authors :

Seungwon Lee, Associate Prof., University Of Toyama
Kenji Matsuda, Prof., University Of Toyama

Al-Si alloys have been used as casting materials for automobile parts. Al-Si-Mg alloys enhance its strength due to precipitation of metastable phase. Moreover, it is effective for increasing both strength and corrosion resistance with Mg addition. We fabricated samples having different Mg content by gravity casting. As a result of TEM observation, we confirmed rod shape metastable phases reported in 6XXX series aluminum alloy.

Influence of Ti on the formation of ageing phases in an AlSi7MgCu0.5 alloy

11:30AM - 11:55AM

Presented by:

Cecilia Poletti, Institute Of Materials Science, Joining And Forming, TU Graz, Kopernikusgasse 24/I, 8010 Graz, Austria. Christian Doppler Laboratory For Design Of High-Performance Alloys By Thermomechanical Processing, Kopernikusgasse 24/I, 8010 Graz, Austria

Co-authors :

Rene Wang, PhD Student, Institute Of Materials Science, Joining And Forming. TU Graz

Carolina Beatríz Gonzalez, Institute For Research In Technology And Engineering Science (IITCI CONICET-UNCo), Comahue National University

Bernhard Stauder, Nemak Linz GmbH

Ricardo Fernández-Gutiérrez, Nemak GmbH

Mihaela Albu, Graz Centre For Electron Microscopy

Titanium added to Al-cast alloys refines the cast grains and acts with growth restriction on the formation of dendrites. However, in particular processing conditions, Ti can consume alloying elements to form the Ti17Al5Si14 phase. Additionally, this phase can affect the kinetics of Q' (Mg-Si-Cu rich phases) and metastable β" (Mg-Si rich) phases that are responsible for the strengthening formed after solution heat treatment, quenching and artificial ageing. We developed and validated a complete modelling routine with the MatCalc© software to obtain the precipitates along any heat treatment history of an AlSi7Cu0.5Mg-alloy. We simulated the solidification of the casting with the Scheil approach, and the secondary phases formed during cooling, solution heat treatment and ageing using the classical nucleation theory. We also modelled the formation of the Ti17Al5Si14 phase and compared aged situations with and without this Ti-rich phase. After validating the model with the heat flow obtained by calorimetry (DSC) and the microstructures obtained by scanning electron (SEM) and scanning transmission electron microscopy (STEM) as well as X-ray analytical investigations, we could determine that Ti accelerates the nucleation of a fraction of the Q' phases and decelerates the precipitation kinetics of the metastable β" and β' phases.

Effect of Microalloying with Silver on the Precipitation Behavior of Over-aged Al–Zn–Mg–Cu Alloy

11:55AM - 12:20PM

Presented by:

Kwangjun Euh

Co-authors :

Yong-You Kim

Hyeon-Woo Son

Young-Hee Cho, Principal Researcher, Korea Institute Of Materials Science

This study employs transmission electron microscopy and atom-probe tomography to investigate the influence of microalloying Ag on the coarsening of η precipitates in over-aged Al–Zn–Mg–Cu alloys. The findings indicate that Ag addition increases the number density of η-MgZn2 type nano-precipitates by serving as direct precursors (Al–Mg–Ag phase) during early aging stages. Furthermore, Ag inhibits the coarsening of η precipitates, promoting a high-density distribution of fine η precipitates during over-aging and improving thermal stability. The mechanism underlying

Ag's inhibitory effect on coarsening of η precipitate is revealed to be the hindrance of Zn diffusion into the precipitate by Ag atoms, thereby directly preventing coarsening.

Effects of Mg content on recrystallization behavior during brazing of 3003 aluminum alloy

01:50PM - 02:15PM

Presented by:

Kodai Ichida, UACJ Corporation

Co-authors :

Dai Yamamoto, Manager, UACJ Corporation

During the manufacture of automotive heat exchangers, brazing sheets are assembled and then bonded by brazing process. In the brazing process, it is important to control recrystallization behavior of core alloy for the brazing sheets. However, effects of Mg content on the recrystallization behavior of the core alloy, such as 3003 aluminum alloy, for the brazing sheets during brazing has not been sufficiently studied. From the result, it is found that adding 0.1~0.4mass% Mg to the 3003 aluminum alloy increased the recrystallization completion temperature during brazing. In addition, the more Mg was added, the more solid solution Mg increased, and the Al-Mn-Si precipitates became finer before and during brazing. From these result, it is considered that the recrystallization completion temperature became high due to the combined effect of the solute drag effect due to the solid solution of Mg and the Zener drag effect due to the fine Al-Mn-Si precipitates.

Thermodynamic study of the impacts of Chromium, Iron, and Silicon elements on phase formation of 6xxx automotive alloy

02:15PM - 02:40PM

Presented by:

Pascal Gauthier, Metallography Manager, Rio Tinto

Co-authors :

Jaesuk Park, Principal Engineer, Novelis

Diana Ilioasa, Lead Process Engineer, Novelis

Matthew Heyen, Lead Engineer, Novelis

Jeffrey Tschirhart, CPS Engineer 1, Novelis

Tao Wang, Manager, Aluminum Technical Marketing, Rio Tinto

The interplay between iron (Fe), chromium (Cr), and silicon (Si) elements, and their impact on phase formations in a 6xxx aluminum alloy for the automotive application were studied in this research. Employing various thermodynamic modeling software such as FactSage™ and Thermo-Calc®, a comparative analysis is conducted to predict the phase evolution within the alloy matrix. To validate the simulation outcomes, the research incorporates Differential Scanning Calorimetry (DSC) and metallographic analysis, providing experimental insights into phase transformations during thermal processes. By aligning simulation predictions with experimental results, a comprehensive understanding of the alloy's phase formation at elevated temperature is

achieved. Furthermore, the mechanical hardness measurement also makes it possible to assess the impact changes of Fe, Cr, and Si interactions for the alloy.

Fabrication of Al-based composite containing cellulose nanofibers

02:40PM - 03:05PM

Presented by:

Seungwon Lee, Associate Prof., University Of Toyama

Co-authors :

Haruhi Shimizu, Student, University Of Toyama

Taiki Tsuchiya, Assistant Prof., University Of Toyama

Sarka Mikmekova

Ilona Mullerova

Yasushi Ono

Cellulose nanofiber (CeNF)/Al-based composites were prepared using CeNFs collected by a non-woven aluminum filter. Gel-like CeNFs were collected by an aluminum non-woven filter and compacted by a warm press to obtain a compressed form with a lighter specific density than pure aluminum. The compressed forms were hot extruded to fabricate bars and plates. They were observed in the macro-and microstructural morphology and XRD measurements. Microstructural observations show that CeNFs are aggregated and present in the pores/cracks between the Al filters in the compressed forms. Al filters and CeNF aggregates were more finely mixed when the material was fabricated into hot extruded plates with a higher extrusion ratio. The maximum tensile strength of the CeNF/Al composite extruded plate was about 1.5 times higher than pure aluminum.

New insights into the precipitate evolution in Al-Cu alloys

03:05PM - 03:30PM

Presented by:

Chamini Mendis, Brunel University London

Co-authors :

Raluca Negrea, Brunel University London

Maaouia Souissi, Brunel University London

Changming Fang, Brunel University London

Quentin Ramasse, SuperSTEM, Laboratory

Zhongyun Fan, Brunel University London

The Al-Cu alloys has been investigated in this contribution using advanced electron microscopy to understand evolution of θ' precipitates from supersaturated solid solution. Traditionally the formation of these precipitates has been understood to be through the formation of number of different metastable phases. However, using advanced transmission electron microscopy techniques we show that the metastable phases expected at very early stages of ageing are present even at peak ageing times. The advanced electron microscopy work is supported by DFT calculations to show that GP zones and θ'' are not metastable structures as previously thought but localized atomic arrangements that lead to the ultimate nucleation of θ' phase. Based on

electron microscopy observations coupled with the DFT calculations we propose a new mechanism behind the nucleation of θ' phase in the Al-Cu system.

