The content in this preliminary technical program was generated on July 15. However, changes are still being implemented for the final technical program. Please refer to the online session sheets for the most up-to-date information.
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**Technical Program**

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defects and prediction of material and component performance continue to pose significant challenges. The kinetics and thermodynamics of oxidation often result in bifilms captured in the liquid existing in a metastable state. Future challenges for improved understanding and control of liquid metal cleanliness will be explored with the objective of highlighting opportunities for design and development of more robust processes and components of assured reliability.

8:55 AM An Experimental Setup to Study the Influence of an External Magnetic Field on Arc Behavior: Ashish Patel1; Jeremy Sensenig1; Timet
A bench top experimental setup was assembled to study arc behavior. The arc was formed using a welding power supply, and a graphite rod as an electrode. The graphite rod was connected to a linear drive for precise vertical positioning. A large grounded copper slug was used as base. A camera with appropriate filters was used for recording. The transverse magnetic field was generated by passing current through a coil; the magnitude and phase shift of the coil current was used for recording. The transverse magnetic field was generated by passing current through a coil; the magnitude and phase shift of the coil current was used for recording. The transverse magnetic field was generated by passing current through a coil; the magnitude and phase shift of the coil current was used for recording.

9:20 AM Investigations on Collective Motion of Cathode Spots in the VAR Process: Abdellah Kharicha1; Ebrahim Karimi Sibaki1; Menghui Wu1; Andreas Ludwig1; VSMPO-AVISMA Corporation
The behaviour of the arc in the VAR process can be considered as the sum of the collective motion of the spots. The spots move discretely at high speed, but based on experimental observation the arc motion is continuous and much slower. The purpose of the present paper is to investigate numerically the movement of the many cathode spots in interaction through their self-magnetic field. The movement of the spots is assumed to be controlled by a combined stochastic-deterministic law using a retrograde Lorentz force. It is shown that the cathode spots randomly nucleate near the centre and then move towards the edge of the electrode. Many spots move collectively in the form of alignments of 3 to 7 spots. For large applied currents, the spots form a cloud that expands periodically in an anisotropic way.

9:45 AM Break and Poster Exhibits Open
10:15 AM Measurement of the Spatio-Temporal Distribution of Arcs During Vacuum Arc Remelting and their Implications on VAR Solidification Defects: Joshua Motley1; Kanchan Kelkar2; Paul King3; Matthew Cibulka4; Alec Mitchell5; VSMPO-AVISMA Corporation
The behavior of vacuum arcs during VAR processing is known to impact product yield and contribute to ingot defects. For example, it has been shown that constricted arcs during the processing of segregation prone Nickel-based alloys can lead to defects in ingots. Despite this knowledge, the role of arc distributions in VAR processing has not been considered in controlling the furnaces. In addition, computational models of the process have typically assumed that the arc provides an axisymmetric, Gaussian heat input to the ingot, while acknowledging that this is the biggest unknown variable. Here we present the theory behind VARmetricTM and present analyses of the spatio-temporal arc distributions measured on a production VAR furnace. We then use the measured axisymmetric arc distributions to provide updated boundary conditions for solidification of the ingot to investigate the implications of the changing distributions on solidification and the relationship between arc distributions and defects.

10:40 AM VT3-1 Titanium Alloy Ingot Solidification during VAR: Evgenii Kondrashov1; Kirill Rusakov1; Mikhail Leder1; Aleksandr Maksimov2; Lev Konovalov2; VSMPO-AVISMA Corporation
A thermal model is developed for the ingot solidification during vacuum arc remelting (VAR) and is applied to calculate pool profiles for a VT3-1 alloy. The pool profiles are calculated for two remelting schedules, and the calculation results are compared with radiography data. The model calculation results are shown to agree satisfactorily with experimental data. The model calculation results are shown to agree satisfactorily with experimental data.

11:05 AM SOLAR Calculation of the Capacity of the Security System to Ensure the Extraction of Heat during Vacuum Arc Remelting (VAR): Isabelle Cressous1; Framatome
VAR is used to produce reactive metals like titanium or zirconium. This technology is used by Framatome to produce zirconium alloys dedicated to nuclear and medical fields. The control of the process is essential to ensure quality through chemical homogeneity or security through the cooling system. For this reason, Framatome and the Institute Jean Lamour, have developed a specific code (SOLAR). The mathematical model is based on the solution of the coupled transient heat, momentum, and solute transport equations, during laminar or turbulent flow conditions, during the remelting and cooling of a cylindrical ingot. The specific case of a single melt M5Framatome ingot was studied: the evolution of the mold temperature is discussed during the process. The critical flow and the critical temperature defined by the free boiling theory are calculated and compared with the values calculated with SOLAR model. The corresponding results would be presented and discussed.

