LMPC 2009

International Symposium on Liquid Metal Processing and Casting

September 20-23, 2009
Eldorado Hotel
Santa Fe, New Mexico USA

FINAL PROGRAM

Organized by:

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Welcome to the International Symposium on Liquid Metal Processing and Casting!

September 20-23, 2009 • Eldorado Hotel
Santa Fe, New Mexico USA

This international forum has featured new discoveries and advances in the world of liquid metal processing for the past 15 years. Prepare to be enriched and to emerge with a renewed drive to perform!

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Gern Maurer, *Carpenter Technology, United States*

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ABOUT THE CONFERENCE

CONFERENCE REGISTRATION

All attendees and meeting participants, including authors and exhibitors, must register for the meeting.

Badge pick-up will be located in the North Concourse during the following times:

Sunday, September 20 .... 5 to 8:30 p.m.
Monday, September 21.. 7:30 a.m. to 5 p.m.
Tuesday, September 22 .... 7:30 a.m. to 5 p.m.
Wednesday, September 23... 8 to 10 a.m.

Recycling bins will be available for unwanted programs and badge holders.

Your value-packed registration includes:

- Admission to technical sessions
- Welcoming reception
- Hosted coffee breaks
- Banquet dinner and reception
- Admission to the meeting exhibition
- Conference Proceedings CD-ROM (with full conference registration)

PROGRAMMING NOTES

TECHNICAL SESSIONS

All sessions will be in the Anasazi Ballroom of the Eldorado Hotel.

Monday, September 21 .... 8:20 to 9 a.m.
Keynote speaker Cynthia A. Powell, of the U.S. Department of Energy's Office of Research and Development, National Energy Technology Laboratory, will discuss, *"Metals Technology to Enable Future Energy Systems."*

VAR Process I .... 9 a.m. to 12:25 p.m.
VAR Process II .... 2 to 3:40 p.m.
Solidification .... 4 to 5:40 p.m.

Tuesday, September 22
Steel Processing.. 8:30 to 11:05 a.m.
ESR Process I .... 11:05 a.m. to 12:20 p.m.
ESR Process II .... 2 to 3:40 p.m.
ESR Process III .... 4 to 5:40 p.m.

Wednesday, September 23
Process Optimization and Novel Techniques..................... 8:30 to 11:45 a.m.

Poster Viewing & Breaks.. Every morning & afternoon Monday and Tuesday
Beverages will be served during both morning and afternoon breaks.

NETWORKING & SOCIAL EVENTS

WELCOMING RECEPTION

Sunday, September 20……………7 to 8:30 p.m. ……..Sunset Room

This casual kickoff event is for all attendees and is sponsored by ALD Vacuum Technologies, USA

CONFERENCE BANQUET

Tuesday, September 22……………7 to 9 p.m.….. Sunset Room.

A cocktail reception at 7 p.m. in the Eldorado Court, just outside the Sunset Room, will introduce this plenary soiree. The grand banquet will follow at 7:30 p.m. Guests may purchase tickets at the registration desk for $105.

EXHIBIT

Tabletop exhibit's will be open during regular conference hours in the Devargas Concourse. Mingle with fellow LMPC conference attendees between sessions and discuss the latest in technological offerings for the liquid metals processing and casting community.

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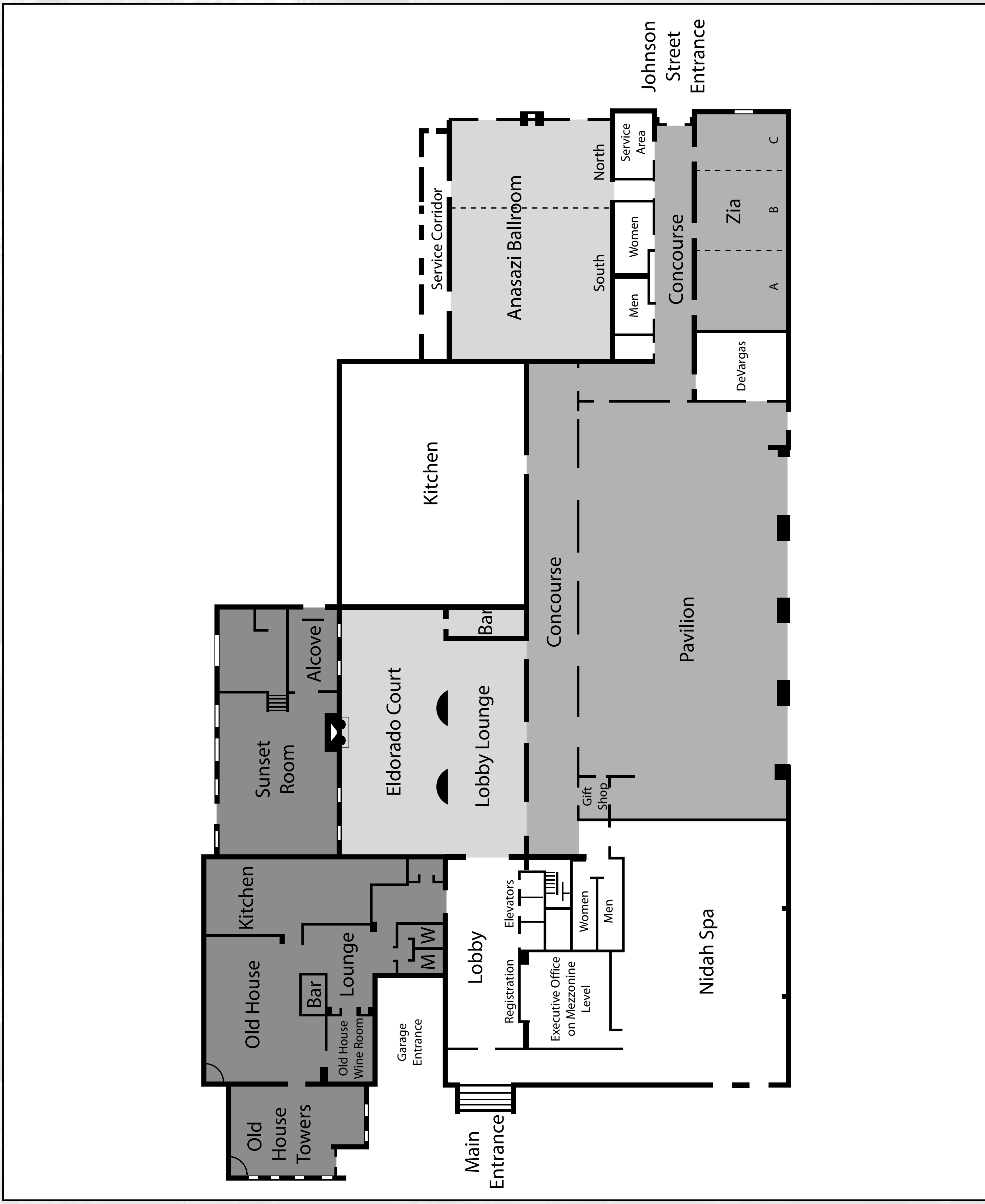
Johnson Street Entrance
Service Corridor
Anasazi Ballroom
North
South
Service Area
Women
Men
Concourse
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DeVargas
Kitchen
Concourse
Pavilion
Bar
Alcove
Sunset Room
Eldorado Court
Lobby Lounge
Gift Shop
Kitchen
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Bar
Lounge
Old House Wine Room
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Lobby
Elevators
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Registration
Executive Office on Mezzonine Level
Nidah Spa
Garage Entrance
Old House Towers
Main Entrance

PROCEEDINGS

The proceedings will be published in CD-ROM and hard-bound volume format. One copy will be given to each full conference registrant. Additional copies may be purchased at the registration desk for $119.

