FABTECH 2026 – AWS Professional Program

Las Vegas, Nevada

Conference Chairs: Thomas Lienert, T.J. Lienert Consulting, LLC; Andrew Iams, NIST; James Zuback, NIST; Derek Shaffer, Phoenix Laser Solutions; Ustun Duman, Duman Consulting, LLC

Plenary 1

Wednesday PM | October 21, 2026
S225 | Las Vegas Convention Center

Session Chair: Thomas Lienert, T.J. Lienert Consulting, LLC

1:20 PM Plenary

Advanced Welding, Materials Engineering and Manufacturing Technologies: *Volodymyr Kachynskyi*[1]; I Krivtsun[1]; V Nesterenkov[1]; O Romanenko[1]; I Klochkov[1]; [1]The E.O.Paton Electric Welding institute

E.O. Paton Electric Welding Institute, founded in 1934, is one of Ukraine's leading research institutions in welding, materials science, and advanced manufacturing technologies. The Institute develops innovative solutions for welding a broad range of materials and structures and conducts research in metallurgy, additive manufacturing (3D printing), construction technologies, and other high-tech areas. Its technologies are widely applied in transportation, aerospace, mechanical engineering, power generation, including nuclear energy, medicine, defense, and national security. PWI's main research areas include advanced welding and joining technologies, including electron-beam technologies and living tissue welding; welding in the space; underwater welding; pressure welding; magnetically impelled arc butt welding; automation of welding and manufacturing processes; structural strength, reliability, and service life of welded components; nanomaterials and nanotechnologies; surfacing, coating, and surface engineering; special electrometallurgy; mathematical modeling of welding processes; and non-destructive testing and technical diagnostics. Today, PWI operates as an integrated scientific and engineering complex that includes research laboratories, design and engineering divisions, and pilot production facilities manufacturing welding equipment, consumables, and electrometallurgical systems. The Institute employs approximately 1,000 highly qualified specialists, including 50 professors and 170 PhD holders, working across 35 research divisions. PWI maintains strong partnerships with leading industrial and academic organizations in Ukraine and internationally. Its partners include globally recognized companies such as Boeing, Plasser; Theurer, Progress Rail Services Corporation, and RW Equipment; Consulting LLC. With a strong commitment to international scientific collaboration, PWI actively participates in European and global research initiatives and has been involved in numerous projects funded by the European Commission, STCU, and DFG. The Institute is also a member of major international professional organizations, including the International Institute of Welding, European Welding Federation, and American Welding Society.

Session 1: Weldability and Welding Metallurgy

Wednesday PM | October 21, 2026
S224 | Las Vegas Convention Center

Session Chairs: Erin Barrick, SNL; Jonah Klemm-Toole, Colorado School of Mines

---

2:00 PM

Enhanced Laser Beam Welding of Dissimilar Metals Using Cold Sprayed Interlayers: *Leah Mills*[1]; Erin Barrick[1]; Austin Pisani[1]; [1]Sandia National Laboratories

Challenges in the joining of dissimilar metals and alloys by laser beam welding (LBW), including differences in thermo-mechanical properties and intermetallic embrittlement, motivate the development of novel strategies to fabricate robust welds. Metallic interlayers deposited by a solid-state cold spray technique prior to LBW provide an opportunity to explore more dissimilar material combinations. The current investigation evaluates joints between stainless steel alloy SS304L and aluminum alloy AA6061. A cold-sprayed interlayer of SS304L is deposited onto the AA6061 substrate prior to partial penetration LBW of the interlayer to a similar SS304L coupon. Three LBW schedules (continuous wave, pulsed, circular beam oscillation/wobble) are investigated, with three different laser powers per schedule. All welds containing the interlayer (as-sprayed condition) stayed adhered to their substrates during welding and are found to be hermetic ($5x10^{-9}$ ATM CC/s) using helium leak detection. The influence of post-deposition heat treatment on the cold spray interlayer is studied with respect to interlayer adhesion, porosity, strength and ductility. The weld region and interlayer interface are characterized using scanning electron microscopy (SEM), including energy-dispersive X-ray spectroscopy (EDS) and electron backscatter diffraction (EBSD). A spherical harmonic transform (SHT) method is used to re-index the EBSD datasets [ref: W. Lenthe et al, *Ultramicroscopy*, 207, 0304-3991 (2019)]. The mechanical behavior of the weld and constituent alloys is evaluated using microhardness and tensile testing.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. SAND#202621918A.

2:20 PM

Evaluation of Ductility Dip Cracking Susceptibility in Weldments of Additively Manufactured Cu-Ni Alloys: *Seth Hixson*[1]; Boian Alexandrov[1]; [1]Ohio State University

The objective of this work is to evaluate the susceptibility to ductility dip cracking (DDC) of additively manufactured (AM) CuNi 70-30. We will quantify DDC susceptibility of material made with laser powder bed fusion (LPBF) and wire arc directed energy deposition (WA-DED) processes and compare results to cast and wrought counterparts to evaluate the performance of AM materials. DDC is a warm cracking phenomenon that primarily occurs in highly restrained multipass welds of FCC alloys. Ductility loss is typically observed in areas that experience grain boundary sliding along migrated grain boundaries in the temperature range between 50% and 80% of a material's solidus temperature. Grain boundary sliding leads to void nucleations that under sufficient strains can become crack initiation sites. In welding and AM, strains are induced by uneven thermal expansion and contraction. DDC has been observed in FCC materials since the 1950's and while some research has been performed exploring DDC susceptibility within the Cu-alloy space, there is no work analyzing the DDC susceptibility of CuNi AM material. To characterize the DDC susceptibility, strain to fracture (STF) and fixed displacement thermal cycling (FDTC) tests will be completed utilizing the GleebleTM thermomechanical simulator. This presentation describes STF and FDTC procedures, quantifies and ranks the DDC susceptibility of the tested materials, and characterizes the DDC failure mechanism.

2:40 PM

Comparing the Hot Cracking Susceptibility of Additively Manufactured, Cast, and Wrought Cu-Ni 70-30: *Justin Nock*[1]; Boian Alexandrov[1]; Dennis Harwig[1]; [1]Ohio State University

Cast and wrought Cu-Ni 70-30 is widely used in marine applications. To improve schedule, reduce costs, and meet high-mix low-volume part demands in shipbuilding, metal additive manufacturing (AM) capabilities using wire arc directed energy deposition (WA-DED) and laser power bed fusion (L-PBF) are needed. The frequent use of welding in the Navy necessitates that material produced by any means is weldable and that any unique limitations or risks are well-understood. Hence, this program compares weldability of Cu-Ni 70-30 alloy AM material to that of its wrought and cast alternatives. Solidification cracking (SC) and liquation cracking (LC) tests were performed on cast, wrought, L-PBF, and WA-DED plates and rods. The Transvarestraint test (TVT) was used to characterize SC susceptibility, while the spot Varestraint test (SVT) and hot ductility test (HDT) were used to characterize LC susceptibility. The TVT and SVT use applied strains to determine the maximum crack distance (MCD) in either the fusion zone or heat affected zone, which are then correlated to the solidification cracking temperature range (SCTR) or the liquation cracking temperature range (LCTR). The total number of cracks (TNC), threshold strain for cracking (\949$_{c}$), and crack saturated strain (\949$_{s}$) are also determined. The HDT is performed in a Gleeble\8482 thermo-mechanical simulator to determine the nil ductility temperature (NDT), nil strength temperature (NST), and ductility recovery temperature (DRT). The LCTR is calculated by taking the difference between the NST and DRT.

3:00 PM Refreshments Break (S227)

3:20 PM

Influence of Copper Content on the Age Hardening Response and Weldability of Aluminum Alloys Derived from Recycled Scrap: Jamie Hamilton[1]; Paul Sanders[2]; J*onah Klemm-Toole*[1]; [1]Colorado School of Mines; [2]Michigan Technological University

Sustainable material production is becoming increasingly necessary to decrease energy consumption and reduce emissions. Aluminum production from ores accounts for 3% of global industrial emissions, therefore finding opportunities to increase scrap utilization can be beneficial. The twitch scrap stream consists of primarily wrought and automotive Al scrap which has been heavily recycled, accumulating several elemental additions like Si, Fe, Cu, and Mg which reduce the recyclability with each successive recycling step. There is opportunity to produce high-strength, weldable alloys from the twitch stream. However, one of the major challenges many high strength age-hardenable Al alloys is solidification cracking. In this talk, we show how tailoring Cu content in the twitch system through modeling and experiments can yield excellent solidification cracking resistance while optimizing the age hardening response. The solidification cracking resistance and aging response was determined for three different twitch-based compositions, one with 0.3 wt% Cu, 0.9 wt% Cu, and 2.2 wt% Cu, to demonstrate weldability and age hardening as a function of composition. Additionally, we will discuss the tensile behavior of each of these alloys as base materials to highlight the versatility of the twitch alloys. Finally, we will discuss how the twitch alloys compare to commercial weldable alloys like 4043 and 5356, and commercial age hardened alloys like 2024, 7075, and 6061. Overall, this work shows that alloy design, with sustainability as a boundary condition, can be implemented to produce useable compositions from the Al scrap stream.