11:30 AM Uncertainty in the Modeling of Nitinol Solidification in VAR: Kyle Fezi1; Matthew Krane2; Fort Wayne Metals; Purdue University
Nitinol’s unique shape memory and super-elastic properties make it desirable for many biomedical, automotive, and aerospace applications, but are highly dependent on the Ni/Ti ratio and other outcomes of solidification behavior in VAR. A cost-efficient method to explore the processing parameter space is numerical modeling, but simulation results reliability is dependent on uncertainty in the model and the input data. The VAR process is modeled using the commercially available MeltFlow-VAR package. The sensitivity of the sump depth prediction to several input parameters, primarily material properties and boundary conditions, were analyzed. Level one sensitivity analysis determined which inputs had the most impact and level two analysis quantified sump depth uncertainty due to those parameters. Uncertainty in the thermal boundary condition on the ingot’s sidewall was found to have a large influence on the sump depth, providing justification for an experimental program to more accurately measure heat loss during the process.

11:55 AM Lunch
1:15 PM  
Numerical Investigation of the Vacuum Arc Remelting (VAR) Process: 
Ebrahim Karimi Sibaki1; Abdellah Kharicha2; Menghuai Wu1; Andreas Ludwig2; 
J. Bohacek1; Harald Holzgruber1; Bertram Ofner1; Alexander Scheriau1; Michael 
Kubin1; 1University of Leoben; ‘University of Leoben; ‘INTECO 
Nowadays, the Vacuum Arc Remelting (VAR) process is effectively utilized to 
manufacture Titanium-based alloys. A comprehensive CFD model is proposed to 
study the interaction between various transport phenomena (flow, heat, etc.) in the 
VAR. All elements of the process including the electrode, vacuum, Titanium-based 
ingot, and mold are taken into account. The electromagnetic field is calculated in the 
entire process. The flow filed in the melt pool is computed. Furthermore, the 
pool profile of the solidified ingot is calculated. The model enables us to compute 
the radiation heat transfer in the vacuum region where the amount of side-arcing 
is prescribed. The impact of side-arcing on the magnetohydrodynamics behaviour 
of the melt pool and consequently the pool profile of the ingot is analysed. 
Eventually, the model is validated against an experiment.

1:40 PM  
3D Numerical Simulation of the VAR Consumable Electrode Melting 
Process: Rayyan Bhar1; Alain Jardy1; Pierre Chapelle1; Vincent Descotes1; 
Institut Jean Lamour; ‘Aperam Alloys Imply 
A 3D numerical model was set-up to simulate the formation and dynamics of 
the liquid metal film under the consumable electrode during VAR process. In 
the present paper the implementation of this model is described. It was developed using 
the open source computational fluid dynamics (CFD) software, OpenFOAM. The 
model solves coupled momentum and energy equations combined with a volume-of-fluid (VOF) method to track the liquid metal free surface. The melting of the 
electrode material is modelled with an enthalpy-porosity approach. The electric 
power supplied by the arc is supposed to be uniform and distributed between the 
electrode as well as the liquid bath. For a given electric arc power, the model 
quantitatively predicts the dripping and possible drip-shorts, hence the overall 
melt rate. Simulations are validated through comparisons with experimental 
data extracted from available literature. Keywords: VAR process, consumable 
electrode, melting, liquid metal film, melt rate 

2:05 PM  
Feedback-based Control over the Spatio-temporal Distribution of Arcs 
during Vacuum Arc Remelting via Externally Applied Magnetic Fields: 
Matthew Cibula1; Paul King1; Joshua Motley1; ‘Ampere Scientific 
Ampere Scientific’s VARMetricTM measurement system for Vacuum Arc 
Remelting (VAR) furnaces passively monitors the distribution of arcs over time 
during VAR in real time. The arc behavior is known to impact both product 
yield and quality and can pose potentially catastrophic operating conditions. Arc 
position sensing with VARMetricTM enables a new approach to control the heat 
input to the melt pool. Transverse external magnetic fields are applied to push 
the arcs via the Lorentz force using feedback of the arc location to control the arc. 
This has been tested on Ampere Scientific’s small-scale laboratory arc furnace 
with electromagnets used for control for up to 60 seconds while monitoring the arc 
location with VARMetricTM. The arc distributions are shown to be significantly 
different from the uncontrolled distributions with distinct thermal profiles at the 
melt pool. Alternatively, this type of control can be periodically applied to react 
to undesirable arc conditions.

