2:50 PM
Maintaining Consistent Conditions over a Wide Range of Material Deposition Rates in Beam-Based Additive Manufacturing: *Jack Beuth*[1]; Shane Esola[1]; Raymond Walker[2]; [1]Carnegie Mellon University; [2]Keystone Synergistic Enterprises

Significant advances have been made in the development of laser and electron beam-based freeform fabrication processes using powder injection, powder bed or wire feed systems for material delivery. Electron beam-based deposition is currently receiving serious consideration for additive manufacturing and repair applications in the aerospace industry. To be successful, these processes must work over a wide range of material deposition rates to combine affordability (requiring high deposition rates) with the ability to precisely deposit fine geometries (requiring low deposition rates). The goal of this modeling research is to identify paths through processing space yielding consistent melt pool sizes independent of material deposition rate, ultimately yielding rules of thumb useable by processing engineers. Process variables to be controlled are beam power and translational speed.

3:15 PM
Effect of Process Parameters on Electron Beam Melted (EBM) Additively Manufactured Components in Ti-6Al-4V: *Micheal Blackmore*[1]; Sinan Al-Bermani[1]; Iain Todd[1]; [1]University of Sheffield

Additive layer manufacturing (ALM) in metallic materials has many potential applications and offers many advantages over conventional subtractive machining practices. However, ALM machines at present are yet to be fully utilised in a production environment due to lack of validation and process maturity. An Arcam S12 EBM machine has been used to deposit near net components in titanium 6Al-4V (grade 5) alloy operating directly from CAD data. The effects of changes in various process parameters such as beam speed, power, focus and scan strategy have been investigated and related to material integrity and as deposited surface finish.

3:40 PM Break

4:05 PM
Powder-Cored Tubular Wire Manufacturing for Electron Beam Freeform Fabrication: *Christine Hillier*[1]; Marcia Domack[2]; Robert Hafley[2]; Stephen Liu[1]; [1]Colorado School of Mines; [2]NASA Langley Research Center

Powder-cored tubular wires exhibit great flexibility in terms of final deposit composition when used in conjunction with a heat source, whether arc, laser or electron beam. By modifying the core composition, a wide range of chemical compositions can be easily produced. With known alloy recovery, powder-cored tubular wires can be used to produce deposits of custom chemical composition. In this work, the manufacturing process of titanium-based cored tubular wires is discussed. These tubular wires are manufactured via U-O bending of CP-Ti Grade 2 strip metal, with a core of Ti-Al-V powder. By adjusting the powder composition, the aluminum loss observed in wire-based electron beam processing can be mitigated. Using a button melting technique, custom powder compositions are being developed with enhanced Al and V chemistries to account for alloy losses, as well as sheath metal compositions.

4:30 PM
Structure-Property-Process Optimization in the Rapid-Layer Manufacturing of Ti-6Al-4V Components by Electron Beam Melting: *Sara Gaytan*[1]; Lawrence Murr[1]; Edwin Martinez[1]; Daniel Hernandez[1]; Stella Quinones[1]; Francisco Medina[1]; Ryan Wicker[1]; [1]University of Texas

Rapid prototype (RP) manufacturing using Ti-6Al-4V powder and electron beam melting (EBM) has presented the prospects of microstructure-property control within small volumes and linear dimensions of <1 mm. Utilizing optical and electron microscopy (SEM and TEM), it has been demonstrated that alpha (hcp) acicular platelet dimensions and dislocation substructures within these platelets, composing simple build geometries, can be varied with related variations in hardness, tensile strength, and elongation. These structure-property variations occur by thermal differences as a consequence of beam current, focus, and scan rate or scan sequencing. In addition, during layer building various defects can be created by beam tripping and related phenomena. These include spherical or irregular voids ranging from a few microns to tens of microns in diameter as well as porous zones of even larger dimensions which result from non-melting or local variations in liquid-phase sintering. Examples of these build-related defects will be described.

4:55 PM
Laser Surface Modification of 2024 Al Alloy to Enhance Thermal Conductivity: *Amit Bandyopadhyay*[1]; B. Vamsi Krishna[1]; Susmita Bose[1]; W. M. Keck[1]; [1]Washington State University

With rapid advances in microelectronics particularly in the areas of miniaturization with increased power and greater functionality, innovative heat-removal materials as well as techniques are needed for thermal management of active devices for next generation military and commercial applications. Different approaches have been used to make materials with properties suitable for thermal management applications, but not via surface modification. We have examined the feasibility of enhancing thermal conductivity of 2024 Al by depositing 80Cu-20Mo using a Laser Engineered Net Shaping (LENS\\153;). Coatings of 667 2.5 micron thickness were formed with metallurgically sound interface. Results showed an 87% increase in the thermal conductivity of 2024 Al alloy. The coating approach in combination with LENS\\153; process can also be used to deposit high TC materials in desired locations to reduce 'hot spots'. The presentation will discuss materials and manufacturing issues related to laser surface modification of 2024 Al alloy to enhance thermal conductivity.