POLICIES

Badge Policy
Conference badges must be worn for admission to technical sessions, the exhibition and all conference events. Advance registrants must check-in at the TMS registration desk to obtain their conference badges.

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TMS strongly supports the Federal Americans with Disabilities Act (ADA) which prohibits discrimination against, and promotes public accessibility for, those with disabilities. In support of and incompliance with this act, we ask attendees requiring specific equipment or services to contact an individual at the registration desk.

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TMS is committed to environmental responsibility as we fulfill our mission to promote global science and engineering by going green at our headquarters, conferences and through membership communication.

Please join us in our effort by using the recycling bins that will be available for programs and badge holders in the registration area.

Be materials-minded. *Join* TMS *in reducing, reusing and recycling.*

The Eldorado Hotel is situated just off the historic Santa Fe Plaza and within walking distance of the heart of the city and its collection of shops, restaurants and cultural venues.

THE GREENER ELDORADO

Here are some ways the Eldorado Hotel is being environmentally conscious:

- Compact fluorescent lighting in guest rooms and offices
- Eighty percent of internal forms are paperless
- Recycling of aluminum, tin, plastic, foil, glass, office paper, cardboard, newspaper & magazines
- Reduction of bottled water
- No Styrofoam or #6 plastic
- No pre-set water at food & beverage functions
- Untouched food donated to the Eldorado Hotel & Spa employee dining room
- Motion sensors in restrooms

AIRPORT TRANSPORTATION

Sandia Shuttle Express is the preferred airport transportation provider. The one-way rate is $25. For more information or to make a reservation, please call 888-775-5696 or visit http://www.sandiashuttle.com.

Note: Please allow approximately 1 to 1 ½ hour(s) for travel times.

For private luxury limousine transportation, please contact Santa Fe Destinations at 505-995-4502 to make arrangements.

ABOUT SANTA FE

With a population of 70,000 primarily Hispanic, Anglo and Native American people, Santa Fe, which means Holy Faith in Spanish, is New Mexico's fourth largest city. Situated at 7,000 feet in the foothills of the southern Rocky Mountains, it is the highest and oldest capital in the United States.

Santa Fe has long been a center for arts and culture, which makes it a world-class tourist destination, drawing more than 1 million visitors each year. In recent years, the city has also earned a reputation with food lovers. Whether you have a craving for basic New Mexican food, creative Southwestern cuisine, or authentic Italian, French, Asian and other world cuisines, the city offers more than 200 choices.

For more information about Santa Fe, visit the Santa Fe Convention & Visitors Bureau web site at http://www.santafe.org/.

AT-A-GLANCE

All technical sessions will be held in the Anasazi Ballroom of the El Dorado Hotel

Monday, September 21, 2009

Tuesday, September 22, 2009

Wednesday, September 23, 2009

Posters

Keynote Session

Monday AM — Room: Anasazi Ballroom
September 21, 2009 — Location: El Dorado Hotel

8:20 AM Introductory Comments

8:30 AM Keynote
Metals Technology to Enable Future Energy Systems: *Cynthia Powell*[1]; [1]Office of Research and Development, National Energy Technology Laboratory, US Department of Energy

A growing realization that the environmental impact of energy production must be reduced on a global scale, combined with an increased desire in this country to reduce dependence on foreign energy sources, is driving significant change in the way the United States will derive and produce power in the future. While renewable energy resources will continue to grow in importance, environmentally responsible fossil energy production will be necessary to provide a bridge to the next energy revolution. This drive to increase efficiencies and reduce environmental impact in fossil-based electricity production will lead to increased steam temperatures and pressures and increasingly aggressive operating environments. The result will be an increase in the utilization of specialty iron- and nickel-base alloys for both boilers and steam turbines. The push to access domestically-available, unconventional sources of energy, such as ultra-deep oil and methane hydrates, will require utilization of higher strength, corrosion-resistant alloys for both

VAR Process I

Monday AM — Room: Anasazi Ballroom
September 21, 2009 — Location: El Dorado Hotel

Session Chairs: Rodney Williamson, Remelting Technologies Consulting; Peter Lee, Imperial College London

9:00 AM
Numerical Simulation of the Thermal Behaviour of the Primary Material in Remelting Processes: Applications to VAR and EBM and Experimental Validation: Jean-Pierre Bellot[1]; Parham Zabeti[1]; Hafid El Mir[1]; Julien Jourdan[1]; Pierre Chapelle[1]; *Alain Jardy*[1]; [1]Institut Jean Lamour

The behaviour of the primary material (VAR consumable electrode, a bar or ingot for EB or plasma technologies) during melting has not been intensively investigated yet. However, the surface temperature activates the volatilization mechanism and plays an important role on material refining and losses of alloying elements. Our research team has been involved for many years in the modelling of remelting processes. A detailed numerical simulation must include the melting stage, in order to correlate the final product quality to actual operating conditions without needing the melt rate as input data. Therefore a mathematical model of the thermal behaviour of the primary material during melting was developed. Using the operating parameters as model inputs, it makes it possible to predict the melt rate and the evolution of the melting area. Model results are successfully compared to melt rate measurements, both in an industrial VAR and a laboratory EBM furnace.

9:25 AM
Calibration of a Simulation Model for VAR with Respect to the Influence of Helium Cooling: *Jan Terhaar*[1]; Martina Maurischat[1]; Nikolaus Blaes[1]; Dieter Bokelmann[1]; Kanchan Kelkar[2]; [1]Saarschmiede GmbH Freiformschmiede; [2]Innovative Research, Inc.

In order to obtain reasonable and reliable results in the simulation of remelting processes a wide variety of input parameters has to be specified. As a starting point for further investigations a set of parameters has to be defined as a reference frame where good agreement between the calculation results and real process performance is evident. In this study, the VAR process of alloy 718 was analysed by the means of transient numerical simulation based on the process data of several experimental batches with pressure-controlled helium cooling. The trial ingots were analysed in terms of resulting pool depth and shape, whereas the logged process data was evaluated with respect to the correlation of helium flow and pressure. The measured pool profiles were used to adjust the simulation model regarding the boundary condition which describes the heat withdrawal from the ingot surface due to the presence of helium.

9:50 AM
A Unified 3D Model of the VAR Process: Valdis Bojarevics[1]; *Koulis Pericleous*[1]; Georgy Djambazov[1]; Mark Ward[2]; [1]University of Greenwich; [2]University of Birmingham

A 3D time-dependent CFD model of the VAR process has been developed to solve the coupled field equations for fluid flow, heat transfer and electromagnetic field, for both the electrode and the ingot. Though VAR is nominally 2D and axisymmetric, time varying external magnetic fields have been observed [1]. These disturbances denote the presence of a time-dependent magnetic field component attributed to an off-axis precession of the mean arc position. Two important questions arise from this behaviour: (1) what causes the arc to behave so, (2) how does the arc movement affect the melt pool? The research answers these questions starting with (2), where a prescribed off-axis rotation of the arc alters flow behaviour and mushy zone response; (1) involves both the pool and the melting electrode. The instantaneous electrode tip shape and pool deformation are computed to produce a map of gap distance, used to correlate with arc motion.