2:30 PM Break and Poster Exhibits Open
Numerous electrochemical reactions were suggested for chemical elements such as S, O, Al, and Fe to describe metal refinement mechanisms in the ESR. Electrochemical (Faradaic) reactions take place within the slag bath or at slag-metal-gas-mold interfaces. Specifically, those reactions are carried out at the liquid film under the electrode tip as well as at the droplet-slag interface. We propose a model for Faradaic reactions at those interfaces as well as electrochemical transport of ions in the bulk of slag. It is found that the intensity of the flow filed and the strength of electric field in the bulk of slag can significantly impact Faradaic reactions and consequently efficiency of metal refinement. Impacts of electrode polarity and electro-migration of ions are analysed. Based on modeling results some explanations are suggested for theses phenomena in DC ESR: higher melt rate for positive polarity, and formation of FeO layer under electrode tip.

Transfer Phenomenon Study of Slag-Metal Reaction during Electroslag Remelting Process: Dong Hou; Zhouhua Jiang; D.Y. Wang; T.P. Qu; J. Tian; H.H. Wang; Soochow University; Northeastern University

The laboratory experiments have been carried out to investigate the mass transfer phenomenon during electroslag remelting (ESR) with a focus of establishing a slag-metal multiphase reaction model. The multiphase reaction model based on the penetration and film theories is established to analyze the concentration changes of sulfur and alloying elements in steel along the height of ESR ingot. The results show that the concentration of sulfur in ingot at the beginning of ESR process is lower than the rest process because of the large distribution ratio of sulfur combined with excellent kinetic conditions. In the first slag-temperature-rising period, the aluminum in ingot has the increasing trend with the increase of temperature. And two ways can solve this problem: the one is starting up the ESR furnace by high temperature molten slag technology, and the another one is adding extra titania into molten slag continually in the first slag-temperature-rising period.

Industrial Electro-steel 

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Liquid Metal Processing & Casting — Casting 1

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8:25 AM
Experimental Study on Alloying Additions in Electro Slag Refining: Harald Scholz; Thomas Kilzer; Gerhard Brückmann; Henrik Franz; ‘ALD Vacuum Technologies GmbH

Electro Slag Refining can be carried out under vacuum, atmospheric or elevated pressure using atmospheric composition or inert gas. Process parameters like electrode sizes, slag systems and the working pressure can be adapted to the necessities of the process to influence the final ingot quality. In pressure ESR gases like Nitrogen can be easily added to the final ingot via feeding of nitrogen containing elements and decreasing the immersion of the electrode in slag. In addition the slag can be de-oxidized to maintain the refining capability of the slag. As a next step the alloying of certain elements during ESR can be done considering the melting temperature of slag. A feasibility analysis was carried out allowing the addition of vanadium oxide and de-oxidation agent at the same time during the ESR process in order to increase the vanadium content in the final ingot.
Numerical Prediction of the Interfacial Heat Transfer Coefficient for Permanent Mold Casting of Mg-Al Alloys: Muhammad Umer Bilal; Norbert Hort

Most Mg alloys are based on the Mg-Al system and casting is the commonly used production process for these alloys. Apart from many governing factors, a parameter of prime importance for the numerical simulation of casting is the interfacial heat transfer coefficient (HTC). Principally, it quantifies the heat flux between casting and mold. The study aims towards finding the unknown boundary temperatures and flux from the experimental temperature measurements using the inverse methodology. The HTC was predicted for a variety of Mg-Al alloys, which were cast using permanent cylindrical mold. Unidirectional heat flow was ensured in order to replicate the experimental conditions for solving the one-dimensional transient heat equation. The numerically determined mold temperature was in good agreement with the experimentally measured values. Moreover, the heat transfer behavior across the interface depicted in the form of HTC is discussed, also various empirical and numerical aspects of the method are highlighted.

Influence of Gap Formation and Heat Shrinkage Induced Contact Pressure on the Development of Heat Transfer in Gravity Die Casting Processes: Thomas Vossel; Björn Pustal; Andreas Bührig-Polaczek; RWTH Aachen

Anticipating the processes and parameters involved for accomplishing a sound metal casting requires an in-depth understanding of the underlying behaviors characterizing a liquid melt solidifying inside its mold. With heat balance and thermomechanical effects as two essential aspects of the casting process, numerical simulations can be used as a tool to predict the advancing solidification and the occurring stress-strain formation. A manifold of parameters gets incorporated in such simulations with some parameters being hard to define in advance. The heat transfer serves as a primal example for such an estimated parameter. This paper evaluates different approaches to estimate the heat transfer coefficient for A356 gravity die casting and will discuss the significance of not treating heat transfer as a pure function of temperature or time but as an effect-driven variable that has to be adjusted locally due to the possibility of local gap forming and heat shrinkage induced contact pressure.