5:20 PM
Spheroidisation and Oxide Disruption Phenomena in Direct Selective Laser Melting (SLM) of Pre-Alloyed Al-Mg and Al-Si Powders: *Eyitayo Olakanmi*[1]; Robert Cochrane[1]; Kenneth Dalgarno[2]; [1]University of Leeds; [2]University of Newcastle

Spheroidisation and oxide disruption phenomena in the direct laser melting of pre-alloyed Al-Mg and Al-Si powders had been explored. Spheroidisation is interpreted in terms of Raleigh's instability, Marangoni convection, laser absorptivity, heat conductivity, fluidity of the melt volume and the powder's oxide content. Balling occurred only in the single layer parts due to the lower thermal conductivity of the bed and possibly the difference in wettability of the powder bed and sintered layers. The existence of a high degree of thermal expansion mismatch between the oxide film and the parent metal and a uniform oxide layer thickness were found to favour the disruption of the oxide shell promoting inter-particulate melting across the layers. This was the case for Al-Si parts, whereas SLM of pure aluminium and pre-alloyed Al-Mg powders gave rise to high incidence of randomly distributed pores.

Materials Processing Fundamentals: Process Modeling

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2:00 PM
Solidification Stresses in Steel for Continuous Casting Conditions: *Matthew Rowan*[1]; Brian Thomas[1]; Robert Pierer[2]; Christian Bernhard[2]; [1]University of Illinois; [2]University of Leoben

Measuring stress development in solidifying steel is very difficult. The submerged split cell tensile (SSCT) test can measure force developed in a cylindrical shell of steel during solidification under controlled conditions identical to continuous casting. Determining the stress profile is difficult given the nonuniform temperature and strength across the shell. A computational model of thermal-mechanical behavior during solidification is applied to simulate the SSCT test. The 2-D axisymmetric elastic-viscoplastic finite-element model features different mechanical properties for delta-ferrite and austenite that vary with temperature and strain rate. The model successfully matched measurements of 1) temperature history; 2) shell thickness; 3) solidification force; and 4) failure location. The results show the effect of carbon content on critical failure strain, and stress profiles, which depend on the phase fraction history. The SSCT test and validated model together is a powerful analysis tool of hot tear crack formation and other phenomena in continuous casting.

2:15 PM
Numerical Simulation of Continuous Casting Process of Bloom by Finite Point Method: *Seyed Ahmad Jenabali Jahromi*[1]; Mostafa Alizadeh[1]; S. Behrouz Nasihatkon[1]; [1]Shiraz University

In this paper a meshless method called Finite Point Method (FPM) is developed to simulate the solidification process of continuously cast bloom steel in both primary and secondary cooling region. The method is based on the use of a weighted least-square interpolation procedure. A transverse slice of bloom as it moves with casting speed is considered as computational domain. The two dimensional heat transfer equation together with temperature dependent thermophysical properties is solved in the computational domain. The enthalpy method is used to calculate the latent heat. The present work is verified in the mold region by the comparison of the surface temperature simulated by FPM and finite volume method (FVM) and also comparison of solidified shell thickness simulated by FPM and measured on a breakout bloom. For secondary cooling region the validation is done by comparison of the surface temperature simulated by FPM, FVM and thermovision measurements.

2:30 PM
Numerical Simulation of Stress Field in a Wide Slab Mold of Peritectic Steel Continuous Casting: *Min Chen*[1]; Liang Zhao[1]; Yongkuan Yao[1]; [1]Northeastern University

A numerical simulation of the stress field of the solidified shell in the mold during continuous casting of peritectic steel slab was calculated with commercial software. The results showed that the maximal stress on wide face of the solidified shell was located at the corner and near middle of the slab, and it increased with increasing the width of slab. In addition, the stress was also influenced by operating parameters such as super heat degree, drawing speed and cooling intensity of the mold, and the maximal stress value and its position changed with these parameters. For the slab with section size of 3200mm×150mm, the proper drawing speed was around 1.2m/min, with cooling intensity of 5500L/min wile the super heating rate was 15°C to 25°C in order to prevent longitudinal crack happening during peritectic steel continuous casting.

2:45 PM
Modeling the Effects of Processing Variables in Simple Castings of Actinide Metal: *Paula Crawford*[1]; Deniece Korzekwa[1]; [1]Los Alamos National Lab

The application of modern computer modeling and simulation techniques to materials processing can aid in providing valuable insight into the effects of process variables and mold design variations on the final casting product. A computer model was developed to simulate the casting process using a multi-physics computational modeling package. The effects of mold design variations on the solidification rates and final product phase stability are evaluated through modeling. Additional sensitivity analysis of various processing variables provides an indication of the process controlling variables. Combining the results of the simulation with the experimental casting results should provide a better understanding of the effect of process variables on the casting of plutonium metal.