10:15 AM Break

10:45 AM
Behaviour of Hard-α Inclusions in the Liquid Pool of a VAR Titanium Ingot: *Ghassan Ghazal*[1]; Alain Jardy[1]; Pierre Chapelle[1]; Yvon Millet[2]; [1]Institut Jean Lamour; [2]TIMET Savoie

A numerical study was undertaken, aimed at simulating the motion and dissolution of a hard-α defect falling from the electrode tip into the melt pool during vacuum arc remelting. The dissolution of the inclusion is governed by nitrogen diffusion from the defect towards the surrounding molten metal. A model describing this phenomenon predicts the particle size evolution during its residence in the pool. Its trajectory is tracked using a lagrangian model. The influence of turbulence is accounted for by modifying the drag coefficient. Both models are coupled and implemented into SOLAR, a CFD code simulating the ingot melting. Results show that inclusion removal is difficult with a single melt since the growth of a β phase layer leads to an initial increase in the defect size. The inclusion behaviour is highly dependent on the pool hydrodynamics (i.e. stirring sequence) and the inclusion characteristics.

11:10 AM
Multiscale Modelling of the Onset of Freckle Formation during Vacuum Arc Remelting: *Lang Yuan*[1]; Georgi Djambazov[2]; Koulis Pericleous[2]; Peter Lee[1]; [1]Imperial College London; [2]University of Greenwich

A multiscale model was developed to simulate the onset of thermosolutal convection in the interdendritic region, which allows direct simulation of the onset of freckle channel formation. On the macroscale, a 3D multi-physics model was used to study complex physical phenomena, including liquid metal flow with turbulence, heat transfer, and magnetohydrodynamics in VAR. The results showed that unsteady fluid flow in the liquid pool causes significant thermal perturbation at the solidification front. On the microscale, by coupling with the macromodel, dendritic growth controlled by solute diffusion was simulated. The natural convection due to solute partitioning was then studied by solving Navier-Stokes equations in the mushy zone. The convection may cause the formation of fluid flow channel crossing dendrites and led to the formation of freckle channels. Under different VAR operation conditions, the onset of convection was investigated and the possibility of freckle formation was analysed by using the multiscale model.

11:35 AM
Effect of Different Control Strategies on Segregation Development in Vacuum Arc Remelting: *Dmytro Zagrebelnyy*[1]; Matthew Krane[2]; [1]Purdue University; Currently at Republic Special Metals Inc.; [2]Purdue University

VAR process control has evolved from fixing arc current to a predetermined profile, to controlling melt rate or total power into the liquid pool. The goal of this work is to compare the existing control strategies with the respect to ingot macrosegregation, which is a function of flow driven by electromagnetic and buoyancy forces during ingot solidification. We examine the transient flow patterns, liquid sump profiles, and the macrosegregation during the VAR of Ti-10-2-3. The process is controlled in turn by the three strategies, where the histories of the controlled quantities are predetermined. The response of the remelting electrode and the consequent ingot solidification behavior and flow patterns are predicted. The segregation patterns with no melting anomalies are used as a reference case, and the three cases are repeated in the presence of electrode cracks. Levels and distributions of segregation are compared and recommendations are made for picking control techniques.

12:00 PM
An Analysis of the Use of Magnetic Source Tomography to Measure the Spatial Distribution of Electric Current during Vacuum Arc Remelting: Bindu Nair[1]; *Mark Ward*[1]; [1]University of Birmingham

Magnetic Source Tomography is explored to analyze the distribution of electric current during Vacuum Arc Remelting (VAR). The goal is to use sensors outside the process to deduce the behaviour within. VAR systems having non-axisymmetric distributions of arc current were modelled using a commercial finite element electromagnetic code (Opera 3d), and a database was created from the resulting patterns of magnetic flux predicted to occur outside the crucible. A reconstruction algorithm was developed using constrained nonlinear optimization to estimate the arc current distribution within the process from the magnetic field data outside. The capabilities of this algorithm were studied, and it was found that given sufficiently low noise in the measurement data it was possible to accurately deduce important features of the spatial distribution of the arc current. Results from both numerical simulations and industrial measurements will be presented and discussed.

VAR Process II

Monday PM — Room: Anasazi Ballroom
September 21, 2009 — Location: El Dorado Hotel

Session Chairs: Alain Jardy, Institut Jean Lamour; Joseph Beaman, University of Texas at Austin

2:00 PM
New Methods of VAR Process Control: Technical Challenges: *Rod Williamson*[1]; [1]Remelting Technologies Consulting

Modern vacuum arc remelting (VAR) control systems use feedback to adjust current so that a target electrode melt rate is achieved. Two methods of control have been proposed to replace simple melt rate control: pool power control and pool depth control. These methods focus on controlling what is happening in the ingot instead of the electrode and both have been successfully demonstrated on laboratory scale VAR furnaces. Optimization of these methods necessitates characterizing process boundaries not important to controlling electrode melt rate. Both require knowing how arc energy is partitioned between the crucible wall and ingot pool surfaces in the arc gap and annulus, and pool depth control requires characterizing heat extraction through the ingot-crucible boundary. The technical challenges of implementing these new methods of VAR control as well as the requirements they place on process characterization and modeling are explored. Additionally, potential improvements in ingot quality are discussed.

2:25 PM
A New Optical Emission Monitor for Vacuum Arc Remelting: *Robert Aikin*[1]; Rodney Williamson[2]; [1]Los Alamos National Laboratory; [2]Remelting Technologies Consulting

This work describes a new method to optically examine the location and behavior of the arc during vacuum arc remelting. The approach uses an array of photo diodes to view the melt pool though the annulus between the crucible and electrode to see the bright light emitted from the arc. Pinholes in front of the diodes limit the detector field of view and allow the individual detectors to gather light from separate and distinct regions of the annulus. This provides a means of locating the average position of the arc and determining if it is symmetric, rotating, or attached to the crucible wall. For the initial trials, data was simultaneously obtained from 4 photo diodes 90 degrees apart at a rate of 10kHz. This was fast enough to observe drip shorts in the voltage and optical signals. Drip shorts, glow, and off center melting have all been observed.

2:50 PM
Characterizing Arc Motion and Distribution during Vacuum Arc Remelting: *Rigel Woodside*[1]; Paul King[1]; [1]National Energy Technology Laboratory

Previous studies have successfully correlated arc distributions in a vacuum remelting (VAR) furnace with the formation of defects during melting, with diffuse arc conditions being the benchmark for high quality ingots. This paper reports on work performed at the National Energy Technology Laboratory directed at determining real time arc distributions. The utilized methodology is based on furnace geometry specific forms of the Biot-Savart Law, which relates internal electric currents to externally measured magnetic fields. The developed measurement system is used to investigate arc behavior during titanium and nickel super-alloy melts. Results are compared to previous experiments investigating VAR arc behavior, as well as theoretical metal vapor arc behavior. It is shown that a magnetostatic single arc model is not sufficient to determine the current distribution inside a VAR furnace at an instant, but it could be used as a tool to detect non-axisymmetric arc distributions during VAR operation.

3:15 PM
On the Origin of the White Spot Defect in Vacuum Arc Remelted Ingots: *Felix Shved*[1]; [1]Lasmet Company

The main currently known peculiarities of white spots are discussed and explained. A number of proofs are provided that the most probable mechanism of white spot formation includes splashing of molten metal on the side surface of an electrode. Subsequent fall to the liquid pool of spatters entraining slag from the pool surface leads to arising in the ingot randomly located metal impregnations accompanied by strings of nonmetallic inclusions. Depletion in niobium of white spot area may be explained by the process of isothermal solidification via atoms exchange between spatter residue and surrounding liquid in the deep layers of the pool. An attempt is made to explain the origin of the defects observed by a group of investigators in Alloy 718 ingot remelted at abnormally long arc gap. It is shown that exogenous defects in the case considered are rather not of white spot but of a crown type.