Ancillary Processes in Casting Manufacturing Introducing Risks in Production: Oscar Caballero; Xabier Esquisabel; Industria De Turbo Propulsores S A

Manufacturing of castings in the aerospace industry is tightly controlled. Process parameters are fixed and customers and producers agree not to modify them for the benefit of having stable processes that always achieve the same quality on products and do not introduce scatter in mechanical properties or other characteristics of the parts. However, manufacturing constraints and other needs make some changes happen during regular production. As long as the changes affect identified critical parameters, these are of course thoroughly assessed to evaluate their effect on the final parts. However, in some occasions, changes in ancillary processes that are not expected to have any influence or risk on the final parts are introduced with no further evaluation. Unfortunately, these assumptions are not always correct. The case of plasma torch cutting for removing gating system in castings is presented here. Changing the gas caused some trouble on the final parts.

Formation of Central Semi-macro Segregation and its Minimization by Soft Reduction during the Continuous Casting of Heavy and Wide Slab: Min Jiang; En-Jiao Yang; Zhi-Gang Xu; Xin-Hua Wang; University of Science and Technology Beijing

Formation of semi-macro segregation in heavy and wide slab was discussed in present work. Central segregation in slab was composed of independent semi-macro spots. It increased with the rise of super heat and was more concentrated because of well growth of column grains. By comparison, well-developed equiax grains helped to scattered such semi-macro spots. However, with the use of soft reduction, central segregation peaks were lower at higher super heat, implying that the segregation was more effectively minimized under developed column grains. The relationship between central semi-macro segregation and solidification microstructure was discussed. Moreover, effect of solidification microstructure on the efficiency of soft reduction was elucidated. Based on these findings, continuous casting process of the heavy and wide slab was improved and quality of the cast products were greatly enhanced.
3:00 PM
Liquid Metal Flow Studied by Positron Emission Particle Tracking: Agnieszka Dybaliska1; Adrian Cadet1; David Parker1; John Wedderburn1; William Griffiths1; ‘University of Birmingham
To improve the properties of castings a new technique to observe fluid flow and study the motion of oxygen-bearing inclusions has been developed. The new technique, Positron Emission Particle Tracking (PEPT), enables a single radioactive tracer particle moving inside a liquid metal casting to be tracked with an accuracy of some millimeters, which depends on the liquid metal and mould material properties. These novel experiments give promising results to observe the liquid metal flow and locate the tracked particle in the cast metal. Experiments have shown that various particle sizes can be used to observe the liquid metal flow if the particle has sufficiently initial radioactivity. The different types of particles are considered and the radioactivity of them is compared in terms of usability for the tracking in the aluminium fluid flow.

3:25 PM
Slag-metal Interactions in the FeMn Tapping Process: Interfacial Properties and Wetting: Sergey Bublik1; Sarina Bao1; Merete Tangstad1; Kristian Einarsrud1; ‘Department of Materials Science and Engineering, NTNU; ‘Metal Production and Processing, SINTEF Industry
FeMn-alleys are produced by transforming ore and carbon materials into FeMn and slag at high temperatures in a furnace. Entrainment of FeMn in slag during tapping reduces the yield. Entrainment and subsequent separation are strongly influenced by slag-metal interfacial properties. In the current work, interfacial properties, including the contact angle, in the FeMn-slag graphite system have been investigated using the sessile drop technique at temperatures above 1300 °C. Two experimental configurations are proposed: (a) slag and metal placed beside each other on graphite; and (b) slag placed on top of the metal layer, which is in contact with graphite. Results demonstrate that the contact angle between slag and metal is 55-60° at temperatures from 1310 to 1350 °C and slag-metal weight ratio around 0,25. In addition, wetting properties are considerably influenced by the variation of slag-metal weight ratio in the range from 0,25 to 1,50 and only marginally by temperature.