3:40 PM

Weldability of Higher Grades of Reinforcing Steel: Preheat Requirements for ASTM A706 Grade 80 and Grade 100: *Jesse Porter*[1]; Stephen Manring[1]; Carolin Fink[1]; [1]Ohio State University

The use of higher strength reinforcing steel, specifically ASTM A706 Grade 80 and Grade 100, is growing in popularity across the structural and construction industries. The current edition of AWS D1.4:2018 does not include provisions for these higher grades, creating the need to validate or develop new minimum preheat temperature recommendations to avoid hydrogen-induced cracking during welding. The manufacturing processes used to achieve these higher strengths, whether through micro-alloying (MA) or quench- and- self-tempering (QST), increase hardenability and produce harder microstructures in the heat-affected zone, making these steels inherently more susceptible to cracking than the lower grades currently covered by the code. To address this, a series of self-restraint cold cracking tests were performed on ASTM A706 Grade 80 and Grade 100 bars in sizes #6, #11, and #14. Both MA and QST bar types were evaluated using shielded metal arc welding (SMAW) and flux cored arc welding (FCAW) with filler metals appropriate for each strength grade. Preheat temperatures were varied in 50°F increments and crack evaluation was conducted on polished weld cross-sections using light optical microscopy a minimum of 48 hours after welding.Results show that the current requirements in Table 7.2 are not sufficient to prevent cracking in the higher strength reinforcing steel, particularly for Grade 100 bars and larger bar diameters. The majority of cracks initiated at the weld root and propagated transgranularly through the coarse grain heat-affected zone (CGHAZ) of the bars. New minimum preheat temperatures required to preclude cracking were developed. Notably, while QST bars required higher preheat temperatures than MA bars for Grade 80, this relationship reversed for Grade 100, suggesting that the influence of bar type on hydrogen cracking susceptibility warrants further investigation. Based on these findings, new suggested minimum preheat values have been developed to inform the next revision of AWS D1.4.

4:00 PM

Novel Resistance Spot Welding Technology for Dissimilar Aluminum to Galvanized Steel Joints with Improved Mechanical Properties: R*akhi Bawa*[1]; Trey Soards[1]; Antonio Ramirez[1]; Jerry Gould[2]; Olga Eliseeva[2]; [1]Ohio State University; [2]Edison Welding Institute

Dissimilar joining via resistance spot welding (RSW) has been long sought after in the automotive industry to improve energy efficiency by optimizing bodyin-white vehicle designs. However, joining dissimilar alloy families such as the commonly used 6XXX series aluminum alloys and advanced high strength steels proves challenging with traditional RSW due to the formation of brittle Fe-Al intermetallic compounds (IMCs). The commonly used RSW technology in automotive manufacturing today is Medium Frequency-Direct Current (MFDC) power supplies, which convert three-phase AC power from the bus bar to a direct current pulse delivered at the tips. While efficiently automated and optimized for similar metal joining, the MFDC RSW process has a long cycle time (~500-1000 ms), which is detrimental to the growth of IMCs at dissimilar interfaces. As an alternative, a new technology for resistance spot welding has been developed which delivers a much shorter and higher current pulse to the sheets without the need for water-cooled electrodes. This Medium Frequency-Frequency Converter (MF-FC) technology uses a power supply designed to deliver a single DC pulse to the sheets with a pulse width of 5ms, drastically reducing the time at temperature experienced by the dissimilar interface; therefore, reducing diffusion and IMC growth. In this work, 6541-T4 Aluminum Alloy and Galvanized Dual Phase Steel with 600 Mpa UTS are joined using the MF-FC process. Parameter development is conducted with current range testing for 1 and 2 pulses with static mechanical tensile shear testing and cross tension testing evaluation methods. Normalized mechanical testing results show improvement over current MFDC RSW technology. Characterization via light optical microscopy reveals the nugget morphology, and characterization of the fracture surfaces and the phases forming at the interface via scanning electron microscopy provide insight into how these dissimilar materials interact during the short welding process.

4:20 PM

Weldability of Bridge Steel with Protective Zinc Coatings: Drawn Arc Stud Welding Performance on ASTM A709: *Jesse Porter*[1]; Carolin Fink[1]; [1]Ohio State University

The 2020 revision of AASHTO/AWS D1.5 introduced a provision allowing welding over protective coatings on structural bridge steel, which was subsequently removed in a later revision. The ability to weld over protective coatings is valuable, as temporary zinc coatings are commonly applied to protect structural steel during fabrication before the final protective coating system is applied. This study, conducted at The Ohio State University and sponsored by the Alaska Department of Transportation and Public Facilities, investigates the weldability of ASTM A709 Grade 50 steel across a range of surface conditions using drawn arc stud welding. Two uncoated reference conditions are examined: steel with mill scale removed and steel retaining its mill scale. Three zinc coating types are investigated: mist coat applied at two thickness levels, arc spray metallized at two thickness ranges, and hot-dip galvanized at a single nominal thickness range that exhibits considerable thickness variation across the plate. Existing AWS standards are adapted as a benchmark for evaluating weld quality through visual examination, macroetch testing, ultrasonic testing, and mechanical testing. Porosity from zinc volatilization and liquid metal embrittlement are recognized concerns when welding over zinc coatings. Technique modifications including arc blow control, current path optimization, and ferrule geometry selection are explored to allow zinc to be displaced from the weld interface prior to solidification.Completed testing on the uncoated conditions and mist coat demonstrate sound welds meeting all acceptance criteria. Thicker coating conditions present greater weld quality challenges, where overall coating thickness/variation is identified as a key factor contributing to reduced repeatability. Final results across all conditions will inform specific recommendations and limitations for drawn arc stud welding over zinc coatings, with findings intended for submission to the AWS Committee for consideration in future revisions to AASHTO/AWS D1.5.

4:40 PM

Investigation of Crack Initiation in Dissimilar Metal Welds: A Case Study of Branch Connections in High-Purity Oxygen Systems: *Min Hyun Cho*[1]; Bashar Fanous[1]; [1]Aramco

This study investigates the failure of a branch connection in an oxygen service line, specifically focusing on the dissimilar metal weld joint connecting a Monel 400 weldolet to an SS316L run pipe. The joint, fabricated using Gas Tungsten Arc Welding (GTAW) with Alloy 625 filler wire, was initially selected to ensure safety in oxygen environments by utilizing materials with high ignition temperatures and low reactivity. Although initial Dye Penetrant Testing (DPT) indicated acceptance with no visible defects, leakage was subsequently detected at the weld toe during pneumatic testing. Subsequent re-verification of the weld joints via DPT revealed multiple linear indications, necessitating a detailed failure analysis. To determine the root cause, a comprehensive laboratory examination was conducted, encompassing macroscopic inspection, microstructural analysis, chemical analysis, hardness testing, Scanning Electron Microscopy (SEM), and Energy Dispersive X-ray Spectroscopy (EDS). The analytical results identified the primary damage mechanism as liquation cracking. This cracking was localized within the Partially Melted Zone (PMZ) on the Monel 400 weldolet side of the dissimilar joint.This investigation further elaborates on the metallurgical conditions that contributed to this failure mode. It discusses potential causal factors, including the complex interaction between the base metals and the filler material during the welding process, which may have led to the formation of low-melting-point phases susceptible to liquation. Finally, the study recommends specific remedies to prevent recurrence, emphasizing strict control over welding parameters and heat input to mitigate the risk of PMZ liquation. These recommendations aim to enhance the integrity of dissimilar metal weld joints in critical oxygen service applications, ensuring long-term reliability and safety.

5:00 PM

The Role of Low-Silicon Welding Wires in Automotive Single-Pass & Multi-Pass Weld Metallurgy: *Raj Kumar Singh*[1]; [1]ESAB

Robotic MIG welding operations are under constant pressure to improve throughput while reducing post-weld labor and total cost per part. This presentation examines the performance advantages of low-silicon ER70S filler metals, with a focus on copper-coated/Non-Copper coated ER70S-9 GMAW filler wires engineered to minimize slag formation and silica islands. By optimizing wire chemistry, low-silicon wires significantly reduce silicon oxide residues that can interfere with downstream painting, coating, or galvanizing processes.Drawing on both laboratory data and real-world robotic welding applications, the session will compare lowsilicon ER70S wires to conventional ER70S products in terms of arc stability, bead appearance, cleanup time, and suitability for high-volume, single-pass & multi-pass welds. Attendees will gain practical insight into how low-silicon consumables help automotive, heavy equipment, and fabricated metal manufacturers shorten cycle times, reduce rework, and improve surface quality before finishing operations—ultimately delivering measurable productivity and cost benefits.

Session 2: Graduate Student Research Symposium

Wednesday PM | October 21, 2026
S225 | Las Vegas Convention Center

Session Chairs: Olivia Russell, Colorado School of Mines; Giacomo Melaragno, Ohio State University

---

2:00 PM

A Comprehensive Study of the Factors Influencing Impact Toughness Variability in Fe-10Ni GMA Multipass Groove Welds: *Salman Matan*[1]; Boian Alexandrov[1]; [1]Ohio State University

Fe-10Ni is a high-strength, high-toughness steel developed for naval structural applications. U.S. Navy researchers developed a matching solid wire consumable based on the Fe-10Ni alloy system that demonstrated acceptable mechanical properties for both gas tungsten arc welding (GTAW) and gas metal arc welding (GMAW). However, GTA weld metal exhibits significantly higher impact toughness than GMA weld metal. This work aims to understand the mechanisms controlling impact toughness variability in Fe-10Ni groove welds produced with GMAW. Multipass GMAW of Fe-10Ni steel produces complex thermal histories that generate significant microstructural heterogeneity throughout the weld metal, resulting in local variations in impact toughness. The as-welded condition was first tested and characterized as a baseline against which reheated regions were compared. The Gleeble 3800 thermo-mechanical simulator was used to replicate heat-affected zone (HAZ) conditions observed in multipass welds, and Charpy V-notch (CVN) toughness was evaluated at -51°C and -17.8°C. Advanced characterization techniques, including electron backscatter diffraction (EBSD), transmission electron microscopy (TEM), scanning transmission electron microscopy (STEM), transmission Kikuchi diffraction (TKD), and X-ray diffraction (XRD), were then employed to link martensitic microstructure evolution and dislocation density to the observed toughness behavior across all reheated conditions.The as-welded condition exhibited the lowest impact toughness and greatest extent of cleavage fracture, followed by the coarse-grain heat-affected zone (CGHAZ), both attributed to coarse martensitic microstructures, dense dislocation tangles, and transformation twins. Multiple reheating cycles produced the greatest toughness improvements. Intercritical reheating refined the martensitic structure through partial reaustenitization while the remaining microstructure underwent tempering, and subcritical reheats above the minimum tempering temperature promoted dislocation rearrangement into lower-energy substructures, eliminated transformation twins, and facilitated the formation of nanoscale retained-austenite films. These results establish the microstructural mechanisms governing impact toughness variability in Fe-10Ni GMAW welds, providing a scientific foundation for developing improved welding procedures and more robust naval structural components.