3:00 PM
Simulation of Microstructure Evolution during Solidification of Magnesium Alloys: *Hebi Yin*[1]; Sergio Felicelli[2]; [1]CAVS, Mississippi State University; [2]Department of Mechanical Engineering, Mississippi State University

A coupled cellular automaton(CA) - finite element(FE) model was developed to calculate the growth of dendrites during the solidification of cubic and hexagonal metals. The model solves the conservation equations of mass, energy and solutes in order to calculate the temperature field, solute concentration and the growth morphology of dendrites, including the grain structure and the dendritic microstructure. Validation of the model was performed by comparing the simulation results with experimental data from previously published works, showing qualitatively good agreement in the dendritic morphology. Application to magnesium alloy AZ91 illustrates the difficulty of modeling dendrite growth in hexagonal systems, observed as deviations in growth direction caused by mesh-induced anisotropy. The model was applied to the simulation of small specimens with single- and multiple- equiaxed grain growths and columnar grain growth in directional solidification. The influence of cooling rate and some kinetics parameters on the grain morphology are also discussed.

3:15 PM
Experimental and Numerical Modelling of the Flow Field in an Industrial Bronze Caster – Improving the Numerical Model: *Sven Eck*[1]; James Evans[2]; Abdellah Kharicha[1]; [1]University of Leoben; [2]University of California Berkeley

In previous work the influence of the casting speed on the flow field and the shape of the solidification front in an industrial 0.82x0.25x0.8m³ bronze caster had been investigated. Both numerical and experimental model represented 1:1 the real caster geometry. A comparison of the results of both numerical and experimental models for the flow during the casting process showed a good agreement in the qualitative velocity fields(flow direction and vortex formation). This work represents a parameter study of the numerical model with variations of the turbulence conditions at the inlet in order to clarify their influence on the flow field in the caster. In order to find the best boundary condition at the inlet, the numerical calculations for water have been compared with the measured flow fields in the water model. The new boundary conditions were then applied to the numerical model of the bronze casting process.

3:30 PM Break

3:45 PM
Advances on Multiscale Design of Deformation Processes for the Control of Material Properties: Nicholas Zabaras[1]; *Babak Kouchmeshky*[1]; [1]Cornell Univ

We will review advances on the development of a robust design methodology for achieving desired distribution of macro-scale properties in polycrystal plasticity problems during metal forming processes. The polycrystal is represented by an orientation distribution function using the Rodrigues parameterization. Using this continuum representation of texture the underlying texture is allowed to evolve during the process. An updated Lagrangian framework is used in modeling the finite deformation processes. A multi-scale sensitivity analysis is utilized for calculating the sensitivity of the macro-scale properties with respect to the perturbation in process parameters. The multi-scale sensitivity analysis is used in a gradient optimization framework for achieving the desired distribution of the macro-scale properties. The effectiveness of the methodology is shown through controlling properties such as ductility and hardness of the product in a metal forming process. Process conditions (e.g. forging velocity, die and performs) and initial texture are used as the design parameters.

4:00 PM
Simulation of the Filling of Moulds by the Method FEM/CV in Techniques RTM: Jamal Samir[1]; *Hattabi Mohamed*[1]; [1]ENSEM

In the course of this study, the simulation of the resin flow in the RTM process is developed by the control volume finite element method (CVFEM) coupled with the equation of the free surface location. This location is made by means of the so called "Volume of Fluid" methods or VOF. Thus, the position of the flow front, the time-lapse and the rate of the non saturated zone are calculated at every step. Our results will be compared with the experimental and analytical models in the literature. On the whole, our study is concerned with the simulation of the thermally insulated filling of moulds in RTM process while adopting the CVFEM and VOF method, taking into account the presence of obstacles, coupled with the thickness variation effect and the reinforcement coats.

4:15 PM
A Comparison of Gas and Low Pressure Carburization of 9310 and 8620 Steels - A Numerical Simulation Study: Gang Wang[1]; Mohammed Maniruzzaman[1]; *Richard Sisson*[1]; [1]Worcester Polytechnic Institute

A comparative study of gas carburization and low pressure carburization processes has been performed using CHTE's numerical simulation software – CarbTool. CarbTool is a 1-D carbon diffusion model developed based on the thermodynamics and kinetics of the carburization process. The model is capable of simulating the complex boost-diffuse processes used in the industry. The output of CarbTool is the carbon concentration distribution inside the part. Two steels- 9310 and 8620 are investigated in this study. The quenching process of carburized rods is simulated using DANTE/ABAQUS FEM software. Results are compared in terms of carbon profile, microstructures and residual stresses.

4:30 PM
A Diffusion Model for the Prediction of a-Case Depth during Heat Treatment of Ti-Alloys: Stephen Brown[1]; *Daniel Clark*[2]; Steven Tuppen[2]; [1]Swansea University; [2]Rolls-Royce Plc

A Fickian model of oxygen diffusion in alpha-beta titanium alloys has been developed. It is well known that the diffusion of oxygen into the surface of Ti-alloys gives rise to a potentially harmful outer layer of a-phase. The validated