The effect of scandium in solution on the precipitation sequence and kinetics in aluminum-copper alloys

03:50PM - 04:15PM

Presented by:

Austin DePottey, PhD Candidate, Michigan Technological University

Co-authors :

Timothy Langan, Sunrise Energy Metals

Paul Sanders, Michigan Technological University

Aluminum-copper-scandium alloys have recently gained interest as potential high-temperature lightweight materials due to scandium stabilizing the θ′ strengthening precipitates. Existing literature predominantly utilizes Al3Sc dispersoids to alter the precipitation of θ′ or explores the effects of scandium in solution on θ′ with respect to coarsening behavior at elevated temperatures. Notably, no previous work has investigated the influence of scandium in solution on the precipitation kinetics and sequence of the GP zone à θ″ à θ′ precipitation sequence. In this study, Al-3.5%Cu samples with 0.1% scandium additions were solutionized to achieve a single-phase aluminum matrix prior to isothermal aging at 160°C. Samples were analyzed using Vickers hardness and eddy current conductivity measurements, complemented by transmission electron microscopy (TEM) to identify the metastable precipitate species present in each alloy. The findings reveal that scandium in solution accelerates the kinetics of θ″ precipitation during aging at 160°C, favoring the formation of θ″ over θ′. These findings shed light on microstructure changes observed in previous studies of Al-Cu-Sc alloys and offer potential heat treatment strategies for this alloy system.

Accelerated nucleation of L12 Al3Zr precipitates via Sn microalloying

04:15PM - 04:40PM

Presented by:

Janet Meier, Postdoctoral Researcher, Oak Ridge National Laboratory

Co-authors :

Dongwon Shin

Jonathan Poplawsky, Oak Ridge National Laboratory

Lawrence Allard, Oak Ridge National Laboratory

Sumit Bahl, Oak Ridge National Laboratory

Allen Haynes, Oak Ridge National Laboratory

Nhon Q. Vo

Amit Shyam, Oak Ridge National Laboratory

Based on characterization and first-principles calculations, we propose a general mechanism for the accelerated precipitation of L12-Al3Zr due to micro-alloying with Sn. This Low melting point Element-Assisted Nucleation (LEAN) mechanism explains the observed formation of L12-Al3Zr nuclei at 200°C due to low-melting point Sn precipitates that accelerated the age-hardening

response at higher temperatures. The LEAN mechanism has broader implications in understanding the nucleation of other hard-to-nucleate phases (e.g., θ′-Al2Cu and α-Al(Mn,Fe)Si) by addition of low melting-point elements (e.g., Sn, In, or Cd).

Microstructure Analysis of T-phase in Al-Zn-Mg Alloy

04:40PM - 05:05PM

Presented by:

Abrar Ahmed, Doctor Student, University Of Toyama

The microstructure and mechanical properties of Al-Zn-Mg alloys with low Zn/Mg ratios have been studied. According to various researchers, the major strengthening is due to η-phase and T'(T) phase. In actual our aim is to observe the T'(T)-phase interface. The MgZn2 phase (η phase) and its metastable phase (η′ phase) were the most prominent precipitates. Another study revealed various Mg32(Al, Zn)49 phases (T phase) and their metastable phase (T′ phase) in Al-Zn-Mg alloys with low Zn and high Mg content. Al-Zn-Mg alloys with a Zn/Mg ratio of 0.71 were explored for this study. The alloy with a Zn/Mg ratio of 0.71 aged at 200 °C for 2000 minutes exhibited the highest hardness, according to the observations. The strengthening precipitates in the investigated alloy were totally T′(T) phase, according to TEM observation.

The influence of hydrogen and deformation on the microstructural evolution of aluminum alloys

05:05PM - 05:30PM

Presented by:

Omar BOUKIR, Phd Student, Groupe De Physique Des Matériaux (GPM)

This experimental study investigates the impact of hydrogen on the structural evolution of an AlCu alloy subjected to various heat treatments after deformation. Two factors, precipitations and deformations, are discussed in this study to gain insights into hydrogen-defect interactions.

The Negative Natural Aging Effect of Al-Mg-Si Alloys

05:30PM - 05:55PM

Presented by:

Haichang Jiang, Professor, Institute Of Metal Research, Chinese Academy Of Sciences

The precipitation hardening Al-Mg-Si alloys are widely used due to their high specific strength, excellent forming property, and good welding performance, however, the inevitable natural aging often reduces the artificial aging peak strength of the alloy by 20%~30%, leading to a serious negative natural aging effect. Therefore, the influence of composition and aging on the negative natural aging effect and corrosion resistance has been systematically studied, and the measures to control the negative natural aging effect are proposed. in order to provide a theoretical basis for the development of Al-Mg-Si alloys with excellent comprehensive performance.

Role of intermediate quenching and dispersoids in controlling planar anisotropy in AA6016-T4 sheets

09:50AM - 06:25PM

Presented by:

Atish Ray, Lead Scientist, Novelis Inc.

Co-authors :

Minju Kang, Novelis Inc.

John Ho, Novelis Inc.

Deep drawability of AA6016 alloy sheets are limited during stamping operation due to high in-plane anisotropy, and lower average r values. In this work we demonstrate improvements to r values by either adjusting the rolling process variables or by adjusting the chemical composition of the alloy. Mechanisms to control Cube texture in annealed aluminum sheets will be presented, and impact of various rolling texture components on r-value will be discussed.

09:50AM - 06:25PM

GLC 225

Sustainability in design and recycling

Counting the Costs of Decarbonization: Balancing Economic Realities with Environmental Ambitions

09:50AM - 10:15AM

Presented by:

Alexander Wimmer, Head Of Technology & Sustainability, Constantia Teich GmbH

Climate change is omnipresent, with new temperature records being set virtually every year. While sustainability was still a hobby for the most companies 10 years ago, departments for sustainability are now established in all companies. Most companies advertise lofty sustainability goals, although on closer inspection they are still talking at the level of missions or visions, and these have usually not yet been broken down into a specific strategy. In this study, a detailed roadmap with associated business impacts (opportunity costs, OPEX, CAPEX, ETS costs) was investigated and optimized for a plant converting 70,000 tons of aluminium foil p.a.

Constellium's initiatives to enhance automotive end-of-life recycling

10:15AM - 10:40AM

Presented by:

Fanny MAS, Senior Metallurgist Engineer, Constellium C-TEC

Due to inherent value and infinite recyclability, automotive aluminium scrap has always been recycled at very high rates. However, the vast majority until now has been consumed in secondary castings. This model is not sustainable anymore as the use of aluminium shifts towards more wrought alloys. End-of-life vehicle scrap recycling will become increasingly important over the next two decades, as the first generation of vehicles with high wrought aluminium content reach their end of life. That is the focus of much of our R&D efforts with several specific projects. First of all, we look for increasing the impurity-tolerance of our main alloys, with a special focus on AA6016 family. Secondly, we work with partners on both scrap flows and sorting technologies to recover high-quality wrought alloys from EoL vehicles. And last but not least, we are currently developing a new alloy able to re-use twitch scrap into automotive body sheets.

Sustainable aluminium alloys to extrusion process, with high scrap content and low Critical Raw Materials.

10:40AM - 11:05AM

Presented by:

Sylvia Cruz, Researcher , EURECAT

This paper describes the effect of minimizing the CRM (Critical Raw Materials) content, in 6111, 6082 and 6063 aluminium alloys. In order to decrease the amount of CRMs used in the alloy production two different strategies were followed: a) by testing new alloys with lower CRM content and reducing their amount as much as possible (6111) and be increasing the amount of end-of-life scrap used in the production of traditional alloys (6082 and 6063), evaluating the effect of main impurities as Fe, Cu and Ti, presents in the scrap. The extrudability of this new alloys was evaluated using a special extrusion device design by Eurecat. The results show that high content of impurities combined with medium Mg content, in the case of 6063 aluminium alloy, present interesting mechanical behavior demonstrating the possibility of use these alloys in high performance requirements.