2:20 PM

A New Framework to Predict Isotherm Location in High-Frequency Electric Resistance Welding: *Daniele Calista*[1]; Greg Lehnhoff[2]; Naveen Ramesh[3]; Kopparthi Ravikiran[3]; Patricio Mendez[1]; [1]University of Alberta; [2]Orion Steel; [3]InterPro Steel and Pipe

This presentation introduces a new theoretical framework for heat transfer in high-frequency electric resistance welding (HFW). Specifically, it focuses on the practical application of a proposed engineering expression to predict the location of critical isotherms, such as the onset of melting along the weld interface. HFW relies on intense volumetric heating from an AC source that decays exponentially with depth, interacting dynamically with a continuously moving substrate. To capture this complex thermal behavior, a novel dimensionless framework was developed. Two new governing dimensionless groups are introduced: the Scott number, capturing the ratio of thermal penetration depth to the depth of AC-Joule heating, and the Haga number, representing the balance between heat generation and thermal conduction. Together, these numbers delineate two asymptotic regimes of the process: one dominated by AC-Joule heating, and the other by thermal conduction. By mathematically blending these regimes, a unified, non-empirical expression was derived to predict isotherm locations across all operating conditions. The practical use of this expression was validated using V-samples extracted from interrupted mill-stop welds. Current state-of-the-art process design relies heavily on costly empirical mill trials or computationally stiff numerical simulations. The newfound ability to rapidly predict thermal boundaries using a single, physics-based closed-form expression provides a robust, low-cost tool for optimizing input power, mill speed, and AC frequency for any mill geometry.

2:40 PM

Weldability and Precipitate Evolution of GRCop42: *Joe Kleindienst*[1]; Jonah Klemm-Toole[1]; [1]Colorado School Of Mines

GRCop42 is a Cu-Cr-Nb alloy important to the aerospace industry due to its combination of high thermal conductivity and high temperature strength. The production of GRCop42 has been limited to powder-based additive manufacturing (AM) and powder metallurgy techniques due to the high cooling rates required to produce small Cr2Nb precipitates and the lack of wire feedstock availability. Wire based directed energy deposition (DED) production of GRCop42 would greatly increase the possible deposition rates, build volumes, and joining applications in aerospace production. In this study, wire GRCop42 feedstock has been used to make DED builds through three processes: laser wire DED, gas metal arc DED (GMA-DED), and electron beam DED (EB-DED). The solidification morphology and length scale of the Cr2Nb precipitates has been studied and the hardness of the builds has been compared. Additionally, the effect of EB remelts of increasing heat input on the size of Cr2Nb precipitates and hardness of the fusion zone has been measured as well as modeled. The results of this work are expected to provide an understanding of how Cr2Nb precipitates behave in GRCop42 processed with various fusion based deposition methods and streamline process selection and parameter development of wire-based AM production of GRCop42.

3:00 PM Refreshments Break (S227)

3:20 PM

Analyzing Cracking Phenomena During Wire Arc Additive Manufacturing of Fe-35Cr-45Ni Based Filler Metals: *Giacomo Melaragno*[1]; Seth Hixson[1]; Boian Alexandrov[1]; [1]Ohio State University

Pipe components in olefin furnaces produced from cast heat-resistant Fe-Ni-Cr alloys have experienced premature failures during high temperature service by creep fracture, thermal fatigue, and/or thermal shock. These failure mechanisms are exacerbated by oxidation from furnace flue gases on their outer diameter (OD) surface and carburization from hydrocarbon-rich process fluids on their inner diameter surface (ID). To improve the service life of these components, a functionally graded material (FGM) based on a creep-resistant Fe-35Cr-45Ni (35/45) alloy with Si and Al additions has been proposed. Based on this concept, three filler metal compositions were selected/designed to fabricate an FGM by wire arc additive manufacturing (WAAM). The present study analyzes the cracking phenomena observed during WAAM of each individual filler metal, which are labeled 35/45, 35/45-Si, and 35/45-Al. WAAM builds from each filler metal were cross-sectioned and characterized by scanning electron microscopy (WAAM) to analyze cracking mechanisms. Across the builds, solidification, liquation, and reheat cracks were identified. Additionally, a unique 'remelt' cracking mechanism was identified that was associated with the complex evolution of Cr-rich carbides in areas of overlapping weld beads. The analysis in this work provided an understanding of the WAAM printability of each filler metal, which can inform further process parameter and filler metal composition development for the production of an FGM prototype.

3:40 PM

Evaluation of Hydrogen Embrittlement Susceptibility in Flat X65 Pipeline Steel Weld Specimens: *Fernando Romero Consuegra*[1]; Boian Alexandrov[1]; [1]Ohio State University

The objective of this study is to evaluate the effect of weld metal and heat affected zone (HAZ) microstructures on the hydrogen embrittlement (HE) susceptibility in API X65 pipeline steel weldments. We utilized the delayed hydrogen cracking test (DHCT), per standard AMPP TM21453, by applying a constant tensile load below the yield strength to unnotched specimens with in-situ electrolytic hydrogen charging. Time-to-failure (TTF) and sustained mechanical energy (SME) of test specimens are considered for ranking the HE susceptibility of different X65 multipass weld combinations. SME quantifies the energy associated with the HE nucleation and propagation mechanisms. Previous DHCT work showed the effect of natural stress concentration from weld cap and root pass geometries on the HE susceptibility of X65 welds. Test results were compared to published data from slow strain rate testing (SSRT) and fracture toughness tests (FTT) of pipeline steel welds under high-pressure hydrogen environments. It was demonstrated that, compared to DHCT, SSRT required up to two orders of magnitude higher SME to generate HE failure. This was attributed to enhanced localized plastic strain, which is required to achieve critical hydrogen concentration for crack nucleation and propagation in the necking region. The SME in DHCT and the provisional fracture resistance (JQH) in literature FTT had overlapping ranges, potentially due to similarities in the crack propagation mechanisms.The current scope of work evaluates the effect of microstructure and hardness on the HE in X65 steel welds. Flat gauge section specimens, extracted from a range of GMAW and SAW weldments with varying weld metal and HAZ strength, were subjected to DHCT. The test results are utilized in a larger scale study, aiming to establish correlation between DHCT and FTT results, and develop a database of HE susceptibility in pipeline steel welds.

4:00 PM

Effects of Welding Process, Filler Metal, and PWHT on the Corrosion Behavior of 347H Stainless Steel in Molten Nitrate Salt: *Olivia Russell*[1]; Xiaolei Guo[1]; Timothy Pickle[1]; Prashant Saini[2]; Julian Osorio[2]; Zhenzhen Yu[2]; [1]Colorado School of Mines; [2]National Lab of the Rockies

Although 347H austenitic stainless steel provides good corrosion resistance in high-temperature molten salts, high susceptibility to stress relaxation cracking (SRC) has been reported in the 347H welds made with matching filler in molten salt storage tanks. Alternative filler metals and post-weld heat treatments (PWHT) have been evaluated as mitigation solutions for SRC. However, the subsequent effect of these strategies on weld region corrosion kinetics remains unclear. This study evaluates the localized corrosion rates and reaction layer of alternative 347H weldments across variations in welding process, filler metal chemistry, and PWHT condition, comparing results against an unwelded 347H base metal and matching filler controls. Isothermal immersion testing was performed at 565\176C in a binary molten nitrate salt (60% $NaNO_3$ – 40% KNO_3) for up to 2000 hours to establish mass-loss kinetics and track oxide layer evolution. Gravimetric analysis quantified degradation rates, while high-resolution scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) characterized the thickness, composition, and stability of the reaction layers across the fusion zone interfaces. Results show that while filler metal selection and welding process parameters alter localized corrosion resistance, the application of PWHT exerts the overriding influence on reaction layer kinetics and oxide stability, especially during early exposure (up to 500 hours). For instance, a maximum corrosion rate of 64.3 \181m/yr was observed in the 347 matching filler weld after PWHT at 250 hours of exposure, in comparison to 2.6 \181m/yr for the as-welded matching filler control for shielded metal arc welding (SMAW). In comparison, as-welded 16.8.2 filler SMAW exhibited a corrosion rate of 10.6 \181m/yr. Overall, the weldment variations exhibited higher corrosion rates compared to both the 347H base metal and matching filler controls. However, these performance differences tend to diminish as exposure time exceeds 1000 hours.