3:50 PM
Calculating Steel Making and Steel Refining Processes using Thermo-Calc’s New Process Metallurgy Module and the CALPHAD Database TCOX9: Nicholas Grunli1; Andreas Markstrom1; Lina Kjellqvist1; Ralf Retting1; Johan Jeppsson1; Johan Bratberg1; ‘Thermo-Calc Software
Computational thermodynamics is a powerful tool widely applied in materials science, e.g. for alloy design. Thermodynamic databases developed through the CALPHAD approach usually give reasonable predictions of thermodynamic properties as well as the phase equilibria of corresponding multi-component systems. A thermodynamic database, TCOX, has been developed for calculating thermochemical interaction between liquid steel and slag. With the TCOX database an attempt is made to develop an internally consistent database for oxygen-containing systems. Today the TCOX database includes the major alloying elements in steels as well as the important slag elements. Additionally, a graphical interface for steel/slag calculations that is easy to use and suitable for the steel industry has been developed. Such an interface, together with the TCOX database, is a powerful tool for controlling complex metallurgical processes, for example desulphurization, dephosphorization or ladle refining, and in the development of new steel grades.

4:15 PM
Dissolution Rate of Carbon in Liquid Metal: Hamideh Kaffash1; Merete Tangstad1; ‘Norwegian Tech N University
In this paper carbon dissolution studies were carried out on four carbon materials, viz. graphite, commercial charcoal and two metallurgical cokes, coke A and coke B. The rate of carbon dissolution into molten Fe-85%Mn at initial stage at 1550°C, were determined. Characterization of the substrates was accomplished using proximate analysis, surface topography and XRD. The results showed that coke A and coke B had the highest overall dissolution rate and the dissolution rate constant was determined to be 6.73×10⁻² cm/s and 5.94×10⁻² cm/s respectively. The dissolution rate constant for graphite was 3.52×10⁻² cm/s and 1.47×10⁻² cm/s for charcoal. Within poorly ordered carbon materials (charcoal and cokes) crystallite size and surface roughness seemed to be dominant factors affecting the dissolution rates. The dissolution mechanism was found to be both mass transfer and interfacial reaction.

4:40 PM
Surface Tension, Viscosity and Specific Heat Capacity of Ni-based Superalloys MC2, LEK94 and CMSX-10 in the Liquid Phase Measured in the Electromagnetic Levitator (EML-ISS) on board the International Space Station: Markus Mohr1; Rainer Wunderlich1; Hans-Jörg Fecht1; ‘Univ Berlin; Nickel-based superalloys combine high temperature strength, creep resistance and toughness, and hence find application in turbines for land-based power generators as well as in aircraft engines. The used casting process is time consuming and costly, making it necessary to perform supporting simulations of the heat and material flow in the melt. This models require good input data of thermophysical properties in the solid and liquid phase. Measurement of surface tension, viscosity and specific heat of liquid metals is challenging, due to the melts high solution reactivity. The method of choice is electromagnetic levitation, a containerless method. However, gravitational forces have to be absent to obtain a spherical droplet with controlled fluid flow conditions. We will present and discuss measurements of surface tension, viscosity and specific heat capacity, performed in the Material Science Laboratory Electromagnetic Levitator (ISS-EML) on board the European Space Laboratory Columbus in the international space station (ISS).

6:30 PM Gala Dinner
Wettability of Molten Fe-Si-B Alloy on Graphite, Al2O3, and h-BN Substrates: Jianmeng Jiao1; Bettina Grorud1; Jafar Safarian1; Merete Tangstad1; 1Norwegian University of Science and Technology

Molten Fe-26.38Si-9.35B alloy (numbers in mass %) is of interest as a phase change material (PCM) because it exhibits high thermal conductivity, moderate melting point, high latent heat, and low cost. This study offers valuable insights into the contact angles of molten eutectic Fe-26.38Si-9.35B alloy on various substrates using the sessile drop method. Moreover, the reactivity has been investigated by examining the cross-sections between Fe-26.38Si-9.35B droplets and substrates with a scanning electron microscope (SEM). The purpose of this study is to find a proper refractory material for the new Fe-26.38Si-9.35B PCM. These wetting tests confirm that the contact angle between molten Fe-26.38Si-9.35B and Al2O3 is about 142°. Molten Fe-26.38Si-9.35B spreads over the graphite plate and the contact angle is estimated to be 311/176 and a continuous silicon carbide (SiC) layer is formed between the molten Fe-26.38Si-9.35B and graphite. Interestingly, three melting/solidification cycles have been performed on hexagonal boron nitride (h-BN) substrate at the temperature range of 1100-1550 °C. The contact angle is observed to be 142° in the first cycle, 105° in the second cycle, and 130° in the third cycle. This study contributes to our understanding of the wettability properties of molten Fe-26.38Si-9.35B alloy on various substrates.