Greener and better: direct extrusion high strength aluminum from scrap via solid phase upcycling

11:05AM - 11:30AM

Presented by:

Xiao Li, Material Scientist, Pacific Northwest National Lab

Co-authors :

Tianhao Wang, Pacific Northwest National Lab

Tingkun Liu, Pacific Northwest National Lab

Zehao Li, Pacific Northwest National Lab

Xiang Wang, Pacific Northwest National Lab

Arun Devaraj, Pacific Northwest National Lab

Jorge Dos Santos, Pacific Northwest National Lab

Recycling of metal and alloy scrap plays an increasingly important role in reducing carbon emissions in sustainable manufacturing. Traditional recycling and manufacturing processes typically involve multiple steps, such as high-temperature melting, forming, and post-treatment, which consume significant amounts of energy. In addition, the properties of the recycled materials are usually degraded compared to the raw materials. In this work, we used friction extrusion, a solid-phase upcycling technology, to directly extrude high-performance wrought aluminum from scrap. It eliminates melting and combines solidification, alloying, and extrusion into a single step. Furthermore, the properties can be enhanced by alloying and microstructure modification. Extruded samples with a chemical composition similar to 7075 Al alloy were produced from 6063 Al alloy scrap blended with copper (Cu), zinc (Zn), and ZK60 magnesium (Mg) additives. Yield strength and ultimate strength were increased by 200% compared to the base material due to nanocluster strengthening.

Characterization and Formability of Sheets Produced from Extruded Aluminum Chips

11:30AM - 11:55AM

Presented by:

Gabriel Marín, Research Associate, Institute For Forming Technology And Lightweight Construction (IUL) - TU Dortmund

With the direct-recycling process of aluminum chip extrusion, the energy-demanding process of remelting can be avoided. Chips, compacted to porous billets, are directly hot extruded to an open tube, which is then flattened and rolled to a sheet. By controlling the plastic strain and pressure in the hot extrusion process, a sound welding of the chips can be achieved. The bonding and, thus, tensile strength of the product can be further increased during rolling. The formability of the resulting sheet is analyzed by bending and deep-drawing experiments and is demonstrated to be similar to sheets extruded from cast billets. A numerical method to predict the extrudate seam quality is in good agreement with the microstructural investigations of the extrudate. Furthermore, an experimental approach to quantify the bond strength of solid-state-welded oxidized aluminum surfaces is introduced. The results can be used to quantitatively predict the weld strength of chip-based extrudates.

Improvement of formability of silicon-containing recycled wrought aluminum by hot stamping after rapid heating

11:55AM - 12:20PM

Presented by:

Shoichi HIROSAWA, Professor, Graduate School Of Engineering Science Yokohama National University

Co-authors :

Ryohei Kawana, Yokohama National University

Tomoyoshi Maeno, Yokohama National University

Yasushi Suzuki, G-tekt

Yuuji Yabuki, G-tekt

In this study, to improve the formability of recycled wrought aluminum, hot stamping after rapid heating was applied to the cold-rolled sheets with 3, 7 and 12%Si. From the results of V-bending test with a punch radius of 2 mm, it was found that Al-7%Si and Al-12%Si sheets cannot be V-bent at room temperature, but rapid heating to 250 or 300°C successfully accomplished their V-bending because deformation resistance of the Si-containing sheets is sufficiently decreased. Therefore, hot stamping after rapid heating to a specific temperature is a useful method to enable such difficult-to-process materials to be formed into desired shapes.

Effect of Fe on the ageing kinetics of aluminium alloys recycled by direct strip casting

01:50PM - 02:15PM

Presented by:

Lu Jiang, Deakin University

Co-authors :

Ross Marceau, Deakin University

Thomas Dorin, Deakin University

Microstructural changes and alumina reinforcement distribution derived from heat treatment and solid state processing of aluminium swarf briquettes

02:15PM - 02:40PM

Presented by:

Jetmira Uka, Doctoral Researcher, Brunel University London

Aluminium swarfs are generated every time an aluminium piece is subjected to subtractive manufacturing. Swarfs have large surface area, consequently showing strong oxidation of the surface, and they are generally covered with lubricant oils and debris from the cutting tools. Overall, the oxides generate the biggest challenge to the recycling of the material as they

generate an almost continuous layer which is very difficult to break, hence that adjacent aluminium fractions cannot coalesce. The method presented here makes direct use of this oxide layer as a reinforcement phase within the aluminium matrix, increasing its concentration and changing its morphology through preliminary heat treatments before subjecting the material to severe plastic deformation (SPD). The plastic deformation step is performed with alternative methods with varying strains using rolling, Equal Channel Angular Pressing (ECAP) and Hight Pressure Sliding (HPS). The heat treatments remove the lubricant contamination while increasing the oxide content, the detrimental effect is that porosity also increases generating a highly brittle material. The research presented shows the changes in porosity, the breakage of the alumina layers and its redistribution and the changes in the microstructure of the aluminium (grain size, elongation and orientation and dislocation density).The experimental work was performed on Aluminium 6082 swarfs obtained by Renishaw. This paper presents the results obtained from different severe plastic deformation treatment performed on material that underwent only one type of heat treatment to evaluate the factors mostly affecting the microstructure. The results indicated that the temperature at which the ECAP is performed is the factor mostly affecting the final microstructure, with a temperature of 350 degrees showing the best performance in terms of level of recrystallisation and alumina breakage and redistribution.

Effect of impurities on mechanical properties and microstructure of recycled Al alloys processed by severe plastic deformation under high pressure

02:40PM - 03:05PM

Presented by:

Yongpeng Tang, Project Assistant Professor, Kyushu University

In this study, Al-1.0 Fe-0.5 Mg-(1.0 and 3.0) Si (mass%) alloys were severely deformed by high-pressure torsion (HPT) and high-pressure sliding (HPS) at room temperature. Fe-intermetallic compounds were finely fragmented. The morphologies of fragmented Fe compounds in the Al matrix depend on the original state. High ultimate strength of 450 MPa and high elongation of 10% were achieved after HPT and HPS processings.

Upcycling of Post-Consumer Twitch Scrap by Shear Assisted Processing and Extrusion

03:05PM - 03:30PM

Presented by:

B. Scott Taysom, Pacific Northwest National Laboratory

Co-authors :

Scott Whalen

Brian Milligan

Timothy Roosendaal

Benjamin Schuessler

In this work, Shear Assisted Processing and Extrusion (ShAPE) is used to upcycle twitch scrap into round tubing with tensile properties similar to AA 6061. Twitch is an aluminum recycling product composed entirely of post-consumer scrap mixed from a variety of aluminum alloys. Compared to primary aluminum, extruded components made from Twitch are 30-40% cheaper and have 80-90% lower embodied carbon. These advantages make Twitch-based alloys processed by ShAPE a potential candidate for construction applications where lower cost components can help enable net-zero buildings.ShAPE is an emerging extrusion process which imposes extreme deformation on the billet material during extrusion to refine grain size and deleterious second phases. Castings were made from Twitch blended with 0-50% AA 6061 pre-consumer scrap. Castings were extruded into tubes via ShAPE. The yield strength, tensile strength, and elongation exceeded ASTM minimum values in the T6 temper and was on-par with ASM typical values for AA 6061. Microscopy showed refinement of large second phases and grain size though ShAPE.

Study of Scrap Additions for Production of 1370 Alloy based Green Electrical Cable Material

03:50PM - 04:15PM

Presented by:

Shahid Akhtar, Principal Research Scientist, Hydro Aluminium

AbstractKnown as the green metal, aluminium is one of the most environmentally friendly metals because of its sustainability. As the most recyclable industrial material, aluminium can be recycled infinitely to produce the same product. In the current work well sorted, process scrap (PS) and post consumed scrap (PCS) were added to primary aluminium (99.7%) in the range 2-20 % in the laboratory scale experiments. The result from these trails show that developed alloys are within the composition limit of 1370 alloy. There is also no degradation of melt quality assessed by the Porous Disc Filtration apparatus (PoDFA). Based on this investigation it is concluded that scrap material is suitable to produce conductor grade aluminium provided that scrap should be well sorted, and its quality should be known and documented.