4:20 PM

An Inverse Modeling Framework for Laser Powder Bed Fusion Additive Manufacturing: *Satyaki Sinha*[1]; Tuhin Mukherjee[1]; [1]Iowa State University

Identifying suitable process parameters in laser powder bed fusion (LPBF) remains a major challenge. Many different combinations of process conditions can produce parts with similar geometry but highly variable microstructures, residual stresses, and mechanical properties. Existing methods for process parameter selection rely on trial-and-error experiments or models, making it difficult to efficiently determine the process conditions required to achieve targeted product attributes. This study presents a physics-based inverse modeling framework that directly predicts feasible LPBF process conditions (inputs) from desired product attributes (outputs). The framework integrates physics-based mechanistic modeling, neural networks, and genetic-algorithm-based inverse optimization within a closed-loop system. Mechanistic modeling helps generate physics-consistent information on melt-pool geometry and temperature distribution. Neural networks enable rapid prediction and the generation of large synthetic datasets trained on model data. The genetic algorithm efficiently explores multiple feasible combinations of process parameters, rather than converging on a single non-unique solution, resulting in a computationally efficient, stable, and physically interpretable inverse design framework. The developed framework accurately captures the relationships between process parameters and melt-pool behavior, showing strong agreement with experimental and predicted data. The developed inverse framework successfully identifies multiple physically consistent combinations of laser power, scan speed, and other process conditions required to achieve targeted melt pool geometry. The physics-informed mechanistic and GA–NN models accurately capture melt-pool behavior, temperature fields, and solidification characteristics across different LPBF conditions. By combining mechanistic modeling, machine learning, and inverse optimization, the framework provides a computationally efficient and physically interpretable approach for process optimization. Overall, this work establishes a scalable pathway for physics-guided, defect-aware, and application-driven inverse design in metal additive manufacturing.

4:40 PM

The Effect of Complex Pre-existing Carbide Populations on Continuous Cooling Transformations in the Heat-Affected Zone of an Ultrahigh-Strength Steel: *Nikolas Vega Michalak*[1]; Boian Alexandrov[1]; [1]Welding Engineering Program, Ohio State University

Medium-carbon Cr-Mo-V ultrahigh-strength steels (UHSS) can have complex carbide populations that affect the continuous cooling transformation (CCT) behavior across the heat-affected zone (HAZ) when welded or additively manufactured. This presents challenges when predicting as-welded or as-built UHSS component properties. The objective of this work is to examine the effect of complex pre-existing carbide populations on the CCT behavior of Gleeble-simulated coarse-grain HAZ (CGHAZ), fine-grain HAZ (FGHAZ), and intercritical HAZ (ICHAZ) regions. The on-cooling microstructural transformations were measured by dilatometry across a range of cooling times relevant to welding and wire-arc directed energy deposition (WA-DED). The varied dissolution and evolution of carbides from HAZ thermal cycling were characterized by transmission electron microscopy (TEM) techniques and transmission Kikuchi diffraction (TKD). The dissolution and evolution of carbides were related to the CCT behavior, microstructure, and hardness of each HAZ region. In the CGHAZ, the pre-existing carbides were completely dissolved, producing a homogeneous austenite with high hardenability that transformed to martensite. There was little variation in transformation temperature and hardness across the tested cooling times. In the FGHAZ, the pre-existing carbides partially dissolved and evolved with cooling time. Increased dissolution occurred at longer cooling times, enriching the austenite in substitutional alloying additions, depressing the transformation temperature from 416 °C to 351 °C at the longest cooling time. This formed mixed martensite-bainite microstructures in the FGHAZ. The ICHAZ showed little dissolution of the pre-existing carbides, transforming to bainite at higher temperatures with increasing cooling time due to the solute-lean austenite that formed during HAZ thermal cycling. These results show that the degree of dissolution of pre-existing carbide populations is related to HAZ peak temperature and cooling time. This significantly affects the on-cooling transformation, microstructure, and final mechanical properties across the HAZ in UHSS components.

5:00 PM

Experimentally Validated Three-Dimensional Quasi-Steady Thermal Modeling of GMAW on Thin Steel Plates: *Mehdi Mortazavi Yazdi*[1]; Daryush Aidun[1]; [1]Clarkson University

A three-dimensional quasi-steady heat transfer model for Gas Metal Arc Welding (GMAW) of thin steel plates is developed using a finite difference method in an arcfixed reference frame, in which the workpiece translates at the welding travel speed. The model incorporates temperature-dependent material properties including latent heat of fusion, a double-ellipsoid volumetric heat source, and nonlinear combined convection–radiation surface boundary conditions. The computational domain is truncated using an experimentally informed criterion.Butt weld experiments were conducted on thin steel plates instrumented with thermocouples at standardized distances from the weld centerline. The quasi-steady moving-frame equivalence is used to compare the predicted spatial temperature distribution directly against measured thermal cycles, and post-weld characterization of fusion zone geometry provides independent validation. The validated framework is used to quantify the influence of plate width on heat source parameter calibration and transferability across specimen geometries.

Session 3: Welding and AM Research Studies

Wednesday PM | October 21, 2026
S226 | Las Vegas Convention Center

Session Chairs: Ustun Duman, Duman Consulting, LLC; Cheryl Hawk, LANL

2:00 PM

Role of Shield Gas Flow in Laser Powder Blown Directed Energy Deposition through High-speed Schlieren Imaging: *Samantha Webster*[1]; Steven Mates[2]; Carelyn Campbell[2]; [1]Colorado School of Mines; [2]National Institute of Standards and Technology

Laser powder blown directed energy deposition (DED-LB) has become a major focus within metal additive manufacturing due to its 5-axis processing capability and propensity for functionally graded materials. While it is known that shield gas flow rate and powder flow rate play a critical role in deposition of material, it is not well understood how shield gas interacts with the melt pool. To better understand the role of shield gas in DED-LB, in-situ high-speed Schlieren imaging was incorporated into the System for AM Alloy Development (SAMAD) at NIST. Single tracks of IN625 were deposited at shield gas flow rates of 5 LPM, 10 LPM, and 15 LPM. Schlieren videography results reveal that the flow field is dominated by the particle-laden carrier-plus-shield gas jet directed at the deposition surface, creating an axisymmetric stagnation point flow with the melt pool at its center. Complicating this classic stagnation point flow is the presence of a counterflowing vapor jet emanating upwards from the melt pool. The schlieren results show that initial momentum of the vapor jet is significant, in some cases rising up to reach the tip of the nozzle. The vapor jet momentum appears to differ depending on the laser power, spot geometry and scan speed. More concentrated laser spots and slower scan speeds lead to a larger initial vapor jet. During deposition, the two counterflowing jets gives rise to a “vapor dome” which fluctuates in size as the nozzle moves across the deposition surface. The height and width of Schlieren activity is found to be minimal at a shield gas flow rate of 10 LPM, and approaches to a stability model are discussed.

2:20 PM

Multi-Objective Inverse Design for Welding Performance Metrics of Robotic GMAW: *Matt Freeman*[1]; Serdar Demir[1]; Ustun Duman[2]; Tuba Firincioglu[1]; [1]globalMOO; [2]Meta

This work is focused on robotic GMAW in industry with multi process parameters to multi welding metrics. 25 robotic GMAW process parameters were co-optimized against 17 competing objectives and constraints, reaching a deployable procedure in ~750 forward evaluations. Production welding is never single objective; competing quality, productivity, and integrity targets must be balanced. Single-objective optimization improves one metric while degrading the rest. This produces procedures that can't be efficiently deployed in production. Instead of a single-objective approach, we applied a customized multi-objective multi-agent system (MOMAS), an inverse solver that resolves all 17 objectives simultaneously. The 25 decision variables include welding current, arc voltage, travel speed, wire feed rate, shielding-gas selection, and number of passes; and the 17 metrics span penetration depth, heat-affected-zone width, tensile strength, throughput, energy per part, angular distortion, and peak residual stress. The forward model is a physics-based digital twin grounded in six published welding-science correlations (Gunaraj-Murugan, Easterling, Lancaster, AWS D1.1, Okerblom, Masubuchi). The solver learns this model once, stores a reusable inverse representation, then inverse solves for new objectives and constraints. Joint optimization yields a Pareto front, including three regimes along a count-versus-magnitude trade-off frontier. The deepest-margin regime improves 10 of 17 with the largest gains: heat-affected-zone width falls 70%, throughput rises 22%, and predicted angular distortion and peak residual stress fall 96% and 58%. Two higher-coverage regimes each improve 11 of 17 with smaller margins; only the balanced one also lowers defect rate, suiting structural welds under radiographic inspection. Six single-objective baselines improve just 6.8 of 17 on average, with the worst worsening 13 of 17.The model reproduced 20 of 23 published reference points within accepted ranges (87%). Simultaneous improvement saturates at 11 of 17; the improved set is identical at 750 and 20,000 evaluations (~25× more), indicating a physics-constrained frontier.

2:40 PM

Role of Powder Feedstock Composition on the Microstructure Variability in Laser Powder Bed Fusion Alloy 625: *James Zuback*[1]; Saadi Habib[1]; Andrew Iams[1]; Fan Zhang[1]; Jordan Weaver[1]; Lyle Levine[1]; [1]National Institute of Standards and Technology

Repeatability and reproducibility are major hurdles in developing standards for metal-based additive manufacturing (AM). The AM community has dedicated considerable time and effort to understand the complex influence of process variables, spatially non-uniform thermal cycles, and machine-to-machine variations on the properties and performance of printed parts; however, the contribution from feedstock chemistry is often overlooked. The 2025 Additive Manufacturing Benchmark Test series addressed this gap through the AMB2025-01 set of benchmarks, which studied the impact of powder feedstock variations on microstructure evolution. Three lots of Alloy 625 powders with distinct variations in chemical composition were acquired from different powder manufacturers, and each material was printed with identical laser powder bed fusion processing parameters and overall build geometry to isolate the effects of feedstock composition. Selected samples were subjected to stress-relief and homogenization heat treatments to probe susceptibility to precipitate formation. Precipitate types, phase fractions, and grain morphologies were characterized in the as-deposited, stress-relieved and homogenized materials using high resolution techniques including scanning and transmission electron microscopy, high energy synchrotron X-ray diffraction, energy dispersive spectroscopy, and electron backscatter diffraction. The results show that subtle differences in powder chemistry, especially interstitial and minor alloying elements, play a decisive role in microstructure evolution and can lead to radically different microstructures. Unlike wrought counterparts, AM alloy 625 materials can be particularly sensitive to these variations. In addition to the findings of the AMB2025-01 benchmarks, the resulting challenges that feedstock variability imposes on standardization efforts will be discussed.