3:40 PM Break

Solidification

Monday PM — Room: Anasazi Ballroom
September 21, 2009 — Location: El Dorado Hotel

Session Chairs: Matthew Krane, Purdue University; Robert Aikin, Los Alamos National Laboratory

4:00 PM
Comparison between Temperature- and Enthalpy-Based Formulations for the Energy Transport Equation in Solidifying Multi-Component Systems: Valerio De Felice[1]; *Alain Jardy*[1]; Hervé Combeau[1]; [1]Institut Jean Lamour

The description of solidification in multi-component systems requires an accurate treatment of the coupling between the energy and solute transfer equations. In the literature, the energy equation is often derived using a temperature based formulation, where the main variables are the temperature T and the liquid fraction fl. In this paper, we present an alternative enthalpic formulation for the heat transfer equation and compare the temperature and enthalpy method in two cases: a simple one-dimensional diffusive problem, then a simulation of a VAR ingot casting. In the latter case, the formulations are implemented in the CFD code SOLAR. The good accuracy and high performance, in terms of rate of convergence, of the enthalpic formulation are evidenced. It is therefore suggested that this method represents a fast and accurate alternative to the classical temperature-based formulation for solving many solidification problems.

4:25 PM
Structure Refinement by a Liquid Metal Cooling Directional Solidification Process for Single Crystal Nickel-Base Superalloys: *Clinique Brundidge*[1]; Tresa Pollock[1]; Denar Van Drasek[1]; [1]University of Michigan

A second-generation single crystal nickel-base superalloy has been directionally solidified over a range of cooling rates in order to assess the benefits using a liquid metal-enhanced cooling casting process compared to a conventional radiation cooling process for turbine airfoils. The effect of cooling rates during solidification on structure refinement and porosity size and distribution has been investigated using liquid metal cooling (LMC). Castings were solidified at a rate of 3.4 mm/min using conventional radiation cooling and at rates between 8.5 and 21.2 mm/min using liquid-metal cooling. The LMC process exhibited higher gradients at all rates in comparison to conventional cooling, which resulted in a refined microstructure in respect to primary ($\lambda 1$) and secondary ($\lambda 2$) dendrite arm spacings. The maximum solidification shrinkage pore size was reduced by approximately 70% with LMC. The influence of cooling rates on defect formation and fatigue properties will be discussed.

4:50 PM

Heat Extraction and Dendritic Growth in the Liquid Metal Cooling (LMC) Directional Solidification Process: *Jonathan Miller*[1]; Tresa Pollock[2]; [1]Air Force Research Laboratory/RXLM; [2]University of Michigan

The liquid metal cooling (LMC) process for growth of superalloy single crystals provides enhanced heat extraction, higher cooling rates and refinement of dendritic structure. However, under some solidification conditions there may be substantial lateral growth of dendrites, normal to the withdrawal direction. The conditions under which lateral dendritic growth occurs during solidification of alloy CM486 have been studied experimentally and with the use of solidification modeling. Solidification experiments have been conducted in LMC furnace that utilizes liquid tin as the cooling medium and a floating ceramic baffle. The tendency for lateral dendritic growth in the LMC process and conventional Bridgman process has been studied with a fixed casting configuration. Correlations between dendritic structure, heat flux and thermal gradients in the axial vs. radial directions will be presented. The location of the solidification front relative to the floating ceramic baffle has an important influence on the development of the dendritic structure.

5:15 PM

High Thermal Gradient Directional Solidification with Liquid Metal Cooling and Its Application in the Processing of Nickel-Based Superalloys: *Lin Liu*[1]; [1]Northwestern Polytechnical University

During directional solidification, thermal gradients in front of the liquid-solid interface (GL) are important in defining the subsequent cooling rate and the solidification microstructure. An elevated GL is frequently demanded, especially in the production of single-crystal superalloys and most metallic materials. In this study, the heat transfer during directional solidification by Bridgman-type directional solidification has been analyzed and a relationship has been established that reflects the effect of alloy properties, process parameters and equipment characteristics on thermal gradients. Based on this relationship, some methods for obtaining high thermal gradients have been developed. By using zone-intensified overheating and liquid-metal cooling, high thermal gradients of up to 800 K/cm were achieved. Application of these methods in the processing of single crystal superalloys indicated that high thermal gradient directional solidification produced more uniform microstructures and optimized mechanical properties.

NOTES

Steel Processing

Tuesday AM Room: Anasazi Ballroom
September 22, 2009 Location: El Dorado Hotel

Session Chairs: Peter Lee, Imperial College London; Jean-Pierre Bellot, Institut Jean Lamour

8:30 AM
Manganese and Phosphorous Distribution Equilibrium between Converter Slags Saturated with 2CaO·SiO2 and MgO and Low Manganese Steel: *Zhaoping Chen*[1]; [1]Baoshan Iron and Steel Co., Ltd.

The equilibrium experiments for manganese and phosphorus distribution between CaO-SiO2-FetO-MgOsat.-MnO-P2O5 converter slags saturated with 2CaO·SiO2 and low manganese steel were carried out at 1850~1923K. The results indicated that manganese distribution ratios do not change obviously with the decrease of slag basicity, and their distribution ratios increased with increasing FetO content in the slags. The phosphorus distribution ratios increased with the increase of slag basicity, and their distribution ratios increased with increasing FetO content at first, then decreased with increasing FetO content. The maximum manganese distribution ratio is 183.1 with the FetO content of 32.5 mass% and the slag basicity of 4.2 at 1873K, and the corresponding contents of manganese, phosphorus and oxygen in steel are 0.011mass%, 0.0012 mass% and 0.051 mass%, respectively. The manganese and phosphorus distribution ratios decreased with increasing temperature. There is a linear relationship between the distribution ratios and temperature in the present work.

8:55 AM
Mathematical Modeling of Two Phase Flow in a RH Degasser: *Roberto Tavares*[1]; Carlos Carneiro[1]; Rafael Reis[1]; [1]Federal University of Minas Gerais

The RH process is a refining process used in the production of interstitial free steels. In this process, the circulation of liquid steel between the vacuum chamber and the ladle has a significant effect on the decarburization and degassing rates and on the productivity of the equipment. In the present work, a mathematical model for two-phase flow in a RH degasser has been developed Different models for turbulence and for the interphase drag and non-drag forces have been considered. An Eulerian-Eulerian approach has been adopted. A model for bubble coalescence has also been considered. The predictions of melt circulation rates were close to the experimental results, but none of the models could exactly reproduce the variation of the melt circulation rate with the gas flow rate. These results indicate that some adjustments are still required to improve the quality of the predictions of the mathematical model.

9:20 AM
Simulation of Non-Metallic Inclusions Formation during Liquid Steel Reoxidizing: *Alexandr Alexeenko*[1]; Elena Baybekova[1]; [1]Lasmet Co.

Processes of inclusions formation during steel reoxidizing were investigated by computer simulation and SEM analysis. The thermodynamic-based model of interaction between oxide inclusions and liquid metal in the line of equilibrium state and program for computation of inclusions transformation are developed. For various steels trajectories of change of inclusions composition from initial Fe_xO phase formed during reoxidation to final inclusions oxide phases were computed. Those finals phases are: heterogeneous inclusions (grains of spinals |$MnO{\cdot}Al_2O_3$,$FeO{\cdot}Al_2O_3$|, phases based on $MnO–SiO_2–Al_2O_3$ system, and Al_2O_3 cover) in LCAK-steel with Si content 0.01%; hard inclusions based on Al_2O_3–$MnO–SiO_2$ system in LCAK-steel with Si content 0.2%, manganese silicates in medium carbon Si-killed steel. Computer simulation of inclusion transformation in LCAK-steel showed that Si significantly increases a time of transformation from initial liquid phase Fe_xO to hard phases. It explains the well-known fact that LCAK-steels with Si > 0.1% has better castability than low silicon ones.