Microstructure and properties of an additively manufactured Al-Si-Mg-Cu alloy with increased Fe impurity

04:15PM - 04:40PM

Presented by:

Sumit Bahl, Oak Ridge National Laboratory

Co-authors :

Jovid Rakhmonov, Staff Scientist, Oak Ridge National Laboratory

Jonathan Poplawsky, Oak Ridge National Laboratory

Lawrence Allard, Oak Ridge National Laboratory

Alice Perrin, Oak Ridge National Laboratory

Alex Plotkowski, Oak Ridge National Laboratory

Amit Shyam, Oak Ridge National Laboratory

The use of secondary (or recycled) Al alloys is limited in structural applications because increased impurity levels lead to solidification of brittle intermetallic phases with large sizes which deteriorate the mechanical properties. The faster cooling rates in additive manufacturing can refine the size of intermetallic particles, potentially enabling the use of secondary Al alloys in structural applications. Fe, a common impurity in secondary Al alloys, is known to be damaging as it promotes the formation of brittle Al-Fe-Si intermetallics. This study investigated the effect of

increased Fe impurity on processability, microstructure, and tensile properties of an Al-7Si-0.3Mg-0.5Cu (wt%) alloy (or cast A356+0.5Cu) additively manufactured with laser powder bed fusion. It is shown that A356+0.5Cu alloy with increased Fe impurity is processable with AM and exhibits good mechanical properties. Additive manufacturing offers opportunity to upcycle secondary Al alloys for structural applications providing cost and sustainability benefits.

Effect of pre-strain on aluminum alloys from the recycling of end-of-live vehicles

04:40PM - 05:05PM

Presented by:

Patrick Krall, Research Associate, Montanuniversitaet Leoben

Co-authors :

Stefan Pogatscher, Montanuniversitaet Leoben

The role of the automotive industry for the sustainability of aluminum alloys is very important. Nowadays, the automotive industry is the biggest consumer of secondary cast alloys and a variety of aluminum alloys is used in the whole vehicle. The overall content of aluminum in a passenger car has increased by three times since 2000. This is explained by a rising demand for wrought alloys. Recycling of mixed automotive aluminum scraps from end-of-live vehicles is mainly done by downcycling to a secondary cast alloy. As they are used mostly in parts of the internal combustion engine their share is expected to sink in future due to electrification. This work however investigates a secondary wrought alloy with a chemical composition deduced from the potential recycling of a pickup truck oriented on Ford´s F150. The alloy is processed under two different solidification conditions and is further rolled to sheets. The influence of a pre-straining step prior to a simulated paint-bake process on the mechanical properties is investigated by tensile testing. The results show a promising combination of strength and elongation for use as a sheet material in the automotive sector.

Towards Aluminum Circularity and Manufacturing Sustainability for Automotive Applications

05:05PM - 05:30PM

Presented by:

Alan Luo, Donald D. Glower Chair In Engineering, The Ohio State University

Aluminum offers a major lightweight solution to the automotive industry as it is transitioning from the traditional internal combustion engine (ICE) vehicles to alternative energy (battery electric, hybrid and fuel cell) vehicles. This transition provides a great opportunity for aluminum to achieve material circularity and manufacturing sustainability. However, primary production of aluminum is energy-intensive with extensive CO2 emission. Re-melting aluminum scrap only uses ~5% of the energy (and reduced emission) required to produce primary aluminum from ores. This presentation looks at effective utilization of the ever-expanding global aluminum scrap stream to develop value added alloys for automotive applications. We address the challenges of impurities in secondary aluminum from two different pathways: One is to remove the "bad actors" through liquid metallurgical processing methods, whereas the second approach is to mitigate the effect of the "bad actors" influencing the effects of microalloying and processing. For automotive design and manufacturing, the growing alternative energy vehicles tend to have more simplified body structures, enabling the use of large and consolidated castings which significantly reduce welding, joining and assembly. The development and evolution of energy-efficient large thin-wall die casting (also called mega/giga casting) will enhance the sustainability of automotive manufacturing.

Influence of Fe and Zn on the rapid solidification behavior of AA6061

05:30PM - 05:55PM

Presented by:

Michael Benoit, Professor, Department Of Mechatronics & Mechanical Engineering, University Of Waterloo

Co-authors :

Mary Wells, Professor, Department Of Mechatronics & Mechanical Engineering, University Of Waterloo
Mark Whitney, PhD Student, Department Of Mechatronics & Mechanical Engineering, University Of Waterloo
Haiou Jin, Research Scientist, Natural Resources Canada

Laser surface melting (LSM) trials were performed on AA6061 alloys with varying Fe and Zn contents to elucidate the influence of these elements on the rapid solidification behaviour of the alloy. The influence of alloy composition and laser processing parameters on melt pool characteristics, intermetallic phase formation and cracking behaviour of each alloy were assessed.

Effect of Fe and Si composition ratio on microstructure and mechanical properties of 3104 aluminum cold-rolled sheets

05:55PM - 06:25PM

Presented by:

Tomotaro Ezaki, Development Department I, Research & Development Division , UACJ Corporation

Co-authors :

Tomoyuki Kudo, Manager, UACJ Corporation

The effects of Fe and Si on the microstructure of 3104 aluminum cold-rolled sheets were investigated. In 3104 alloys, it was known that Si causes coarse precipitation of solute Mg from homogenization to hot rolling, leading to a reduction in strength. It was also reported in Al-Fe alloys that Fe increases the formation of Al-Fe compounds, which then preferentially react with Si to form Al-Fe-Si compounds1). In this study, we examined the possibility of suppressing strength reduction by adding an appropriate amount of Fe relative to the amount of Si. Indeed, at a Fe/Si ratio greater than the certain value (about 2.0 in this study), no strength reduction was observed, while at a Fe/Si ratio less than 2.0, strength decreased with an increase in Si amount. It was considered that by adding an appropriate amount of Fe corresponding to the amount of Si, the precipitation of solute Mg caused by Si could be prevented. And by maintaining the amount of solid solution, the reduction in strength could be avoided.

09:50AM - 06:25PM

GLC 222

Advanced Characterization and Testing

In-situ nanometallurgy via TEM for aluminum alloy development

09:50AM - 10:15AM

Presented by:

Stefan Pogatscher, Montanuniversitaet Leoben

Co-authors :

Phillip Dumitraschkewitz, Montanuniversitaet Leoben

Transmission electron microscopes are increasingly becoming multi-purpose instruments in the characterization of aluminum alloys, including a strong capability for in-situ experiments. Recently, we have been able to show that, in addition to solid-state reactions such as the precipitation and dissolution of phases or recrystallisation phenomena, both melting, solidification and even alloying can be directly studied in-situ via transmission electron microscopy (TEM). The method has been described as a metallurgical toolbox, i.e. the transmission electron microscope becomes a nanoscale chemical reactor for nanometallurgy. In this work an overview of this field of nanometallurgy is given and new potential applications are discussed. One interesting area is the investigation of intermetallic phases in such a chemical reactor at the nanoscale. Intermetallic phases, e.g. with Fe in particular, are important in the recycling of aluminum alloys, as the increasing content of impurities in mixed scrap is bringing them into the focus of research. Their morphology can have a strong influence on the mechanical properties. Direct observation of their formation would therefore be a great help for research. This paper discusses approaches to enable such an investigation using a transmission electron microscope.

Diffusion controlled early-stage L12-D023 transitions within Al3Zr

10:15AM - 10:40AM

Presented by:

Shiwei Pan, Postdoctoral Researcher, Beijing Institute Of Technology

Co-authors :

Chunan Li

Feng Qian, Lecturer, Beijing Institute Of Technology

Yanjun Li, Norwegian University Of Science And Technology

ole in the L12-D023 phase transition, the formation of which has long been explained through the shearing/slipping mechanism. Herein, the detailed atomic structures of conservative {100} APBs within L12-Al3Zr particles forming at the early-stage of L12-D023 transition in an Al-Zr alloy were systematically studied by high angle annual dark-field scanning transmission electron microscope (HAADF-STEM). As a strong evidence of diffusion-limited phase transformation process, significant de-ordering of atoms in APBs and the neighboring atomic planes have been found. By analyzing the two possible pathways, it is suggested that L12-D023 phase transition has been achieved through a diffusion mechanism, instead of shearing mechanism while the formation of APB is an intermediate stage of the phase transition process. First principles density functional theory (DFT)

reveals that the formation of APBs and subsequent phase transition are energetically favorable, which provide the driving force for diffusion.