3:00 PM Refreshments Break (S227)

3:20 PM

Kinematic Digital Twins for Process Informed Additive Manufacturing and Repair: *Kyle Goodman*[1]; Logan McNeil[1]; Alex Kitt[1]; Dennis Harwig[1]; Samuel Bedard[1]; [1]Edison Welding Institute

Kinematic digital twins are providing the framework for developing, validating, and adapting industrial robots for additive manufacturing. AM processes need adaptive controls and process-informed predictions, which is a challenge for traditional hard-coded robot programming. The offline environment offers many practical advantages for production, and a transition point for innovative technologies. As a research and development organization, EWI has applied a range of digital twin software, robots, cobots, and advanced sensor technologies to processes such as Arc-DED, Laser-DED, Thermal Spray, and Cold Spray for commercial and government applications. These processes are relevant to industries where component repair, remanufacturing, and low-volume production require flexible robotics, including aerospace, defense, energy, and heavy industries. EWI will present representative kinematic digital twins incorporating industrial robots used in multiple additive manufacturing modalities. Digital twins have been paired with sensing technologies for improved accuracy and verification aided by extensive convergent workflow development across multiple additive processes. Simulation validation will be demonstrated - showing the difference between simulated and actual robot motion, predicted and measured deposition, success in collision avoidance, and reach verification for process feasibility before production. Together, these results demonstrate how validated kinematic digital twins can reduce uncertainty in robotic additive processes while supporting progression in sensor informed additive manufacturing.

3:40 PM

Role of Thermal Gyrations on Microstructure Evolution During Wire Arc Additive Manufacturing of Nickel Aluminum Bronze: *Jared Garthwait*[1]; Sahil Pradhan[1]; William Chen[1]; Nathan Young[2]; Gianna Valentino[1]; Jeff Kikel[3]; Sudarsanam Babu[1]; [1]University of Maryland; [2]University of Maryland, College Park; [3]AML3D

Wire arc additive manufacturing (WAAM) is emerging as an attractive manufacturing route for large-scale nickel aluminum bronze (NAB) components used in demanding marine applications because of its high deposition rate, material efficiency, and potential to alleviate supply chain constraints. Although WAAM processed NAB has demonstrated superior mechanical properties compared with conventionally cast material, the repeated thermal cycles inherent to layer-by-layer deposition generate complex thermal gyrations that can produce significant spatial variations in phase transformations, microstructure, and mechanical properties. Understanding these localized thermal effects is essential for achieving reliable qualification of WAAM components.

In this study, the influence of thermal gyrations on the microstructural evolution of WAAM-fabricated NAB was investigated through an integrated experimental and computational approach. Spatially resolved X-ray diffraction (XRD) was performed across the build to quantify variations in phase constituents, lattice spacing, peak broadening, and crystallographic texture. Automated microhardness mapping was conducted at 0.5 mm intervals to evaluate local mechanical property variations, while finite element thermal simulations using ABAQUS were employed to predict localized thermal histories during deposition.

The results reveal substantial microstructural heterogeneity throughout the deposit. Hardness mapping shows local variations approaching 85 HV, indicating pronounced differences in mechanical response. XRD measurements demonstrate spatial variations in κ-phase distribution, α-phase texture, lattice strain, and diffraction peak broadening, confirming that repeated reheating cycles significantly alter the local microstructure. A systematic left-to-right trend in lattice spacing suggests the presence of residual stress associated with the deposition direction. However, direct correlation between simulated reheat temperatures and measured microstructural or hardness variations remains inconclusive, indicating that multiple interacting thermal and metallurgical factors govern the evolution of the deposit.

Ongoing work will focus on refining thermal simulations, validating residual stress distributions, performing Gleeble® based thermal cycle experiments, and conducting detailed SEM/TEM characterization of κ-phase morphology and chemistry. These efforts will establish quantitative relationships between thermal history, microstructure, residual stress, and local mechanical properties, providing the scientific foundation for microstructure-informed qualification and process optimization of WAAM-produced NAB components.

4:00 PM

Exploring Wetting Behavior of Various Filler Metals for Vacuum Furnace Brazing Ti and Ta: *Claire Adams*[1]; Connor Mackenzie[1]; Jesse Martinez[1]; Devin Davis[1]; Alex Prada[1]; David Gresham[1]; Cheryl Hawk[1]; [1]Los Alamos National Laboratory

Welding Titanium to Tantalum can be challenging due to large differences in melting temperature and thermal conductivity. Vacuum furnace brazing avoids certain welding challenges by melting only the filler in a relatively clean environment, reducing embrittlement from interstitial elements. Certain fillers have the potential to significantly improve material properties of a joint and offer exceptional wetting behavior; however, the filler must wet to both base materials while also avoiding brittle intermetallic formation. The goal of this work is to understand which filler metals can be used to braze a dissimilar joint of pure Ti to pure Ta. Sessile drop experiments for six different Ag-based fillers were completed on Ti and Ta base plates. The wetting behavior of each filler, as well as the formation of brittle intermetallic phases, were investigated. Characterization techniques were utilized to determine spreadability of the filler, microstructure, and composition across the interfaces.

4:20 PM

Understanding and Control of Distortion in Welding and Additive Manufacturing: *David Hebble*[1]; [1]ARC Specialties

Additive manufacturing has recently generated interest due to its convenience, speed, and versatility compared to traditional manufacturing methods such as casting or forging. One such method is Wire Arc Additive Manufacturing (WAAM), which uses welding to deposit layers of metal, providing alternate construction methods for metallic parts. However, welding and WAAM are subjected to residual stresses from localized high temperatures during the process, which accumulate and interact as subsequent layers are added. This affects the final geometry and, in some cases, the ability to continue accurate metal deposition on large parts. Though distortion is a known phenomenon in welding, examining and quantifying the effects on additively manufactured parts remains to be investigated in greater detail. This study examines distortion as a function of welding process variables while keeping weld volume constant: high and low heat input, weaved bead progression, preheating the substrate, and peening after each bead. Distortion is characterized, and methods for mitigating distortion in WAAM-made parts and welding are discussed.

4:40 PM

Experimental Efforts to Develop the Process and Operations of Laser Beam Welding in Space: *Andrew O'Connor*[1]; Emma Jaynes[1]; Benjamin Rupp[1]; Louse Littles[1]; Brace White[2]; Derrick Seubert[2]; Alex Sowell[3]; Emily Sheetz[3]; Parker Shake[1]; Raju Subedi[1]; Jonathan Bonebrake[1]; Thomas Bryan[1]; Matthew Mahlin[2]; Christopher Protz[1]; Jennifer Jones[1]; Jeffrey Sowards[1]; [1]NASA Marshall Space Flight Center; [2]NASA Langley Research Center; [3]NASA Johnson Space Center

In-space joining enables in-space manufacturing and repair of metallic structures such as those envisioned on the Lunar surface for NASA Moon Base. Compared to brazing or soldering, in-space welding (ISW) can provide hermetic, strong, and complex joints without necessarily requiring additional material. However, the influence of extreme temperatures, reduced pressure, and reduced gravity on ISW requires further study. Several experimental efforts at NASA are investigating laser beam welding (LBW) as a joining and repair method for use in space. The Lunar Assembly and Servicing by Autonomous Robotics (LASAR) project led by NASA Marshall Space Flight Center (MSFC) has demonstrated LBW in thermal vacuum (TVAC) and will soon attempt weld repair in TVAC. Previous TVAC testing campaigns have welded aluminum workpieces using a ruggedized laser weld head and positioning cameras mounted on a robotic arm; this occurred at cold and warm temperature with almost all components, save the laser generator, under vacuum. NASA Johnson Space Center (JSC) is integrating perception and supervised autonomy for ISW in this project. NASA Langley Research Center (LaRC) provides structural expertise to mature joints for ISW. An upcoming TVAC testing campaign will focus on weld inspection via a non-contact nondestructive evaluation (NDE) technique – electromagnetic acoustic transduction (EMAT) – and weld repair with filler wire. While LASAR has advanced LBW operations in extreme temperatures and reduced pressure, the MSFC DISCMAN -- DIsk-Shaped Configurable and Modular vAcuum uNit – project is developing the process of LBW in reduced pressure and reduced gravity. The DISCMAN is an experimental payload that can provide a vacuum environment while in microgravity. This compact, reconfigurable payload is first being developed to perform LBW process development on the International Space Station (ISS), with parabolic flights anticipated as a stepping stone to orbital flight. The process data collected will inform future modeling efforts.