9:45 AM
Modelling Solidification and Slag Infiltration during Continuous Casting of Slabs: *Pavel Ramirez Lopez*[1]; Peter Lee[1]; Kenneth Mills[1]; [1]Imperial College London

A numerical model to predict the effect of changes in casting speed, mould flux composition and pouring temperature during continuous casting of steel slabs is presented. The model calculates the flow dynamics of molten steel and slag within the mould including the infiltration of the slag into the shell-mould gap, which provides lubrication and thermal insulation within the mould. The coupling of fluid dynamics, heat transfer and solidification allows for the first time, the visualisation and prediction of typical defects such as the oscillation marks formed in the meniscus region. A sensitivity study has been carried out to explore the influence of various casting conditions and defines optimal settings on the process; this provides a valuable tool for both understanding and improving the casting practice.

10:10 AM Break

10:40 AM

The Study of the Macrosegregation in Heavy Steel Ingots: *Baoguang Sang*[1]; Dongrong Liu[1]; Xiuhong Kang[1]; Dianzhong Li[1]; [1]Institute of Metal Research, Chinese Academy of Sciences

A small ingot was deliberately designed with the aid of numerical simulation to generate all kinds of typical segregation, which can be used as experimental carrier to investigate the formation mechanism and the suppression measure of macrosegregation in heavy steel ingots. Macrosegregation in Fe-0.45wt%C alloy solidifying with equiaxed morphology is numerically simulated and a weak-coupling numerical procedure is designed to solve conservation equations. A melting model for solid particles is developed and simulations are conducted to study the effect of the solid particles addition on the macrosegregation distribution in the ingot. Numerical simulation results show that the macrosegregation in the ingot were dramatically reduced by addition of solid particles and the produced ingot has only slight segregation by the practical ingot sulphur print test and metallographic analysis. Thus, this method can be applied to a heavy ingot to control the macrosegregation.

ESR Process I

Tuesday AM Room: Anasazi Ballroom
September 22, 2009 Location: El Dorado Hotel

Session Chairs: Stewart Ballantyne, ATI Allvac; Rodney Williamson, Remelting Technologies Consulting

11:05 AM
Bounds on Model Parameters for Computational Analysis of the ESR Process: *Ashish Patel*[1]; Michael Gierula[1]; [1]Carpenter Technology Corporation

In recent years, there is renewed interest in the area of mathematical modeling of the ESR process. The underlying formulation of the problem has not changed significantly since the 70's. Almost all the recent work is based on adaptation of commercial CFD codes for the numerical solution of the problem. As with any model, there are key input parameters that significantly alter the predications. These include processing data, physical properties of both the slag and metal, and other numerical parameters. In this paper the expected ranges for these parameters will be discussed by analyzing ESR melting data, analytical modeling, and direct measurements. Once the bounds are established, results of a sensitivity analysis will be presented. This study would be useful for industrial application for such tools to develop robust melt practices. In addition, it would also highlight the limitations of our current understanding of input parameters for the ESR process.

11:30 AM
A Detailed Examination of Remelt Ingot Structures: *Alec Mitchell*[1]; [1]University of British Columbia

Several models have been proposed for the analysis of the solidification conditions in remelted ingots. The results of these models have generally been tested by comparing their predictions of the liquidus position to the "pool profile" found experimentally in remelt ingots. Since the solidification process is governed by the temperature gradients in the liquid + solid region, and not by the simple position of the liquidus isotherm, such a test is inconclusive. In this work we present the results of tests of a CFD model of two remelt ingots, one VAR and one ESR, of alloy IN718, made from the same master vacuum induction heat. The VAR ingot was made under conditions intended to provoke a solidification transition from columnar-dendritic to equaxial in the ingot centre; the ESR ingot was made so as to produce a columnar-dendritic structure throughout. The same

Tue. AM

solidification conditions as those predicted by the model were used in laboratory directional solidification tests on the same alloy to provide comparison structures. We find that the model is able to predict the ingot structure with good accuracy, including the transition between columnar-dendritic and equiax. In view of this finding, we propose that this or similar models may be used to predict not only the steady-state structures in such ingots but also may be used to analyse the results of structural instability and the possible occurrence of defects.

11:55 AM
Couple Modeling of Electromagnetic, Fluid Flow and Heat Transfer in Slag Bath during Current-Conductive Mould ESR process: Fubin Liu[1]; *Zhouhua Jiang*[1]; Ximin Zang[1]; Xin Geng[1]; [1]Northeastern University

A mathematical model for describing the interaction of multiple physical fields in slag bath during current-conductive mould ESR process was developed, based on assumption of three-dimensional axisymmetrical geometry and quasi-steady state. The commercial software ANSYS was applied to calculate the electromagnetic field, magnetic driven fluid flow, buoyancy-driven flow and heat transfer. Moreover, the model has been verified against the temperature measurements obtained during remelting GCr15 steel with a slag of 50~60%CaF2, 10~20%CaO, 10~20%Al2O3, =10%SiO2,=10%MgO in a 600 mm diameter current-conductive mould. There was a good agreement between the calculated results and the measured results. Further, comparison of the calculated results during current-conductive mould ESR process with that during conventional ESR process indicated that current density distribution, velocity patterns and temperature profiles are obvious distinctness. The ability of removal of non-metallic inclusions in current-conductive mould ESR process is not lower, even higher than the traditional ESR process.

ESR Process II

Tuesday PM — Room: Anasazi Ballroom
September 22, 2009 — Location: El Dorado Hotel

Session Chairs: Stewart Ballantyne, ATI Allvac; Ashish Patel, Carpenter Technology Corporation

2:00 PM
Estimation of Electroslag Remelting Process with an Unscented Kalman Filter: *Joseph Beaman*[1]; Seokyoung Ahn[2]; [1]University of Texas at Austin; [2]University of Texas-Pan American

High quality ESR ingots require that electrode melt rate and immersion depth be controlled during the process. This can be difficult when process conditions are such that the temperature distribution in the electrode is not at steady state due to start up, hot top, or disturbances during the melt. To address these transient melting situations, a new method of ESR estimation has been developed that incorporates Monte Carlo based state estimation with a reduced order nonlinear model. This estimation technique is more accurate than standard Kalman filter techniques for nonlinear processes such as ESR. Unfortunately, implementation of Monte Carlo estimation often requires a large amount of processing time, which can preclude using the technique in real time. In this paper we discuss a technique that uses a relatively small amount of processing time, but still captures many of the benefits of the Monte Carlo estimation, the Unscented Kalman Filter.

2:25 PM
Numerical and Experimental Investigations on the ESR Process of the Hot Work Tool Steel W300: *Abdellah Kharicha*[1]; Wolfgang Schützenhöfer[2]; Andreas Ludwig[1]; Robert Tanzer[2]; [1]University of Leoben; [2]Böhler Edelstahl GmbH Kapfenberg

In the present paper a numerical model based on the Euler-Euler multiphase approach is developed to account for the interaction between the steel droplets and the slag phase in the slag region of an ESR process. For a given electric intensity, melting rate and droplet size, the model predicts the hydrodynamic, the electric current distribution, as well as the radial mass and energy droplet flux entering the liquid pool. Solidification of the ingot is modeled with the Enthalpy-porosity method. The results given by the model are analyzed and compared with experimental data. For this the hot work steel W300 (H11) was chosen and different parameters such as melting rate and the slag height were varied. The numerical models were validated by the experiments and a very detailed understanding of the process was reached. This simulation tool will be used for the optimization of the process and product quality.