Advanced Characterization and Modelling of Dispersoids with Nucleated Precipitates in Recycling 6xxx alloys

10:40AM - 11:05AM

Presented by:

Ruben Bjorge, Research Scientist, SINTEF Industry

Co-authors :

Calin Daniel Marioara, Senior Scientist, SINTEF Industry

Zeqin Liang, Senior Metallurgy Scientist, Novelis

Qiang Du, Senior Research Scientist, SINTEF Industry

A methodology based on transmission electron microscopy was applied to measure size distribution, volume density, volume fraction and type of dispersoidal particles in the base and the recycled variant of a 6xxx alloy. The latter was also subjected to a modified homogenization procedure. It was found that industrial cooling from solution heat treatment produced metastable rod-shaped, Q'-type precipitates nucleated on dispersoids, despite the low Cu content in the alloys. Prediction by PreciMS software of type and solute fraction of dispersoids based on the thermal history of the alloys has a good match with the experiment.

The nucleation and interactive transformation mechanisms of multiple metastable precipitates in a Si-rich Al-Mg-Si alloy

11:05AM - 11:30AM

Presented by:

Lipeng Ding

Co-authors :

Flemming Ehlers, Associate Professor, Key Laboratory Of Light-weight Materials, Nanjing Tech University

Zhihong Jia

The precipitate evolution mechanism of the Al-Mg-Si alloys with a Si-rich composition have been a long-term challenge due to the complex transformation paths among multiple precipitates. In the present work, the interactive transformation process of multiple metastable precipitates in a Si-rich Al-Mg-Si alloy were thoroughly studied by atomic resolution high angle annular dark field scanning transmission electron microscopy (HAADF-STEM), in-situ heating TEM and first-principles calculation. It was revealed that the GP zone → β″ transformation proceeds via the mechanism of precipitation in a precipitate, as opposed to formation of Si2 nanopillars of considerable length. The β″ phase transforms simultaneously to various types of precipitates in the over-aged stage. Two different evolution paths are proposed. Firstly, the β″ phase transforms directly to the U1, U2 and β′ phases. Secondly, the U2 phase, as an intermediate phase, transforms to the U1, β′ and B′ phases during the prolonging aging. During the severe over-aging, the evolution of precipitates is governed by the dissolution of small precipitates (β′ and B′ phases) entails the growth of the large ones (U1 phase). These results provide scientific basis for both property improvement of the commercial Al-Mg-Si alloys and development of new 6xxx aluminum alloys.

Structural Connections Between Al-Mg-Zn Alloy Phases and a Quasicrystalline Phase in an Al-Mg-Cu-Ag Alloy

11:30AM - 11:55AM

Presented by:

Ruben Bjorge, Research Scientist, SINTEF Industry

Co-authors :

Tor S. Haugland, SINTEF Industry

Calin Daniel Marioara, Senior Scientist, SINTEF Industry

Elisabeth Thronsen, SINTEF

Sigurd Wenner, SINTEF Industry

Sigmund J. Andersen, SINTEF Industry

Oskar Ryggetangen, NTNU

Randi Holmestad, Professor, Norwegian University Of Science And Technology (NTNU)

Quasiperiodic crystals, or quasicrystals, were discovered by Dan Shechtman in 1984 in a rapidly cooled Al-Mn alloy. Quasicrystals contain orientational order, but no translational symmetry. Quasicrystalline approximants, on the other hand, are crystals that contain local arrangements of atoms with non-crystalline symmetry (such as five-fold rotational symmetry) but are still periodic overall. Since the initial discovery, several other quasicrystals have been shown to form in Al alloys, including through precipitation from solid solution. A quasicrystalline precipitate phase was previously reported in an Al-3Mg-1Cu-0.4Ag (wt.%) alloy after artificial aging for 11 days at 170 °C (M. Mihara et al., Mater. Sci. Eng. A 658 (2016) 91-98). These plate-shaped precipitates contained five-fold symmetry when viewed along the <112>Al direction. Here we report further transmission electron microscopy investigations that reveal structural similarities between this phase and the quasicrystalline approximant phase, T, with composition (Al,Zn)48Mg32 (G. Bergman et al., Acta Cryst. 10 (1957) 254), as well as the η-MgZn2 Laves phase (J.B. Friauf, Phys. Rev. 29 (1927) 34).

Phase and particle analysis in aluminium alloys using SEM EBSD and Dictionary Indexing

11:55AM - 12:20PM

Presented by:

Knut Marthinsen, Professor, NTNU, Norwegian University Of Science And Technology

Co-authors :

Håkon Wiik Ånes, Sceintist, Xnovo Technology

Yaping Wang, Post Doctor, NTNU

Antonius Theodorus Johannes Van Helvoort, Professor, NTNU

Indexing is a key step in the analysis of SEM EBSD patterns and so far, use of the Hough transform has been the standard option (as well as being part of most commercial EBSD analysis software). Hough-indexing is based on detecting/identifying the bands and zone axes and uses pattern geometry (bands and zone axes positions) as basis for indexing. It is fast and reliable for most patterns but is less suitable for very noisy patterns due to challenges in estimating band positions and assigning consistent indices to the bands. These difficulties can be largely overcome by Dictionary Indexing (DI), which is based on pattern matching of experimental Kikuchi patterns and dynamically simulated diffraction patterns, sampling the orientation space for selected candidate phases. In this presentation we will illustrate the capabilities of DI for phase and particle identification in different aluminium alloys, as well as for correlated sub-grain and particle analysis in an AlMn-alloy.

Comparisons of XRD and EBSD crystallographic textures

01:50PM - 02:15PM

Presented by:

Jean Savoie, New Forming Processes And Alloy Development, National Research Council Canada

Co-authors :

Siyu Tu, Advanced Material Characterization And Machine Vision, National Research Council Canada - CTA

Crystallographic textures were initially measured by the method of X-ray diffraction (XRD) in the form of few incomplete pole figures. The orientation distribution function (ODF) is then calculated through the series expansion or direct methods. Since over 25 years, textures are more and more measured and analyzed from EBSD in a SEM, a method that not only provides a global view of the texture, but also details at grain or subgrain levels. However, unlike its XRD counterpart, EBSD is sensitive to the deformation level: increased dislocation densities blur the diffraction patterns and reduce the indexation rate. Textures of highly deformed materials hence becomes less and less reliable. We will use two existing methods to increase the EBSD indexation rate of two heavily rolled aluminum alloys: the first consists to impose a recovery anneal to reduce the dislocation density, the second involves the use of dynamic template matching from Oxford Instruments. XRD textures are measured from large samples (e.g., 10mm x 15mm) that generally include a sufficiently large number of grains to provide statistically significant results. EBSD on the other hand often rely on smaller samples to keep down the measurement time. We will present here XRD (taken as the standard) and EBSD textures of recrystallized and rolled samples with various measurement areas to get their influence on the texture results.

Elucidation of Deformation Mechanisms in Aluminum Alloys by In situ X-ray Micro and Nanotomography

02:15PM - 02:40PM

Presented by:

Nikhilesh Chawla, Purdue University

Co-authors :

Suwaree Chankitmunkong, King Mongkut's Institute Of Technology Ladkrabang

Feng Wang, Univerity Of Birmingham

Deformation characteristics of Al alloys and their change with the addition of intermetallic phases

02:40PM - 03:05PM

Presented by:

Irmgard Weißensteiner, Montanuniversität Leoben

Co-authors :

Petra Spoerk-Erdely, TU Graz

Bernhard Trink

Stefan Pogatscher, Montanuniversitaet Leoben

The boundaries of the established classes of aluminum alloys are currently being extended, either to improve their performance (through the crossover alloying concept, which combines the positive properties of two classes), or to produce alloys with high content of recycled input material. This results in a change in the microstructural constituents in terms of type, volume fraction and distribution. As they have a strong influence on the mechanical properties, one of the current challenges is to maintain or restore the formability in these alloys. In the present study, three groups of alloys (based on 5xxx, 6xxx and pure Al) were adapted by alloying to obtain different volume fractions of primary and secondary phases. These variations were then correlated with their formability, particularly in tensile tests (also via in-situ diffraction experiments) and bending tests.