9:15 AM Break and Poster Exhibits Open

10:10 AM

Numerical Modelling and Optimization of the Electrode Induction Melting for Inert Gas Atomization (EIGA): sergejs spatins1; henrik Franz1; egbert baake1; 1alD Vacuum Technologies GmbH; 2Institute of Electrotechnology, Leibniz University

Electrode Induction Melting Inert Gas Atomization (EIGA) is one of the leading processes for manufacturing of high-quality titanium, zirconium, niobium and precious metal alloy spherical powders for use in aerospace, medical, energy, chemical, electronic and other industries. To study the EIGA process a numerical model for the electrode induction melting has been developed by means of coupling between the Lorentz force and Joule heat calculation in ANSYS and a transient heat transfer, melting and turbulent free surface flow calculation (including droplet detachment) in FLUENT. Parameter studies revealing the impact of the induction coil design and process conditions on the electrode melting behaviour (melting stability and regime, droplet size and superheat) will be presented. Finally, using numerical modelling we have successfully tailored our EIGA systems for atomization of new refractory materials with especially high melting temperatures like Tantalum (3017°C), Ø40mm and ensured the further scale-up of established process (Ti-6Al-4V, Ø150mm).

10:35 AM

Thermo-hydrodynamic Modeling of the Plasma Arc Melting Cold Hearth Refining Process (PAMCHR): Lea Découtot1; Alain Jardy1; Stéphane Hans1; Emiliane Doridot1; Jerome Delfosse2; Fabienne Ruby-Meyer3; Jean-Pierre Bello4; 1Aubert & Duval; 2institut Jean Lamour; 3Saflan Tech; 4MetaFensch

In order to set up a titanium alloy recycling route in Europe, UKAD, a joint-venture between Aubert & Duval and UKTMP, ADEME and Crédit Agricole Centre France, created the company EcoTitanium. The recycling is performed thanks to the PAMCHR process with the aim of producing aeronautical titanium alloy ingots. The research work is focused on the refining hearth stage, a very important step where low and high density inclusions have to be removed. A 3D numerical simulation of the thermal and hydrodynamic behavior of the liquid metal bath has been set up based on Ansys-Fluent CFD software. Thermal and shear effects of the plasma jet on the turbulent flow have been modelled together with the transient displacement of the torches. A comparison between the results obtained experimentally and numerically is carried out in order to validate the numerical model, both for a pilot furnace, and the industrial EcoTitanium furnace.

11:00 AM

Defect Curing using Plasma Arc for Continuously Cast Steel Slabs: Ki Hyeon Moon1; 1Posco

Although many kinds of countermeasures have been applied to reduce the surface defects during continuous casting of slabs, limit has been always met not to completely remove the casting defects. In this paper, a new trial is introduced to cure surface defects and consequently to improve the surface quality for cast slabs. Plasma torches were applied to cure the defects, especially corner cracks at the slabs. Melting and solidifying moments were observed, and microstructures were examined during and after plasma curing. Also mechanical properties were evaluated after the hot rolling. By examining the micro structure, it was found that the cracked part was completely melt and solidified without any defect. The mechanical properties such as tensile and bending strength were almost same as those of no-crack part.

11:25 AM

Modelling the Cold Crucible Pouring Dynamics: Valdis Bajarevics1; Kyriacos Pericleous1; 1University of Greenwich

The paper uses the mathematical modelling technique to investigate cold crucible operation with a non-consumable nozzle made of copper segments. The combination of two coils, one for the main crucible and the other for the nozzle with different power supplies, requires to superpose the effects of the two independent AC electromagnetic force fields. This leads to complex transitional flow structures and turbulence of the melt, contributing to the melt shape dynamics and the heat loss to the walls to satisfy the narrow balance between the thin solidified protective layer while avoiding the blockage of the outflow if the nozzle is frozen. The sensitivity of the outflow to the nozzle diameter is investigated. The beneficial features of the cold crucible melting to purify the melt from particulate contamination are explained using the particle tracking during the pouring process.

11:50 AM Lunch
The Realization of a Dynamic Regulation Process for Nodularization and Inoculation of Ductile Iron: Dayong Li1; Zhenyu Xu1; Xuliang Ma1; Dequan Shi1; Guili Gao1; Peihong Zhang1; ‘School of Materials Science & Engineering, Harbin University of Science and Technology

Nodularization and inoculation are the two necessary processes for the production of ductile iron. Due to the uncertainty of the metallurgical state of the base iron, fixed nodularization and inoculation often lead to “over-nodularization” or “under-nodularization”. In order to avoid “over-nodularization” or “under-nodularization”, the authors designed and trial-produced a dynamic control system for the nodularization and inoculation. Based on monitoring the main chemical composition, oxygen content, sulfur content and melt temperature and evaluating the nodularized and inoculated performance of the base iron, the addition amount of nodulizer and inoculant can be given. After nodularization and inoculation, the nodularization and inoculation effects are detected by the rapid analysis equipment in front of the furnace, unqualified melts shall be fine-tuned or reheated. Through the simulation test in the casting production practice workshop of the school, the experimental results preliminarily show that this method can effectively control the nodularization and inoculation process of ductile iron.