5:00 PM

Analytic Solution for Heat Flow in Finite-Thickness Slab with Convective Cooling: *Alex Kitt*[1]; Mohamed Aly[1]; Luke Mohr[1]; [1]EMI

Additive manufacturing processes are highly sensitive to heat dissipation, with inaccurate thermal control leading to residual stresses, distortion, cracking, and degradation of material performance. Classical analytical heat-transfer models provide valuable physical insight but are typically restricted by assumptions that neglect much of the geometry, rely on simplified boundary conditions, and only partially account for thermal dynamics. These restrictions limit their ability to accurately represent realistic manufacturing processes. In this work, we take a step toward a more general analytical framework for fast, physics-based thermal prediction in finite three-dimensional domains. The framework is designed to systematically incorporate finite-geometry effects, transient dynamics, realistic heat-loss mechanisms, and flexible spatial and temporal heat-source descriptions. Using two complementary analytical approaches based on Laplace transforms and Fourier-series expansions, we derive closed-form and semi-analytical expressions for transient and steady-state temperature fields under several commonly used heat-source representations, including Gaussian, ellipsoidal, double-ellipsoidal, and time-dependent on/off sources. The resulting analytical predictions are compared with numerical implementations and demonstrate strong agreement while retaining direct physical interpretability. More importantly, the framework provides a computationally efficient alternative to repeatedly solving the full governing equations numerically, which is particularly important for real-time process control where conventional finite-element or finite-difference simulations can become computationally prohibitive.

Plenary 2

Thursday AM | October 22, 2026
S225 | Las Vegas Convention Center

Session Chair: Thomas Lienert, T.J. Lienert Consulting, LLC

8:00 AM Plenary

New Experimental Data in Brazing Titanium and the Practical Interpretation: *Alexander Shapiro*[1]; [1]Titanium Brazing, Inc.

Brazing of titanium alloys has been fairly well studied over the last six decades. However, some technical problems are still not resolved and brazing technology is not fully optimized. This presentation reviews the results of experimental studies and tests made by Titanium Brazing, Inc. over the period 2015-2025, to answer important practical questions involved in improving production of titanium brazed structures and enhancing their industrial applications: (1) Applications and methods of brazing titanium alloys. (2) The positive effect of a post-braze diffusion treatment on strength and microstructure of titanium brazed joints, (3) The negative effect of brazing temperature in the range 680-1000°C on mechanical properties of titanium base metals Ti Grade 2 and Ti-6Al-4V (4) The effect of one and two re-brazing cycles on the strength of titanium brazed joints, (5) The effect of the form of applied filler metal (foil, powder, or transfer tape) on the structure and strength of brazed joints, (6) The negative effects of cryogenic treatment on the properties of titanium brazed joints, (7) New high-entropy brazing filler metals for joining titanium and refractory metals.(8) Brazing titanium tubes in air.

Session 4: AI, ML, and Data Science

Thursday AM | October 22, 2026
S224 | Las Vegas Convention Center

Session Chairs: YuMing Zhang, University of Kentucky; Edward Wang, Case Western Reserve University

8:40 AM

AI-Driven Adaptive Welding: Advancing Autonomous Arc Welding from Development to Deployment: *Jonathan Tatman[1];* Darren Barborak[1]; Will Siefert[1]; Julius Neuß[2]; Carlo Holly[2]; [1]EPRI; [2]Fraunhofer ILT

The declining availability of skilled welding operators has created a growing need for intelligent welding systems that can improve consistency, productivity, and reliability while reducing operator burden. Over the past several years, EPRI has led development of an AI-driven adaptive welding platform that integrates real-time sensor data, machine vision, weld parameter acquisition, and artificial intelligence algorithms to move mechanized arc welding toward autonomous operation. This presentation will summarize adaptive welding development efforts performed by EPRI, including system architecture, welding data collection, algorithm maturation, and transition from laboratory demonstration toward deployable industrial solutions. In collaboration with Fraunhofer ILT, EPRI has evaluated convolutional neural networks and a modified self-supervised learning approach (DINOv2) to segment key weld image features such as the weld pool, wire, torch, and joint geometry with reduced manual labeling requirements. These capabilities support real-time weld monitoring, wire position control, reinforcement prediction, and closed-loop adjustment of welding parameters.The presentation will highlight the broader technology maturation pathway, including integration with commercial welding equipment, expansion across multiple welding processes, including additive manufacturing applications, and ongoing efforts to support technology transfer for high-consequence nuclear and industrial welding applications.

9:00 AM

Beyond Process-Specific Molten-Pool Modelling: A Physics-Structured Dissipative Neural State-Space Framework: Yue Cao[1]; *Yize Chen[2];* Hai Lin[3]; Yuming Zhang[2]; [1]University of Michigan; [2]University of Kentucky; [3]University of Notre Dame

The molten pool governs geometry, stability, and defect formation in arc welding and metal additive manufacturing, yet its modelling remains largely processspecific. High-fidelity physical solvers provide mechanistic accuracy but are too computationally expensive for online prediction and control, whereas purely data-driven models often lack stability, extrapolation capability, and cross-process generalizability. This paper investigates whether molten-pool dynamics across different processes can be represented by a shared physics-structured model rather than by separately trained process-dependent predictors. This paper proposes a transferable latent dynamical modelling framework with two components. First, raw molten-pool images are mapped to compact latent states using a pretrained DINO encoder, while Neural ODE regularization enforces temporally smooth and physically consistent representations. This design reduces dependence on processspecific feature engineering and provides a reusable state representation across molten-pool processes. Second, a physics-structured dynamic model derived from a lumped molten-pool energy balance specifies the dynamic form while data learn the nonlinear internal functions. The model separates a fast geometric state from a slow thermal state associated with accumulated workpiece heat, showing that pool geometry alone is not Markovian and must be augmented by a hidden thermal variable. The resulting dynamics describe molten-pool evolution as a dissipative relaxation process in which geometry contracts toward an equilibrium determined by process input and accumulated heat.The framework combines transferable visual representations with stable and interpretable physics-structured dynamics. It is validated on GTAW simulations with known ground truth, real GTAW and GMAW experiments, and the multi-source Melt-Pool-Kinetics dataset. Across these settings, the same framework is applied without process-specific redesign, demonstrating a reusable modelling strategy for molten-pool dynamics across welding and metal additive manufacturing processes.

9:20 AM

High-Speed Video Analysis of Metal Transfer in GMAW using a Vision Transformer with Temporal Memory: *Lucas Taipe[1]*; Gabriela Pinheiro[2]; J. Eduardo AlvarezRocha[1]; Xingyu Li[1]; Patricio Mendez[1]; [1]University of Alberta; [2]University of São Paulo

Welding performance is influenced by current and voltage parameters. Understanding their impact on metal transfer is essential for optimizing power source design and welding output prediction. Recent advances in computer vision, driven by transformer-based foundation models, have moved beyond conventional frame-by-frame segmentation by enabling coherent video interpretation through object temporal evolution. EfficientTAM, a promptable segmentation architecture that integrates a lightweight vision transformer with efficient temporal memory, was adapted to analyze high-speed videos of GMAW using ER4043 aluminum wire. The model was fine-tuned in two phases to segment process regions, including detached droplets, molten consumable, and arc, and to improve droplet temporal continuity during metal transfer. Based on these predictions, a droplet-tracking system quantified transfer frequency, projected area, volume, and postdetachment kinematics in sequences of approximately 15,000 frames. The refined segmentation achieved an Intersection over Union of 0.862 for the droplet class, while transfer-frequency estimation reached an absolute percentage error of 1.25% +/- 1.39% relative to manual reference. Droplet volume was estimated using a weighted least-squares formulation based on temporal trajectory and an approximately constant-volume assumption during flight. Total transferred volume was obtained by summing reconstructed droplets and comparing it with a reference calculated from wire diameter and wire feed speed. Using the WLS estimator with 1-pixel erosion, the absolute percentage error in volume was 23.61% +/- 19.61%. These results show that temporally coherent segmentation combined with droplettrajectory analysis can automate quantitative characterization of metal transfer in GMAW. The proposed pipeline provides a basis for relating electrical parameters to droplet frequency, size, and dynamics, supporting future analysis of waveform-design strategies. The main limitation remains volume estimation, although improved segmentation accuracy could strengthen volumetric reconstruction and enable more robust estimation of plasma drag force on droplets.

9:40 AM

Rapid Prediction of Inherent Strain Parameter with Machine Learning for Metal Additive Manufacturing Distortion Simulation: *Andrew Tong[1]*; Wei Zhang[1]; [1]Ohio State University

Metal Additive Manufacturing (AM) allows for great versatility in part fabrication but suffers from significant residual stress and distortion due to the extreme thermal gradients inherent to the melting process. While thermo-mechanical finite element analysis provides high-fidelity predictions, its computational cost is prohibitive for industrial-scale components. The Inherent Strain Method offers a rapid alternative to predict welding-induced distortion by treating it as a result of incompatible strains. More recently, the Modified Inherent Strain Method (MISM) refines this approach by specifically accounting for the global evolution of the elastic strain field under the evolving boundary conditions characteristic of the layer-wise AM process. However, the accuracy of MISM remains dependent on an Inherent Strain Parameter (ISP) that typically requires expensive experimental calibration or thermo-mechanical simulation of a representative sample part for every new material-parameter combination. This work proposes a machine learning framework to predict the ISP within a bulk region of deposited material by leveraging latent vector representations of material properties and laser powder bed fusion (LPBF) processing parameters. By integrating a dimensional bottleneck into a Deep Kernel Learning (DKL) architecture, the model is forced to capture the underlying physical relationships governing distortion. The uncertainty quantification provided by DKL is then leveraged alongside thermo-mechanical simulations in an active learning loop to autonomously identify the next best sampling points in the parameter space, reducing the required training data. The model was validated against the distortion of an austenitic stainless steel 316L overhangs printed by different laser processing parameters. The developed model enables rapid, confidence-informed ISP estimation, facilitating accelerated distortion prediction for large-scale AM parts.