Development of microstructurally graded samples in 7xxx alloys aiming for high throughput precipitate characterization

03:05PM - 03:30PM

Presented by:

Pejot Thomas, PhD Student, SIMaP-UGA

Co-authors :

Julien Barlier, Transvalor

Ludovic Bourgeon, Aubert Et Duval

Alexis Deschamps, SIMaP-UGA

Frédéric De Geuser, SIMaP-UGA

Recently, compositionally graded alloys obtained by diffusion couples have been developed for implementing combinatorial approaches in metallurgy. These specimens are used to quantify the effect of alloying elements on precipitation kinetics and mechanical properties during ageing. In the present study, such specimens have been developed on 7xxx alloys. In addition, graded samples have been developed for variations of pre-straining and quench rate (Jominy test). These different gradients, together with appropriate high throughput characterization, will permit to evaluate and predict microstructure and mechanical properties of 7xxx alloys over a wide range of composition and processing parameters. Since the strengthening of 7xxx alloys is controlled by the precipitation of the nanoscale η-Mg(Zn, Cu)2 phase and its precursors, Small-Angle X-ray Scattering (SAXS) characterization is suited to quantify their volume fraction and radius, and these measurements can be spatially, and time resolved to performed in situ characterization on graded samples. This high throughput microstructure analysis can be complemented by systematic spatially resolved hardness to obtain the full microstructure / properties picture in alloy design space.

3D observation of hydrogen-related pores in surface-modified Al-Zn-Mg alloys using synchrotron X-ray CT

03:50PM - 04:15PM

Presented by:

Keitaro Horikawa, Assosciate Professor, Osaka University

The internal microstructure of Ni-P plated Al-Zn-Mg base alloys was investigated through synchrotron X-ray tomography, together with a high-speed microscope. It was shown that hydrogen micropores were segregated near the surface region in the commercial purity graded 7075-T6 aluminum alloys with Ni-P plating. In contrast, such segregation of hydrogen micropores was not observed in the 7075-T6 alloys without Ni-P plating or in high-purity-based alloys. This suggests that hydrogen entered the Ni-P plating layer during the plating operation generating micropores at the surface region.

X-ray computed tomography-based 3D morphological analysis of intermetallic particles of as-cast aluminum alloys

04:15PM - 04:40PM

Presented by:

Satyaroop Patnaik, Graduate Research Assistant, Purdue University

Co-authors :

Eshan Ganju

Nikhilesh Chawla, Purdue University

Minju Kang, Novelis Inc.

Jaesuk Park, Principal Engineer CPS Cluster Lead, Novelis

Sustainable Al alloy development at scale requires a fundamental understanding of the link between process, property, and microstructure. Historically, the microstructure of Al alloys has been determined using 2D electron and light microscopy-based techniques that are inherently destructive in nature and time-consuming. While the 2D microstructure of typical Al Alloys has been well studied, the 3D microstructure of Al alloys is still not widely understood. To shed light on typical 3D microstructural features of Al alloys and to highlight the importance of 3D microstructural characterization, a comprehensive microstructural analysis was conducted on two types of as-cast Al alloys, using a combination of X-ray microtomography (XRM) and scanning electron microscopy (SEM). The intermetallic particles and voids in the two alloys were characterized in 3D using laboratory scale XRM to identify distinguishing features between the two alloy compositions. A new morphology descriptor – particle volume to convex hull volume (P/H) – was proposed to capture the differences between microstructural features observed in the two alloys. A comparative assessment of typically used morphological descriptors (such as surface area to volume ratio) showed that the P/H ratio was better in capturing the morphological differences in the intermetallic particles in comparison to traditional particle shape parameters.

4D full field characterization of recrystallization in Al using synchrotron X-ray Laue micro-diffraction

04:40PM - 05:05PM

Presented by:

Yubin Zhang, Senior Researcher, DTU

Over the past two decades, advanced three-dimensional synchrotron techniques, notably Laue X-ray micro-beam diffraction (3DμXRD), have undergone significant development, emerging as powerful tools for comprehensive microstructural analysis. These techniques offer the capability to measure crystallographic orientations, morphologies, and local lattice strains/stresses within bulk samples with sub-micrometer resolution. Recently, a series of well-designed ex-situ experiments have been conducted using 3DμXRD to characterize the recrystallization of pure Al in full field, exploring various aspects, such as recrystallization nucleation and boundary migration, the formation of residual stresses within recrystallizing grains, and the selective growth behavior of multiple nuclei within a well-characterized deformed microstructure. These 4D (x, y, z, time) studies highlight the important role played by the local microstructure, e.g. the geometrical alignment of dislocation boundaries, and the potential influence of local residual stresses on the nucleation and selective growth behaviors. The aim of this work is to present a comprehensive review of both the 3DμXRD technique itself and the new findings it has facilitated, shedding light on the local heterogeneous recrystallization phenomena. The critical need for full-field microstructural characterization in advancing our understanding of recrystallization processes and new possibilities offered by laboratory 3D X-ray techniques will also be briefly discussed.

X-ray Tomography Analysis of Intermetallics and Voids in 6XXX alloys

05:05PM - 05:30PM

Presented by:

Francisco García-Moreno

Co-authors :

Tristan Kammbach, PhD Student, Technische Universität Berlin

Tillmann R. Neu, Scientist, Helmholtz-Zentrum Berlin

Paul H. Kamm

Elisa Cantergiani, Novelis

Jonathan Friedli, Novelis

Zeqin Liang, Senior Metallurgy Scientist, Novelis

Sustainable aluminum wrought production for the automotive industry with a high content of recycled material offers considerable potential for CO2 and cost savings.1 With this in mind, we carried out a three-dimensional characterization of the intermetallics and casting voids morphology using high-resolution X-ray tomography. For this purpose, various samples provided by Novelis Switzerland SA were measured and compared at different processing steps and conditions. The three-dimensional quantitative analysis of clusters made it possible to obtain information about their size distribution, volume fractions, total number, surface area and aspect ratio.

Development and Application of a Novel in situ X-Ray Diffraction Method for Electrodeposition of Alloys

05:30PM - 05:55PM

Presented by:

Jakub Pepas, Graduate Student, Georgia Institute Of Technology

Co-authors :

Yifan Ma

Minju Kang, Novelis Inc.

John Carsley

Hailong Chen

Electrodeposition is an attractive method for the production of single- and multi-component metal coatings due to its relatively low cost and high scalability. However, the electrodeposition environment has many factors that can affect the properties of the deposit, such as electrolyte composition, temperature, additives, deposition current and time, etc. The complexity of the deposition environment makes systematic analysis and optimization of the deposition process challenging and time-consuming. Furthermore, underlying mechanisms affecting the deposition process such as electrolyte dynamics and texture evolutions during sustained film growth are difficult to investigate using conventionally prepared ex situ samples. We have developed an electrodeposition testing method with gradient current density that is high-throughput and compatible with in situ X-ray diffraction. We tested the method with selected model systems and calibrated the nominal current density using multi-physics and analytical models. We demonstrate the ability to perform high-throughput and high-time resolution in situ experiments that analyze the phase, composition, quantity, and texture of deposited films across a wide range of deposition conditions in a single sample. Analysis using this method enables the rapid screening of electrolyte compositions and insight into the progression of deposited film growth over the course of the electrodeposition process.