Alloy Grain Refinement by Means of Electromagnetic Vibrations: Kyriacos Pericles1; Valdis Bogarrieve1; Georgi Djambazov1; Agnieszka Dybalaska1; William Griffiths1; Catherine Tony1; ‘University of Greenwich; ‘University of Birmingham

A tuned electromagnetic induction coil generates ultrasonic pressure waves in an alloy melt. Under acoustic resonance conditions cavitation of dissolved gases is observed leading to microstructure refinement, dispersion of added particles and degassing. The method is an alternative to the immersed sonotrode technique but offers several advantages. Being contactless, it can be applied equally to high temperature or reactive melts, avoiding contamination due to probe erosion; consequently, it is maintenance free. The consequent induction stirring means that larger volumes of melt can be treated (a major limitation of the traditional method), as the liquid is forced to pass repeatedly through zones of cavitation activity. The coil configuration used depends on application. Here, a top conical coil immersed in aluminium melt (contactless due to EM repulsion) was used. Simulations of sound, flow and EM fields are given, compared with experiments and indicating strong stirring, evidence of cavitation and grain refinement.

Plant Design Aspects and Attainable Ingot Quality of Most Modern Super Alloy Production Plants: Michael Kubin1; S. Ress2; Alexander Scheriau; Harald Holzgruber; ‘INTECO Melting and Casting Technologies GmbH; ‘INTECO

High performance material such as nickel base alloys are usually produced via the route VIM-ESR and/or VAR. Due to the complexity of these alloys special requirements on the furnace design and the process parameters has to be taken into account. This paper gives a brief overview of the basic principles of each process and the overall plant design highlighting the main features of VIM, ESR and VAR furnaces. Results will be given regarding the attainable ingot quality with respect to the chemical composition of VIM ingots as well as a comparison of the achievable macrostructure of ESR and VAR ingots.
Mechanism of Metallurgical Quality Improvement of Ingot Processed by Vacuum Electroslag Remelting: 

Yu Liu; Guangqiang Li; Xuechi Huang; Yulong Cao; Qiang Wang; Baokuan Li; 1Wuhan University of Science and Technology; 2Northeastern University; 3Northeastern University

To clarify the role of vacuum on cleanliness improvement and structural evolution of H13 ingot processed by electroslag remelting (ESR), two heats were carried out under Ar atmosphere and vacuum, respectively. The results show that the total oxygen contents in ingots remelted under Ar atmosphere and vacuum are 38 ppm and 16 ppm, respectively. The inclusions in two ingots are both (Ti,V)N, CaO-Al2O3-MgO and CaO-Al2O3 oxide covered by (Ti,V)N. The inclusions are predominantly (Ti,V)N, and the size are finer in ingot processed by ESR under vacuum. The remelting rate is more rapid under vacuum because the fluoride vaporization becomes severer, resulting in that the electric resistance of slag melts increases. Meanwhile, the fluoride vaporization also strengthens flows in slag melts, contributing to the more uniform temperature distribution in slag melts. As a result, the secondary dendrite arm-spacing (SDAS) and the sizes of carbides are smaller in ingots remelted under vacuum.

Effect of Vacuum on Oxygen Control during Electroslag Remelting of H13 Die Steel: 

Xuechi Huang; Baokuan Li; Zhongqiu Liu; 2Northeastern University

In order to decrease total oxygen content, vacuum electroslag remelting is developed. Vacuum refining is supposed to be conducive to deep degassing in steelmaking process, such as carbon monoxide. A transient model coupling the magnetohydrodynamic flow and heat transfer was therefore proposed to investigate the effect of vacuum on oxygen control during electroslag remelting process of H13 die steel. Oxygen transfer in ESR under Ar gas atmosphere and vacuum condition was discussed. A kinetic model based on the thermodynamic analysis was established to predict the thermochemical reaction rates. The result shows that the ingot remelted under vacuum condition has the lowest oxygen content, which indicates the carbon deoxidation occurs. Besides, the less heat loss under vacuum condition leads to a higher remelting rate, which shortens the reaction time that oxygen transfers from slag to steel. The calculated results agree well with the experiments.