10:00 AM Poster Session (Location: TBD) and Refreshments (S227)

10:30 AM Invited 1: See Information below

11:00 AM

Real-time Weld Monitoring System from Optical Images with Limited Labeled Data: *Molan Zhang[1]*; Jian Chen[1]; Zhili Feng[1]; Jonathan Tatman[2]; Darren Barborak[2]; Will Siefert[2]; [1]Oak Ridge National Lab; [2]Electric Power Research Institute

Real-time monitoring of welding processes remains difficult in practice due to the need for large amounts of fully labeled data, varying lighting and surface conditions, and the complexity of extracting useful geometric information from optical images. In this work, we develop a self-supervised learning based weld monitoring system that works with only 100 labeled images. The system uses a self-supervised model DINOv3 developed by Meta to segment the melt pool, wire, and torch from ordinary grayscale images. Then system can automatically extract key geometric features, such as melt pool contour, wire tip offset, and other. Based on these features together with welding parameters including current, speed, and voltage, the system predicts reinforcement width and classifies weld quality using two lightweight neural networks. The complete pipeline runs in real time and can be integrated with LabVIEW for live production use. Our results show that the system provides accurate geometric measurements and reliable quality predictions, even with limited labeled training data. By turning optical images into actionable information with minimal labeling effort, this work offers a feasible solution for low-cost, real-time weld monitoring that can provide live suggestions in adjusting welding parameters and support closed-loop control in automated manufacturing.

11:20 AM

Resistance Spot Welding Quality Prediction: *Colleen Hilla[1]*; Jeremy Rogers[1]; Tyler Del Rose[1]; [1]Savannah River National Laboratory

Pinch welding, a specialized resistance spot welding technique, is widely used for sealing stainless steel tubing in critical applications such as hydrogen containment, where weld integrity and microstructural homogeneity are paramount. Traditionally, weld quality assessment relies heavily on destructive testing, which is both resource-intensive and time-consuming. This study explores the use of advanced data analysis and machine learning methods to predict weld quality from process controller data, aiming to minimize destructive testing requirements. Raw process signals—including force, current, displacement, and voltage—were collected from pinch welding operations and subjected to fast Fourier transform (FFT) analysis for noise reduction and feature extraction. Supervised learning algorithms, such as regression and classification models, were trained on labeled datasets to predict key weld qualification metrics based on real-time process data. In parallel, unsupervised learning techniques, including clustering and principal component analysis, were utilized to segment welding cycles and reveal underlying patterns in process variability. The integration of FFT-based signal processing with machine learning enabled accurate identification of weld cycles and robust prediction of weld quality metrics, such as bond strength and weld dimensions. The results demonstrate a strong correlation between process parameters and weld outcomes, supporting the feasibility of in-line, data-driven weld qualification. This approach not only improves process monitoring and control but also offers significant potential for reducing reliance on destructive testing, thereby enhancing efficiency and reliability in critical pinch welding applications.

11:40 AM

Physics-Constrained Multi-Task Neural Network for Real-Time Thermo-Geometric Prediction in TIG Welding Digital Twin Systems: Mukhtar Sama[1]; Amit Sata[1]; Gaurang Joshi[1]; *Himanshu Thaker[2]*; [1]Marwadi Univesity; [2]Piping Technology & Products, Inc.

In the development of reliable Digital Twin systems (DT) for Tungsten Inert Gas (TIG) welding, accurate and fast prediction of thermo-geometric responses is essential. While conventional physics based thermal simulations can accurately simulate the transient heat transfer process, it is not practical to use them directly in real-time decision making, process optimization, and online quality monitoring due to their high computational costs. To overcome this drawback, this study introduces a Physics-Constrained Multi-Task Neural Network (PC-MTNN) for simultaneously predicting the peak temperature, maximum weld pool width, and the maximum HAZ width in TIG welding. A total of 318 simulation derived cases were used to train the model under different welding currents, arc voltage, travel speed, arc gap and plate thickness. A shared neural representation was used to capture the coupled thermal and geometric behavior and task-specific output heads were used to predict individual responses of the welding process. The physical consistency was directly incorporated into the model architecture by introducing the constraint of non-negative weld pool and HAZ widths as well as the constraint that the predicted HAZ width should be equal to or greater than the weld pool width.The proposed PC-MTNN showed a good predictive performance with unseen test data. The R2 values for the model were 0.9937, 0.9804 and 0.9634 for peak temperature, weld pool width and HAZ width, respectively. The corresponding mean absolute errors were 21.87 °C, 0.216 mm, and 0.224 mm, while the root mean square errors were 36.77 °C, 0.311 mm, and 0.475 mm, respectively. The developed surrogate model is a physics-aware computational layer for the TIG welding Digital Twins that can be used to predict, monitor, and optimise the TIG welding process in real time without the need to repeatedly execute the computationally expensive numerical simulation.

Session 5: Applied Technology

Thursday AM | October 22, 2026

S225 | Las Vegas Convention Center

Session Chairs: James Zuback, NIST; Andres Acuna, Lincoln Electric

---

8:40 AM

Achieving High Weld Performance While Advancing EHS Goals with Reduced-Manganese Cored Wires: *Neil Farrow[1]*; [1]ESAB

Controlling welding fume exposure is a growing priority as regulatory limits tighten and fabricators focus on protecting welder health without sacrificing productivity. This technical presentation reviews a practical, layered approach to fume mitigation, including local exhaust ventilation, fume extraction MIG guns, PAPRs and emphasizes the often-overlooked role of filler metal chemistry—specifically low-manganese consumables—as a highly effective, upstream control strategy.Low-manganese filler metals are engineered to reduce manganese emissions at the source while maintaining required mechanical properties, arc stability, and weld appearance. Field and laboratory data show that these consumables can reduce manganese particulate emissions by roughly 50 percent with no changes to welding procedures, equipment, or welder technique. Attendees will gain actionable insight into how combining consumable selection with conventional controls delivers measurable reductions in fume exposure, simplifies compliance, and creates a healthier welding environment across high-volume fabrication applications.

9:00 AM

Hydrogen Control in Welding: Challenges, Monitoring, and Industry Practices: *Andres Acuna*[1]; John Procario[1]; Corwin Miller[1]; [1]Lincoln Electric

Hydrogen is known to adversely affect susceptible weld-metal alloy systems, making it a critical topic for the welding industry. Despite significant efforts to study and understand these concerns, manufacturing environments do not always provide optimal conditions for hydrogen control. Additionally, many codes, standards, industry requirements, and recommended practices address hydrogen-related issues. However, hydrogen problems are typically delayed in nature, making it difficult to identify issues retrospectively after production or to monitor the conditions of common sources during production.This study discusses common hydrogen sources, industry requirements, and standard practices for monitoring and controlling production conditions.

9:20 AM

Hyper Duplex Stainless Steel: A Sustainable Choice for High-Performance Applications: *Per-Åke Björnstedt*[1]; [1]ESAB

Hyper Duplex Stainless Steels (HDSS) offer superior corrosion resistance and mechanical performance. Characterized by high Pitting Resistance Equivalent Number (PREN ≥ 45), HDSS benefits from elevated chromium and nitrogen, ensuring enhanced resistance to localized corrosion and high yield strengths above 700 MPa, important for seawater exposure and petrochemical systems. HDSS welding fillers maintain a balanced ferritic-austenitic microstructure during complex thermal cycles, minimizing formation of detrimental intermetallic phases like sigma. Compared to super duplex stainless steels, HDSS filler metals improve the corrosion resistance of weld roots and caps and maintain mechanical integrity without increasing susceptibility to 475°C-embrittlement. Experimental studies confirm HDSS weld overlays and claddings show similar phase transformation kinetics to SDSS but with significantly higher corrosion resistance, especially under critical pitting conditions. These attributes position HDSS as a sustainable and high-performance choice for advanced structural applications, offering a viable alternative to more expensive nickel-based alloys in corrosive and high-pressure environments.

9:40 AM

Often Missed Resistance Weld Machine Specifications that Impact Quality: *Robert Cohen*[1]; [1]WeldComputer Corporation

Attendees will learn why failing to consider the ram/cylinder static and kinetic friction of a resistance welding machine can leave a manufacturer with elevated expulsions and weld variability over the capital life of the installation. The physics of the welding process will be discussed in sufficient detail to develop an understanding of how high static friction, which results in excessive ram breakaway force, and variations in kinetic friction as the ram moves, are responsible for inconsistent and erratic ram motion response during each weld, and from weld to weld, and why such inconsistent ram response results in inconsistent welding performance.

10:00 AM Poster Session (Location: TBD) and Refreshments (S227)

10:30 AM Invited 1: See Information below

11:00 AM

Sense and Nonsense - PWHT for Repair of Surfacing Welds for H2S Service: *Richard Holdren*[1]; David Hebble[1]; [1]ARC Specialties Technical Services

Qualification of welding procedures for corrosion-resisting overlays (CROs) and buildups on components subject to survival in hydrogen sulfide (H2S) environments requires testing in accordance with ASME, API, and NACE standards. In addition to the standard testing specified in ASME Section IX, these procedures must also satisfy the performance requirements found in various API standards as well as the corrosion-resistance requirements of NACE. This testing program requires that a given weld test coupon be subjected to two PWHT holding times. The shorter time is the minimum holding time for the original production weld. The longer PWHT time then provides verification that the base and filler metals will withstand multiple PWHT required for each repair/rebuild of these components. That way, the life of the component can be extended by the replacement or repair of the degraded surface. The current requirements state that the minimum PWHT time must be applied for each repair/rebuild cycle. Research has revealed that the current requirements may be excessive, and that shorter PWHT times can accomplish the same result without the risk of degrading the base and filler metals being used. This paper will describe recommendations for dramatically reducing the PWHT times to both reduce cost and, more importantly, reduce the potential for material degradation due to excessive exposure to PWHT temperatures. The presentation will also discuss how PWHT can be eliminated completely.