12:20PM - 01:50PM

Lunch

03:30PM - 03:50PM

Break

06:20PM - 10:00PM

Free Evening

Day 5, Jun 27, 2024

08:00AM - 09:55AM

GLC 236

Early Research Award Introductions and presentations

10:15AM - 11:55AM

GLC 236

Microstructure Design; Alloying and Heat Treatments

Core-shell precipitation in Al - Mg - Sc - Zr alloys

10:15AM - 10:40AM

Presented by:

Ian Amedeo

Co-authors :

Thomas Dorin, Deakin University

Frédéric De Geuser, SIMaP-UGA

The formation of secondary phases in the form of precipitates has been studied in Al-Mg-Sc-Zr alloys. Two main types of precipitates have been observed: large, non hardening precipitates that remain stable during solution treatment and nanoscale precipitates that provide significant hardening. The influence and relevance of solution treatment and its impact on the properties of the alloy has been investigated. Two advanced and complementary experimental techniques have been used (anomalous SAXS and APT) to provide fine observation on individual precipitates as well as global monitoring of precipitation.

The Effect of Co-addition of Ce, Sc and Zr on the Microstructure and Mechanical Properties of Direct Chill-Cast Al-5wt%Mg Alloy

10:40AM - 11:05AM

Presented by:

Shengze Yin, Post-Doc Fellow, Queen's University, Kingston, Canada

Co-authors :

Hesam Pouraliakbar, Queen's University

Mohammadreza Jandaghi, Linköping University

Johan Moverare, Linköping University

Andrew Howells, CASTechnology

Mark Gallerneault, Queen's University

Vahid Fallah, Queen's University

The effects of Ce addition on the solidification microstructure and mechanical properties of as-cast Al-Mg alloy are investigated in this work. 80 mm thick Al-5wt%Mg ingots, with and without the addition of 1wt%Ce, 0.1wt%Sc and 0.1wt%Zr, were cast through Direct Chill (DC) casting. Samples were taken near the center of the ingots for analysis via optical microscopy (OM), Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), Electron Backscatter Diffraction (EBSD), and tensile tests. Measurements of secondary dendritic arm spacing in both casts suggested a similar cooling rate experienced by the ingots during solidification. Contrary to the grain refining effects of Ce reported in the literature, larger grain sizes were observed under EBSD in the Ce-added sample. In both casts, ~0.01wt% Ti (in the form of TiC rods) was added as the grain refining agent. However, it has been reported that Ce reacts with Ti to form Al-Ti-Ce secondary phases at higher temperatures. This reaction neutralizes the Ti grain refiners, leading to fewer grains nucleating and thus a significantly coarser grain size evolution in the Ce-added sample. OM examination revealed differences in the evolution of second-phase intermetallics between the Al-Mg samples with and without Ce addition. SEM and EDS analysis revealed the typical Al_3Mg_2 β and Al-(Fe,Mn) α phases on the cell/grain boundaries of the Al-5Mg sample; in contrast, an abundance of Ce-rich $Al_{11}Ce_3$ and $Al_{13}CeMg_6$ phases appeared to decorate the cell/grain boundaries with no obvious presence of either the Al_3Mg_2 β phase or Al-(Fe,Mn) α phase in the Ce-added sample. A definitive confirmation of the above second-phases identification will require a higher-resolution EDS and diffraction patterns obtained via Transmission Electron Microscopy (TEM), which is planned for the near future. Moreover, the minor Sc and Zr contents in the Ce-added sample did not appear to have influenced the solidification microstructure and phase constitution in the as-cast state. The above observations are further examined against Schiel-Gulliver simulations using ThermoCalc Software for Al-5wt%Mg-0.4wt%Fe-0.8wt%Mn with 1wt%Ce addition. Furthermore, the effect of the absence of the Al_3Mg_2 β phase on mechanical properties was confirmed via tensile tests, where a delay in the occurrence of serration points from 2% to nearly 9% elongation was observed in the Ce-added sample, i.e., the delay in the Portevin-Le Chatelier (PLC) effect commonly occurring in the Al-Mg alloys. Such a delay in triggering the PLC effect for deformations up to 9% elongation can significantly improve the formability of final sheet products. Moreover, the absence of the Al_3Mg_2 β phase in an Al-5Mg is a substantial development from the perspective of improving its corrosion properties. It also opens the door for the development of Al-Mg alloys with Mg contents higher than 5wt.% with little to no content of β phase present, thus allowing for a more effective utilization of solid-solution strengthening effect of Mg (i.e., without compromising corrosion properties and formability). TEM and Digital Image Correlation (DIC) tests will be underway on both as-cast and heat-treated samples to further investigate phase alteration with Ce addition in Al-5wt%Mg alloys, as well as its effects on mechanical properties and heat treatment response. The heat treatment response, in particular, will include the impact of minor Sc and Zr addition by inducing some levels of precipitation hardening capacity as well as thermal stability (i.e., the resistance to recrystallization and grain growth). These preliminary results will lay the foundational work and are intended to serve as a baseline for the development of Ce-containing rapidly-solidified Al-5Mg strips using Hazelett's thin strip casting machine.

Microstructure observation of Al-1.0%Mg2Si-(Cu, Ni) alloy with two-step aging treatment

11:05AM - 11:30AM

Presented by:

Kazunobu Fujimoto

Al-Mg-Si 合金は、さらなる高強度を得るためにさまざまな方法で研究されてきました。王ら。遷移金属の添加により、Al-1.0mass% Mg2Si 合金の析出物の数が増加し、その機械的特性が改善されることが報告されました。松田ほかAl-1.6mass%Mg2Si 合金の時効硬化に対する 2 段階時効のプラスの効果を報告しました。この研究の目的は、硬度試験と微細構造観察によって、Al-Mg-Si 合金の微細構造に対する遷移金属の添加と 2 段階の時効の影響を調査することです。

Effect of Ag and Zn on Ultra-high Strength Al-Li Alloy

11:30AM - 11:55AM

Presented by:

Yuxing Tian, Senior Engineer, Chinalco Materials Application Research Institute

Co-authors :

Cheng Liu

Hailong Cao

Xiaobing Zheng

Wei Li

Jiaqiang Han

Using lightweight materials in aerospace equipments is a constant pursuit not only for material researcher but also for equipment designer. Over past sixty years, Al-Li alloy were used widely in aerospace field because of its high elastic modulus, high specific strength, good corrosion resistance and other advantages. Up to now, develop excellent alloy with low density and ultra-high strength is still a very important research direction. However, the difficulty is how to balance the mechanical properties and density, as well as minimizing cost as much as possible. Even in some cases, the cost reduction becomes a more critical factor for material application. International researchers had reported valuable results on high strength Al-Li alloy, including the effects of Cu, Li and micro-alloy elements on mechanical properties, precipitation sequences of T1 and δ′ phase, grain structure evolution, failure modes and so on. For the ultra-high strength Al-Li alloy, the main technical approach is to optimize the contents of Cu, Li, Mg and Ag elements, as well as using Zn to substitute for noble metal Ag in order to reduce the material cost. Recently, researchers from Chinalco Materials Application Research Institute made a valuable experimental study on developing ultra-high strength Al-Li alloy. The developed novel alloy without Ag element has an ultra-high tensile strength of above 650MPa, compressive yield strength of 600MPa, considerable fracture elongation of above 8% and low density of 2.7g/cm3 , showing its advantage for application on aircraft upper wing panel. To obtain basic high strength, the total amount of Cu and Li elements is controlled to be 5.5~5.7wt.%. Additionally, a certain amount of Zn substitute for Ag, showing the lower cost comparing with the registered alloys with Ag, such as 2195, 2065, 2055, 2071 and 2075. Certainly, grain structureoptimization also gives necessary contribution to strength, where the area proportion of recrystallization is below 10% and the density of low angle grain boundaries is not less than 150 mm/mm2 . During the experimental study, ingots were fabricated using vacuum melting furnace. Homogenized ingots were hot-rolled at 450°C to plates with thickness of 25mm. And then the plates were suffered T8 treatment to obtain final temper. By TEM observation it is found that the alloy with Zn and the alloy with Ag display the same precipitate sequence during aging process, Cu-rich cluster (GP-Ⅰ) →θ′ (GP-Ⅱ) →T1+θ′ phase, and the precipitate phase is composed of high density of T1 and small amount of θ′ phase. However, Ag and Zn have different capability for assisting T1 and θ′ phase. For peak-aged state, Ag element increases the diameters both of T1 and θ′ phase, and slightly increases the volume fraction ratio of T1 to θ′. This increases the tensile strength of the alloy with Ag higher than with Zn. But when the alloy achieves an ultra-high strength level, the strengthening effect of Ag becomes slightly, and the alloy containing Ag element loses its optimum cost performance. Inversely, moderate Zn addition shows even better balance between properties and cost. The results show that the alloy with 0.6wt.% Zn also has an ultra-high strength of 650MPa and good ductility, but further adding no obvious strengthening.