2:50 PM
Thermodynamic and Kinetic Simulation and Experimental Results Homogenizing IN718: *Paul Jablonski*[1]; Christopher Cowen[1]; [1]US Department of Energy

Many cast articles are subjected to a homogenization heat treatment in order to improve their hot working characteristics if wrought processed or in-service performance if used as a casting. Traditionally, the homogenization heat treatment is based upon past practice of related alloys or trial and error laboratory experiments. If the chemical inhomogeneity profile is known apriori, kinetic modeling software such as DICTRA (Diffusion Controlled TRAnsformations) can be used to model the homogenization kinetics of an alloy. In this study, the Scheil module within the Thermo-Calc software was used to predict the as-cast segregation present within IN718. The segregation profiles were read into DICTRA to refine the homogenization heat treatment. It was found that a stepped heat treatment profile was required to fully optimize the process. The thermodynamic and kinetic modeling of the computationally predicted heat treatment and microstructure, and subsequent experimental verification on a real casting of IN718, are presented.

3:15 PM
Thermophysical Properties of ESR Electrofluxes (Part 1: Density): *Semiramis Akbari*[1]; Jan Reitz[1]; Bernd Friedrich[1]; [1]RWTH Aachen

Electroslag remelting (ESR) currently undergoes a renaissance in the refining of steels and non-ferrous alloys, with a large number of new furnaces coming into op-eration these days and continuous improvement efforts on existing ESR operations due to ever increasing requirements on material quality and homogeneity. Process optimisation is nowadays often based on numerical simulation of the process which depends on accurate knowledge on properties of the liquid phases modelled. For the commonly applied ESR Electrofluxes in the system CaF2-CaO-Al2O3, the density, surface tension, viscosity and electrical conductivity are presently investigated. This publication is dedicated to the measurement of density as a function of temperature and CaF2 content, based on the Archimedes method. Measurements are supported by FactSageTM calculations and DTA measurements for determination of heat capacities, enthalpy of melting, solidus and liquidus temperatures. The accuracy of both measurements and calculations are carefully discussed with respect to their practical relevance.

3:40 PM Break

ESR Process III

Tuesday PM — Room: Anasazi Ballroom
September 22, 2009 — Location: El Dorado Hotel

Session Chairs: Alec Mitchell, University of British Columbia; Mark Ward, University of Birmingham

4:00 PM
On Nitrogen Pick-up during Pressure-ESR of Austenitic Steels: *Ashish Patel*[1]; J. Reitz[2]; J. H. Magee[1]; R. H. Smith[1]; G. Maurer[1]; B. Friedrich[2]; [1]Carpenter Technology Corporation; [2]IME Process Metallurgy and Metal Recycling, RWTH Aachen University

High nitrogen stainless steels produced by pressure melting processes offer increased strength, and superior corrosion resistance. Pressure ESR with the feeding of nitrogen bearing additives during the remelting process, has emerged as the most robust process for their production. In this study, a laboratory scale pressure ESR furnace was used to examine the effect of furnace pressure and addition of different additives to the slag on nitrogen distribution in a Fe-Cr-Mn-N alloy system. Experimental parameters were obtained by modeling this alloy system using commercially available software. Small ingots were cast, sectioned, characterized and composition was analyzed. The influence of P-ESR processing parameters especially on the nitrogen variation on the ingot's horizontal and vertical axis of various alloys in the investigated system will be presented in this paper.

4:25 PM

Electroslag Remelting of Steels with Inoculation: *Mrinal Chatterjee*[1]; P. Sarkar[1]; [1]MIDHANI

Inoculation of high strength steel 15CDV6 with Ti, Nb or Zr during electroslag remelting (ESR)resulted in considerable improvements in homogeneity and refinement of microstructural feature. These improvements were reflected in enhancement of ductility and toughness by 30 to 40% in the remelted steel in the cast as well as wrought conditions. The enchanced properties achieved due to ESR and inoculation were sacrificed by suitable modification in chemistry of the parent steel, to achieve significant increase in strength to 1550 Mpa coupled with toughness of 85 MPa√m after remelting. This possibility of trade off between strength and toughness is seen as an important contribution of ESR to designing of steels to suit specific needs. The results generated in laboratory have been validated on industrial scale melts. The paper highlights structure and properties of inoculated and remelted high strength steels.

4:50 PM

New Plant Concepts for the Production of Large Size ESR Ingots: *Harald Holzgruber*[1]; Alexander Scheriau[1]; Barbara Rinnerhofer[1]; [1]Inteco Special Melting Technologies

Inteco is executing the engineering of three ESR furnaces which can produce ingots up to 250 tons. The large size ingots are produced in short collar mold or in static mold meltstations. In both cases, electrode change technology is used. Additionally, smaller static mold meltstations are installed to increase the capacity. Plant concepts, dimensions as well as electrode and ingot configurations are discussed, with a focus on the following aspects: The choice of the type of power supply and its correct dimensioning are discussed. The influence of the high current line design on the plant's resistance and reactance is shown. In short collar mold melt stations, a slag breaking device and heat shields are installed. For the remelting of segregation prone alloys, the CCM® concept is applied, which allows remelting at low melt rates by heating the slag bath through conductive elements in the mold.

5:15 PM

Modeling of the ESR Ingot Enlargement: *Lev Medovar*[1]; [1]E.O.Paton Electric Welding Institute

Well controlled solidification at ESR cannot guarantee acceptable level of ingot quality for segregation sensitive alloys, especially in case of needs of ingots more than 1000mm diameter and higher. Many attempts were made to overcome nature of solidification by the way of big ingots manufacturing from the several smaller by the various technology of enlargement such as electroslag welding, MHKW and others. Overview of such methods is presented. Recently it was proposed to adapt technology of electroslag surfacing by means of liquid metal (known as ESS LM) for low segregation forging ingots manufacturing. For that goal detailed results of computer simulation of the process are presented. Possible ways of process industrialization are discussed.

NOTES

Process Optimization and Novel Techniques

Wednesday AM
September 23, 2009

Room: Anasazi Ballroom
Location: El Dorado Hotel

Session Chairs: Rodney Williamson, Remelting Technologies Consulting; Alain Jardy, Institut Jean Lamour

8:30 AM

Levitated Liquid Droplets in AC and DC Magnetic Field: *Valdis Bojarevics*[1]; Stuart Easter[1]; Koulis Pericleous[1]; [1]University of Greenwich

Numerical simulation is a method of gaining insight into applications of liquid metal processing and investigating new technologies. Knowing the values of the physical properties of liquid metals is vital for these numerical simulations. Electromagnetic levitation of liquid metal droplets can be used to measure the properties of highly reactive liquid materials. Numerical model has been developed to solve the transient electromagnetics, fluid flow and thermodynamic equations, which describe these measurement processes. The model incorporates free surface deformation to accurately model the oscillations that result from the interaction between the temperature dependent surface tension, turbulent momentum transport, electromagnetic and gravity forces. The model is adapted to incorporate a periodic laser heating at the top of the droplet, which have been used to measure the thermal conductivity of the material by calculating the phase lag between the heating and the temperature response at the bottom of the droplet.