Numerical Investigation on the Ingot Solidification with Different Solidification Paths and Permeability Models in Electroslag Remelting Process: 

Jia Yu; Fubin Liu; Zhouchua Jiang; Ao Wang; Wenchao Zhang; Huabin Li; Xin Geng; 2Northeastern University

A 2D transient axisymmetric model has been established to investigate the effects of solidification path and permeability model on ingot solidification in electroslag remelting process based on the volume of fluid (VOF) and dynamic mesh technique. The governing equations are discretized by means of the finite volume method (FVM). The modified heat capacity is employed including the change in enthalpy. The hypothetic linear dependence and the solidification path obtained from Thermal-Cale are incorporated into the model with User Defined Function (UDF) respectively. The Dracy’s law is used to describe the flow in the mushy zone. Both the isotropy permeability and anisotropy permeability model are employed for comparison. The local solidification time (LST) is also predicted. The results could enhance the understanding of ingot solidification.

Rapid Solidification and Microstructure Formation in Designed Ni-based Immiscible Alloys: 

Jie He; X. Sun; Y. Xi; H. Ma; L. Zhang; H. Jiang; J. Zhao; M. Zhu; H. Hao; 1Institute of Metal Research; 2Chinese Academy of Sciences; 3University of Science and Technology of China; 4Chinese Academy of Sciences; 5Shenyang Aerospace University; 6Chinese Academy of Sciences; University of Science and Technology of China; 7Chinese Academy of Sciences; 8Chinese Academy of Sciences; University of Science and Technology of China

In this work, a quaternary Ni–Cu–Nb–Ta system has been designed to obtain composite microstructures with spherical crystalline Cu-rich particles embedded in amorphous Ni-rich matrix and with glassy Ni-rich particles embedded in crystalline Cu-rich matrix. The alloy samples were prepared by using rapid quenching. The microstructure and related properties of the as-quenched alloy samples were characterized by X-ray diffraction, scanning electron microscopy, high-resolution transmission electron microscopy, and differential scanning calorimetry. It shows that the spherical crystalline Cu-rich particles are embedded in the amorphous Ni-rich matrix. The average size of the Cu-rich particles is strongly dependent upon the Cu content. The effect of the alloycomposition on the behavior of liquid-liquid phase separation and microstructure evolution was discussed. The formation of structure with the glassy Ni-rich particles distributed in crystalline Cu-rich matrix and thereby the effect of the structure on the related properties were analyzed.
**Effects of Yttrium on the Microstructure and Mechanical Properties of an Austenitic Hot-Work Tool Steel: Chengbin Shi; Yongfeng Qi; Jing Li; Lan Peng**

The microstructure and mechanical properties of high-Mn austenitic die steel with yttrium addition were investigated with the help of optional microscope (OM), scanning electron microscope (SEM) and electron back scattered diffraction (EBSD). The microsegregation of alloying elements were analyzed by electron probe microanalysis (EPMA). The results showed that the microstructure were refined and mechanical properties were improved when the amount of soluble yttrium in as-cast ingot reached to 60\% by 106. The secondary dendritic arm spacings and corresponding the size of primary carbides were reduced with increasing yttrium addition up to 60\% by 106, but increased when excessive yttrium addition. The grain sizes decreased with increasing yttrium addition after heat treatment. The intragranular twin grain boundaries were increased with increasing yttrium addition, which resulted in the increasing in grain boundaries area ratio. Therefore, the strength and toughness of the steel were simultaneously increased due to the refined grains, reduced carbides and impeded movement dislocation.

**Effects of Slag Containing Rare Earth Oxide on Steel Cleanliness and Tensile Properties during Electroslag Remelting of AF-3 Steel: Harbo Cao; Yanwu Dong; Zhouhua Jiang; Zhiwen Hou; Kean Yao; Shuyang Du; Yushuo Li; Fei Peng**

The effects of slag containing rare earth oxide under on non-metallic inclusions and tensile property during of the AF-3 steel by ESR were experimentally investigated. Specimens were taken at the electrode and each remelting ingot for analyzing the compositions, dimensions, and types of non-metallic inclusions. After hot rolling and sensitization treatment, electronic universal testing machine was employed to investigate normal and hot tensile performance. The results show that under simple nitrogen atmosphere combined with reduction treatment steel solidified under high pressure die casting can be achieved quality over the entire production route leading finally to a material with superior quality and enhanced properties. Achievable quality over the entire production route leading finally to a material with superior quality and enhanced properties. Achievable quality over the entire production route leading finally to a material with superior quality and enhanced properties. Achievable quality over the entire production route leading finally to a material with superior quality and enhanced properties. Achievable quality over the entire production route leading finally to a material with superior quality and enhanced properties.
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