Statistical date from the diameters of T1 and θ′ phase reflects its strengthening principle. That is Zn only increases θ′ phase diameter but has little influence on T1 phase diameter. So the more Zn adding can achieve an equivalent strengthening effect comparing with relatively few adding of Ag element. In future, material researcher and equipment designer would pay more attention to the balance between mechanical properties and cost. Present study displays a considerable novel alloy and also suggests the positive effect of Zn element, which has an actual meaning for developing ultra-high strength or other Al-Li alloy.

10:15AM - 12:20PM

GLC 225

Sustainability in design and recycling

Investigating the corrosion behaviour of 100% secondary metal content high strength AA6xxx alloys formed using HFQ technology

10:15AM - 10:40AM

Presented by:

Richard Hunt, Head Of Metallurgy And Materials Characterisation, Impression Technologies Ltd.

Co-authors :

Jinghui Chen, PhD Student, The University Of Manchester

Xiaorong Zhou, Professor , The University Of Manchester

Reducing the embodied carbon in vehicles has rightly grown in significance in recent years. One method to achieve this is to use less material through the application of high strength alloys whilst another is to use the highest possible secondary metal content. However, the in-service performance of the material needs to be thoroughly assessed and optimized so the future potential of low embodied carbon can be realized. Impression Technologies, working with partners, produced full scale sheet of 100% recycled (>40% post-consumer) as well as smaller batches of 100% post-consumer scrap sheet. These were formed into full scale A- pillars using hot form quench (HFQ) technology. The tensile properties were equivalent or better than incumbent, conventional high strength alloys, but the intergranular corrosion resistance and VDA238-100 bending angle were both diminished. This work outlines the initial findings from an investigation of the corrosion mechanisms. The laboratory analysis revealed that the results did not support the findings of the initial standardized accelerated tests and instead the highly recycled content alloy may exhibit behaviour which contributes to a retardation of the material corrosion.

Characterization of local strain in iron-bearing Al-Si-Cu-Mg alloys using an in-situ tensile module

10:40AM - 11:05AM

Presented by:

DaeHan Kim, Postdoc, Korea Institute Of Industrial Technology

Co-authors :

JaeKwon Kim, Ph. D Student, Seoul National University

EunSoo Park, Professor, Seoul National University

JaeHwang Kim, Principal Researcher, Korea Institute Of Industrial Technology

Iron-bearing Al-Si-Cu-Mg alloys were fabricated by a deformation-semisolid extrusion (D-SSE) process. Fracture of the iron-bearing alloy was delayed showing necking compared to the iron-free alloy. An in-situ tensile module was used to clarify the local strain of iron-bearing alloys. The evolution of local strain was systematically investigated to understand strain concentration at particles and Al matrix by strain maps with real-time tensile testing.

Effect of impurity elements on microstructure and tensile properties of sustainable cast aluminum alloys

10:15AM - 11:30AM

Presented by:

Nicholas Richter, Postdoctoral Research Associate, Oak Ridge National Laboratory

Co-authors :

Sumit Bahl, Oak Ridge National Laboratory

Ying Yang, Oak Ridge National Laboratory

Alice Perrin, Oak Ridge National Laboratory

Gerald Knapp, Oak Ridge National Laboratory

Indranil Roy, General Electric Research

Alex Plotkowski, Oak Ridge National Laboratory

Allen Haynes, Oak Ridge National Laboratory

Amit Shyam, Oak Ridge National Laboratory

The aluminum (Al) industry is faced with a sustainability conundrum as increasing quantities of Al alloys are employed in energy-saving lightweighting applications, yet their primary production generates ~1.1 Gigatons of carbon dioxide per year. Manufacturing Al components from secondary sources could alleviate this environmental burden, however impurities associated with recycled Al significantly limit ductility and fracture toughness due to the formation of large intermetallic particles, most notably Al-Fe-Si intermetallics. High pressure die cast Al components in the automotive industry provide a potential application where scrap source material could be introduced. However, these parts often require strict mechanical property and casting requirements. Designing alloys to accommodate expanded impurity tolerance limits while still meeting property specifications offers significant environmental and economic opportunity.Castaduct-42 (Al-4.3Mg-1.6Fe in wt%) is an Al-Mg based alloy used in high pressure die casting designed with a high Fe content that possesses moderate strength and high ductility. Currently, minimal literature exists centered around the recycling of the Al-Mg alloy family. In this study, Si impurities were added into cast Al-4.3Mg-1.6Fe alloys to simulate the addition of high Si containing scrap material and study microstructural, phase and property development. Electron microscopy, X-ray diffraction and thermodynamic modeling were combined to quantify the evolving intermetallic phase content. Tensile testing was performed to link microstructural development to the resulting mechanical properties. Further, a high-throughput thermodynamic calculation and solidification simulation based on the CALPHAD approach was implemented to provide alloy design strategies for mitigating adverse intermetallic phases in recycled Al-Mg-Fe-Si alloys. Some preliminary attempts at phase mitigation will also be discussed.

Influence of varied concentrations of alloying elements on the precipitation of intermetallic phases in wrought 6xxx series aluminum alloys

11:30AM - 11:55AM

Presented by:

Dominik Steinacker, Research Associate, FAU Erlangen

Aluminum alloys provide significant potential for the realization of modern and sustainable lightweight construction concepts due to their good formability and versatile properties. In the context of electric mobility, a high demand for lightweight structural components persists in the automotive industry in order to counteract the increasing vehicle weights resulting from the required battery. In general, the need for aluminum alloys that are suitable for technical applications is continuously rising. The aluminum alloys of the 6xxx series are particularly important, as they offer the possibility of enhanced strength through artificial aging and excellent corrosion resistance, so that they find application in the car body and axle components. The main challenges associated with the increasing demand for aluminum alloys are higher raw material costs compared to standard steel designs and the high amount of CO2-emissions that result from the primary aluminum production. Thus, usage of secondary aluminum from End of Life (EoL) scrap for alloy production is a strong trend in current research activities, which has the potential to reduce fabrication-related CO2-emissions of aluminum alloys by up to 95 percent. In this regard, it is crucial to understand the influence of the secondary material on the properties of aluminum alloys in order to avoid a degradation of the mechanical properties and to facilitate the application of aluminum alloys with a high recycle content in technical safety components.The usage of secondary material from End of Life scrap for the production of aluminum alloys will often cause an increased concentration of alloying elements compared to the common alloy compositions. This leads to the question whether existing alloy specifications can be applied up to their upper limits in terms of element contents.In this contribution, the aluminum alloys 6082 and 6110A were produced with a maximum content and also slightly above the maximum content of each alloying element according to the related standards. Subsequently, the cast billets were forged and aged according to a heat treatment scheme that is applied for the alloys with common composition. In order to evaluate the influence of the high concentration of alloying elements, the alloys were investigated by tensile testing and SEM. The formation of two different types of intermetallic sludge phases was observed. By using STEM-EDS, the composition of the formed phases was measured. In addition, the crystal structure of the sludge phases was analysed by EBSD. Nanoindentation in the sludge phases and tensile tests accomplish the investigations in order to evaluate their influence on mechanical strength and ductility of the tested aluminum alloys.

12:20PM - 12:30PM

Closing ceremony

12:30PM - 01:00PM

Travel Home/ Break

01:00PM - 05:00PM

Tour 1 -Novelis Global Research and Technology Center

02:00PM - 05:00PM

Tour 2 - Tour of Georgia Institute of Technology