8:55 AM

Freckling Tendencies of Ni-Base Superalloys: *Koji Kajikawa*[1]; Takeshi Sato[1]; Hitohisa Yamada[1]; [1]The Japan Steel Works, Ltd.

In order to reduce CO2 emissions from fusel power plants, advanced ultra super critical (A-USC) steam turbine development was started in Europe in the 1990s, followed by United States and Japan in the 2000s. Candidate materials for A-USC are Ni-base superalloys because 700-760C is beyond maximum service temperature of heat resistant ferrite steels. Ni-base superalloys have superior high temperature properties, however, the alloys are well known as freckle prone material. One of the keys to the success of A-USC development is the availability of large size ingots for turbine shaft materials. There is few study of large size ingot productivity of Ni-base superalloys. In this study, some of A-USC candidate alloys were tested. Freckling tendencies of those A-USC candidate alloys are assessed using horizontal directional solidification apparatus. The experiment revealed freckling tendency of A-USC candidate alloys.

9:20 AM

Modeling of Macro-Segregation in a Permanent Mold Casting: *Laurentiu Nastac*[1]; Ashish Patel[2]; Gern Maurer[2]; [1]Concurrent Technologies Corporation; [2]Carpenter Technology Corporation

Minimizing macro-segregation during static casting of segregation prone alloys has always been a challenge. Over the years, alloy manufacturers have optimized the processing techniques for these alloys by balancing the total heat input of a casting and the rate of heat extraction from the casting surface. In this study, a generic framework for studying macro-segregation in various casting processes was developed using a commercial computational fluid dynamics (CFD) code by solving for the temperature, flow and solute balance in multi-component alloy systems. Experiments were designed to measure solidification parameters using micro-probe compositional analysis. Thermal boundary conditions were determined by first measuring the mold temperature in a laboratory scale mold, and then using an analytical model to infer the flux leaving the mold. The model predictions were validated against experimental measurements. The effect of processing parameters like super-heat, mold taper, mold type, and mold diameter on macro-segregation will be presented.

9:45 AM

Thermoelectromagnetic Convection - An Alternative Stirring Technique in Metallurgy: *Andreas Cramer*[1]; Xiugang Zhang[1]; Gunter Gerbeth[1]; [1]Forschungszentrum Dresden-Rossendorf

Thermoelectromagnetic convection in an electrically conducting cubic container was studied experimentally. Two opposing side walls were cooled respectively heated to produce a uniform temperature gradient. Inhomogeneous magnetic field distributions were achieved with a small permanent magnet located above the melt layer. Ultrasonic Doppler velocimetry measurements demonstrated that even a moderate temperature gradient may drive a distinct convection. Two different flow regimes were investigated. When the magnet was positioned in the vicinity of a isothermal wall with its direction of magnetization parallel to the temperature gradient, a single vortex spreading the whole container developed while the flow might be assessed as relatively stable. Moving the magnet to the center led to a modified distribution of the magnetic field, which altered the flow structure. The convective pattern changed to four vortices and the velocity fluctuations were intensified. Numerical results obtained for the Lorentz force and the rotor thereof support the experimental findings.

10:10 AM Break

10:30 AM

The Use of Smooth Particle Hydrodynamics to Model Dross Formation during Crucible Tipping of Aluminum Melts: *John Taylor*[1]; Mahesh Prakash[2]; Gerald Pereira[2]; Patrick Rohan[3]; [1]CAST CRC, University of Queensland; [2]CAST CRC, CSIRO Mathematical and Information Sciences; [3]CAST CRC, CSIRO Materials Science and Engineering

Liquid aluminum is readily oxidised during melt handling, resulting in the formation of dross (a mix of oxide and trapped metal) that must be skimmed off prior to casting. In a typical primary smelter, the net melt loss is ~1% of total production (a large financial impost and CO_2 footprint), with ~50% estimated to occur during furnace filling. Dross reduction is typically addressed in casthouses by best-guess engineering approaches; however, computational modelling techniques may be used to explore the effects of process design and conditions, thus leading to new strategies for dross minimisation. This paper describes the use of Smoothed Particle Hydrodynamics to simulate the amount of oxide generated during molten metal transfer from a tilting crucible furnace into a sow, using an experimentally-determined oxidation model. The predicted oxide levels are compared with the experimental results from the crucible transfers.

10:55 AM

New Measurement Protocol for Modulated Calorimetry Using Electromagnetic Levitation: *Jacqueline Etay*[1]; Pascal Schetelat[1]; [1]Centre National de la Recherche Scientifique (CNRS)

Modulation calorimetry is a indirect method to measure specific heat capacity and thermal conductivity. Joined to electromagnetic levitation, it allows measurements for highly reactive molten and undercooled alloys. The total joule power is taken as the system input when measured temperatures responses are taken as outputs. Then, currently, an analytical model is used to calculate the physical values. 2D-axisymetric simulations evidence electromagnetic stirring effects on the sample temperatures distribution. In order to separate this flow effect from the conduction effect, a new signal processing method, based on both system identification and total heating power modulated by a pseudo white noise, is proposed Typical thermal times are obtained directly from black box models. Indirect measurement of the sample properties is performed by stating the equality between those black box models and the currently used heat transfer model. We demonstrate the relevance of the proposed method on samples presenting large Biot number.

11:20 AM

Physical and Mathematical Model of Aluminium Refining Process in the URC – 7000 Reactor: *Mariola Saternus*[1]; Jan Botor[1]; [1]Silesian Technical University

In the metallurgical industry, especially in aluminium production, the barbotage method of refining process is very popular. Nowadays many batch reactors are replaced by the continuous reactors and at the same time they become more and more popular. The paper presents short characteristic of available continuous reactors with special emphasize put on the URC – 7000 reactor. The influence of the refining gas flow rate on the process of hydrogen removal from aluminium is presented taking into consideration the refining process of AlSi7Mg alloy. The mathematical model of this process is shown, particularly the equation needed for calculation of the final hydrogen concentration as a function of the equivalent bubble diameter. The physical model (water one) of this process is also presented, mainly schemes of gas dispersion in liquid metal, taking into account the fact that the refining gas flow rate is changing from 2 to 30 dm3/min.

Poster Session

Mon AM-Wed AM — Room: Anasazi Ballroom
September 21-23, 2009 — Location: El Dorado Hotel

Development of Flow Modifiers for the Mold to Reduce the Intermixing Length in Slab Casting: *Roberto Tavares*[1]; Renata Elias[1]; Fernando Torres[1]; Flávio Policarpo[1]; [1]Federal University of Minas Gerais

An intermixed slab is formed when different grades of steel are cast in sequence. Use of flow modifiers and reduction of the steel level in the tundish during grade transition to decrease the intermixing length have a limited effect. Beyond a certain point, the length of the intermixed slab is mainly determined by the mixing that occurs inside the mold. To further reduce the intermixing length, it is necessary to change the flow pattern inside the mold. In the present paper, the use of flow modifiers in the mold was proposed and investigated. The grade transition experiments were conducted using fully integrated and automated physical models of a tundish and a mold (strand) of a two-strand continuous slab caster. It was determined that flow modifiers consisting of two boards with special shape can lead to reductions of up to 30 % in the intermixing length.

Investigation on Solidification Quality of Industrial-Scale ESR Ingot: Yanwu Dong[1]; *Zhouhua Jiang*[1]; Zhengbang Li[2]; [1]Northeastern University; [2]Central Iron and Steel Research Institute

An experiment had been carried out at an industrial-scale electroslag remelting (ESR) furnace for manufacturing Cr5 ingots of 950mm diameter. The purpose was to find out the solidification quality of large ingot. Liquid pool was marked by sulphur printing of the ingot axial section. The depth and shape of liquid pool was coincident with the calculated one by the model established previously. Local solidification time and secondary interdendritic spacing had been calculated, which was used to analyze the segregation phenomena of the ingot. Most carbides were M7C3 in ingot, a small quantity of MC type carbide was found, too. The dimensions and content of carbide precipitation due to the element segregation increased with the increasing of the secondary interdendritic spacing (or local solidification time) from the surface to centre. The distribution of element was much more uniform from the surface to centre than conventional casting ingot.

Kinetic Model of Hot Metal Dephosphorization in a Torpedo Car: *Zhaoping Chen*[1]; [1]Baoshan Iron and Steel Co., Ltd.

The behavior of physical chemistry of flux powders injected into hot metal in a torpedo car was studied. Based on the thermodynamic and kinetic theory, the kinetic model of desiliconization, dephosphorization of hot metal was developed to predict the rate of desiliconization and dephosphorization in a torpedo car. Some parameters used in these models were optimized by statistical method according to practical plant data. The combination of theoretical deriving and statistical optimizing makes the models can predict the concentration change with time for silicon, phosphorus in a good accuracy. The results of model calculation for the final concentration of silicon and phosphorus in pretreatment processes are in good agreement with the plant data.

New Approaches for Recycling of Aluminum Scraps: *Jirang Cui*[1]; Hans Roven[1]; [1]Norwegian University of Science and Technology

Characterization of aluminum scrap oriented to remelting processing and solid state recycling processing was carried out by using a variety of technologies, such as TG/DTA-MS, ICP/AES and FESEM. The results show that ferrous scrap, magnesium and zinc diecastings as well as plastics and fabric are common contaminants in shredded aluminum scraps. Organic coating of scraps results in hazardous gas emissions when the scrap is processed by decoating and/or remelting processing. A quite recently developed technique of Severe Plastic Deformation - Equal Channel Angular Pressing of aluminum alloy scraps with high contents of iron and silicon were investigated at laboratory scale. Preliminary results show that ECAP could be an effective technique for particle and microstructure refinement in recycled materials.

Quick Determination of Total Fluoride in Electroslag Refining Fluxes: *Krzysztof Wroblewski*[1]; Jerry Fields[1]; James Fraley[1]; Rod Werner[1]; Stuart Rudoler[1]; [1]American Flux and Metal

Electroslag refining flux is a fused mixture of calcium fluoride, lime, magnesia, alumina, and other oxides used in metal refining to facilitate removal of impurities and prevention of oxide formation during production of high-quality alloys and superalloys. A method for a quick routine determination of fluoride content using potentiometry in the presence of an ion-exchanging resin has been described. Removal of calcium and other heavy metals from the sodium carbonate/borate fusate remedies the method developed by Yeager at al., and makes it usable not only to a wide variety of freshly fused fluxes but also slags and recycled flux materials. The method has been tested on several flux formulations and the results were as accurate and precise as obtained using conventional technology.

Physic-Chemical Model of Degassing and Simulation of Metal Foam Formation at Vacuum Treatment: Lyudmyla V. Kamkina[1]; *Ganna Stovpchenko*[1]; Yuri. N. Yakovlev[1]; Olexander G. Velichko[1]; [1]National Metallurgical Academy of Ukraine

The physic-chemical dynamic mathematical model of vacuum degassing process of steel was developed. The small-scale level of model describes the nucleation of carbon mono oxide (CO) bubbles, their growth due to diffusion of oxygen and carbon to the surface of CO bubble, reaction on surfaces and CO diffusion into the volume of bubble. The large-scale transfer includes the transfer of oxygen from the boundary of delivery (gas phase, slag, and streams of oxygen) into the melt, redistribution of oxygen and carbon and moving of dispersed phase (CO bubbles) in the volume of metal. Numerical experiments by developed model allow determining CO bubbles sizes and kinetics of the dissolved oxygen removing as well as metal foam formation and intensity of metal stirring by ladle height.

Precious Metal Recovery from the Used Auto Catalytic Converters: *Agnieszka Fornalczyk*[1]; Mariola Saternus[1]; [1]Silesian University of Technology

The paper presents characteristics of catalytic converters used in cars and the review of available technologies during recycling process. The possibility of removing platinum group metals (PGM) from the used catalytic converters applying pyrometallurgical methods was also investigated. Metals such as copper, cadmium and magnesium were used in the presented research. In the first test the catalytic converters carrier was broken-up and located in the basket with the copper. During the melting process in high temperature (1000 – 1500°C) the carrier was melted with copper and PGM were separated from the ceramic substrate. In the second test, cadmium and magnesium were used for the research. The magnesium/cadmium vapours were blown through the whole carrier located in the pit furnace. Analysis of PGM contents in the carrier before and after melting/blowing process was performed by means of atomic absorption spectroscopy. Obtained result were discussed.

PESR Processing of TiAl-Electrodes Made by Aluminothermic Reduction: *Bernd Friedrich*[1]; Jan Reitz[1]; Tobias Mionskowski[1]; Jan-Christoph Stoephasius[2]; [1]RWTH Aachen; [2]TARGUS Management Consulting AG

Titanium aluminides received high importance due to their corrosion resistance, low density and outstanding mechanical properties at elevated temperatures. The requirements for cost cutting led to various process alternatives for high performance γ-TiAl-X and aluminothermic reduction (ATR) of titanium oxide, actually under development in Germany, show high potential. Success-ful pilot-scale experiments have proofed the feasibility of this process (including co-reduction of alloying metals), yet leading to a material relatively rich in oxygen. As a refining step, liquid metal deoxidation by pressure electroslag-remelting (PESR) is under investigation to process these raw-TiAl-alloys. The influence on metal/slag equilibria during PESR of TiAl by feeding of Ca to a CaF2-based slag was modelled with focus on oxygen activity. Electrodes of different al-loy compositions were prepared by ATR of 190 kg primary reaction mixture and successfully refined via PESR. The obtained ingots were examined with regard to oxygen content, chemical homogeneity and occurrence of inclusions.

The Mechanical Properties and Corrosion Resistance of Cast and Wrought Hastelloy C Are Significantly Enhanced When the Unwanted Complex Carbides Are Removed through a Dissolution Process: *George Calboreanu*[1]; [1]A.R.W & Sons Inc.

Tensile strength, yield strength and elongation of Hastelloy CW-2M are 25%, 17% and 95% higher then the minimum requirement of ASTM A494 when the undesired complex carbides are removed through an additional dissolution process. The comapartive corrosion performance of Std. Hastelloy CW-2M and Improved Hastelloy CW-2M were tested in the following applications: 1) In 91-97% phosphoric acid at 257°F the Improved Hastelloy CW-2M had two corrosion pits on a 0.75 mm^2 while Std. Hastelloy CW-2M had 38 pits. 2) In 6% hydrochloric acid at 140°F the corrosion rate of Improved Hastelloy CW-2M was nil while the NACE doesn't recommend Hastelloy CW-2M in such application. 3) The corrosion rate of Improved Hastelloy CW-2M in 6% sodium Hypochlorite at 200°F is 0.14 MPY versus 46 MPY the NACE published corrosion rate. 4) In 75-90% sulfuric acid the corrosion rate of Improved Hastelloy CW-2M is 0.95 MPY versus 20 MPY the corrosion rate of Std. Hastelloy CW-2M. With the use of optical and electron microscopy the paper discusses all the above tests.

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Grid

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