11:20 AM

Welding Deformation Control in Tank Bottom Construction: *John Chen*[1]; [1]KBR

KBR recently was involved in the construction of storage tanks in a new plant. Due to the large amount of welding operation, deformation of tank bottom was inevitable while the large number of plates were assembled together to form the tank bottom. To reduce the deformation to acceptable level, a collection of techniques was implemented, including the adoption of optimal welding sequence, the preform of anti-deformation joints, minimizing the welding heat input, and straightening after welding. The selected use of different techniques was the key to ensuring a successful tank bottom construction activity.

11:40 AM

Welder, Technician, Teacher: Lessons on Retention and Mobility in the Welding Talent Pipeline: Michael McGinnis[1]; *Charles Jeffress*[1]; [1]LeTourneau University

The welding industry continues to face a significant workforce shortage, with demand outpacing the supply of skilled professionals. While much attention has been given to recruitment into welding careers, less focus has been placed on the pathways, transitions, and retention of individuals within the profession. The result is a "leaky pipeline," in which talented individuals enter the field but often exit or shift roles in ways that are not fully understood or strategically supported. This paper explores the welding talent pipeline through the lived experience of a professional who has navigated multiple roles within the field—including welder, community college instructor, university educator, and technical specialist responsible for laboratory infrastructure. This longitudinal perspective provides a unique lens into how individuals grow, adapt, and remain engaged in the welding profession over time. Drawing from this case study, along with broader observations from engineering education and workforce development, the paper identifies key factors that influence retention and mobility within the welding workforce. These include technical skill development, opportunities for advancement, relational dynamics within teams and institutions, and the importance of meaningful, purposedriven work.In addition, the paper offers practical insights for industry leaders, educators, and institutions seeking to strengthen the welding pipeline—not only by attracting new talent, but by sustaining and developing the professionals already within it. Attendees will gain a deeper understanding of career pathways in welding, common points of attrition, and actionable strategies to improve retention, mentorship, and long-term workforce engagement.

Session 6: Sensing and Monitoring

Thursday AM | October 22, 2026
S226 | Las Vegas Convention Center

Session Chairs: Jesse Porter, Ohio State University; Derek Shaffer, Phoenix Laser Solutions

8:40 AM

Analysis of Thermal and Visual-Band Imaging for In-Situ Weld Pool Monitoring: *Henry Dennis*[1]; Nate Sena[1]; Dennis Harwig[1]; Mark Cola[2]; [1]Ohio State University; [2]Los Alamos National Laboratory

Many industrial welding applications heavily rely on post-weld NDE techniques for quality assessment, where process modification and anomaly identification are limited by skilled welder and machine operator availability. In-situ data collection of weld pool morphology (length, width, aspect ratio, etc) can address these shortcomings by providing quantitative metrics for process anomaly detection and first-time-quality improvement. The current leading technology for monitoring weld pool behavior uses side-view or high-angle camera configurations to balance movement obstruction with process field of view. Weld pool imaging is commonly carried out with either standard optical CCD sensors coupled with narrow-band bypass filters or thermal imaging using short-wave infrared (SWIR) sensors. Thermal imaging typically employs temperature thresholding to detect melt pool edges, while visible-band monitoring uses machine learningbased segmentation approaches such as YOLO or edge detection algorithms such as Sobel. While both approaches have been proven in literature, there remains a need for an apples-to-apples comparison of measurement accuracy, robustness, and reliability between each modality for weld pool analytics. Bead-on-plate gas tungsten arc welding (GTAW) experiments were performed using an OPTRIS 08M camera for thermal analysis and a visible-band Xiris XVC-1000 camera under varying welding conditions to compare pool measurements across wire-feed-to-travel-speed ratios and heat input conditions. Synchronized optical and thermal measurements are evaluated to identify where each sensing method is most sensitive to process variation, arc interference, emissivity effects, and segmentation uncertainty. These results contribute to an analytical relationship between process condition and pool morphology while establishing practical guidance for sensor selection in automated welding monitoring. The findings also inform future work toward coaxial weld vision capable of omnidirectional measurement, in-situ anomaly detection, and closed-loop process correction.

9:00 AM

Relationship Between GMAW metal transfer mode and welding fume particle size and morphology: Ivan Pigozzo[1]; *Daniele Calista*[1]; Kerry Chen[1]; Pooja Saini[1]; Franklin Wang[1]; Samantha Skiba[1]; Luu Nguyen[1]; Jason Olfert[1]; Patricio Mendez[1]; [1]University of Alberta

This work presents an investigation into the production of weld fumes from different GMAW metal transfer modes as a first step in a broader project aimed at understanding the physical mechanisms of weld fume generation. Experiments consisted of depositing ER70S-6 wire onto low carbon steel plate, using five metal transfer modes: short-circuit, Regulated Metal Deposition\8482 (RMD), globular, spray, and free-flight with pulsed current (FFPC). Fumes were collected using a probe tube positioned in-stream with a full-scale fume exhauster. The mobility diameter (MD) and total concentration of aggregate particles (APs), which were composed of smaller primary particles (PPs), were measured using a Scanning Mobility Particle Sizer (SMPS). AP morphology, including nominal diameter and projected area, was characterized via Scanning Electron Microscopy (SEM). To preserve their inherent structure, these particles were collected directly onto quartz membranes during welding. MD analyses indicated that APs produced from short-circuit, RMD, globular, spray, and FFPC transfer modes had a count mean diameter of 136 nm, 112 nm, 140 nm, 148 nm, 103 nm, respectively. MD analyses also indicated the diameter of APs produced from all transfer modes can require different filtration mechanisms. SMPS measurements also demonstrated that, for all metal transfer modes, the net amount of fumes increased with average current. For the same average current, FFPC produced higher fume concentration than short-circuit, RMD, and globular. The size of PPs and morphology of APs indicated that particles may be produced by different physical mechanisms. Future work includes further investigation in the mobility diameter and aerodynamic diameter of APs produced from GMAW. Applying this fundamental knowledge to the design of engineered safety controls will enable the targeted, controlled reduction of operator exposure risk.

9:20 AM

Ultrasonic Property Maps for Characterizing Aluminum Resistance Spot Welds: *Sean McGinnis*[1]; Desmond Bourgeois[1]; [1]Ohio State University

Resistance spot welding is widely used in automotive applications, yet reliable nondestructive evaluation of thin sheet aluminum spot welds remains challenging due to strong attenuation, geometric constraints, and complex wave interactions. This work presents an ultrasonic imaging approach for characterizing aluminum spot welds with improved spatial and temporal insight into the weld integrity. Ultrasonic data is acquired using a microscopic resolution ultrasonic imaging system, ultrasonic property maps are reconstructed to form images of ultrasonic wave propagation through the weld region. This study will analyze the resistance spot weld region by using amplitude, attenuation, velocity, frequency maps to understand how the ultrasonic wave interacts with the welded region. Furthermore, ultrasonic property maps could have a high probability to identify weld conditions in time and frequency domains to understand shape and size of the weld as well as detailed examination of defects.The proposed ultrasonic property map framework emphasizes thin-sheet considerations, including plate-mode behavior, limited weld thickness, and sensitivity to nugget geometry and kissing-bond defects. Ultrasonic property maps could reveal distinct scattering and attenuation patterns associated with weld nugget size, lack of fusion, and interfacial discontinuities. Experimental results obtained on aluminum lap-shear spot weld specimens demonstrate that the techniques enhance defect contrast and provides intuitive visualization of weld formation compared to solely time-integrated imaging approaches. Overall, ultrasonic property maps offers a promising avenue for quantitative and interpretable assessment of thin aluminum spot weld quality, with potential for integration into in-line inspection and advanced data-driven evaluation methods.

9:40 AM

Weld Process-Signal-Structure Relationship Development Through In-Situ and In-Operando Monitoring of Laser Beam Welding: *Richard Li*[1]; Boyd Panton[1]; Carolin Fink[1]; [1]Ohio State University

Laser beam welding is an advanced process characterized by high penetration, high travel speeds, and low heat input welds. However, numerous welding defects stem from beam parameters, component machining and fit up, and beam-material interactions. As a result, standard weld procedure development can be prohibitively costly or can have exceedingly long timelines with certain material types and applications. Attempts have been made to study beam-material interactions to streamline qualification processes but lack proper process characterization and monitoring data. This work will utilize a multimodal sensor approach with laser beam processes to study fundamental keyhole behavior and correlate process signals to final weld quality. Laser power modulation will further be explored to evaluate the effects of modulation amplitude and frequency on keyhole stability and resultant weld quality.

10:00 AM Poster Session 1 (Location: TBD) and Refreshments (S227)

Invited 1

Thursday AM | October 22, 2026
S225 | Las Vegas Convention Center

Session Chair: Thomas Lienert, T.J. Lienert Consulting, LLC

10:30 AM Invited

Structural Alloy Welding and Performance in High Temperature Gas Reactors: *George Young*[1]; [1]X-energy

Helium cooled, high-temperature gas reactors are a proven power generation technology that is being commercialized for widescale deployment by X-energy. Due to the unique advantages of helium gas as a coolant, system temperatures range between ~285-750°C and require a variety of structural alloys from conventional pressure vessel steels to highly alloyed iron-based and nickel-based alloys. For the pressure vessel steels, few issues exist in weldability or weld performance as their use in the Xe-100 reactor system is bounded by light water reactor experience. For the 316H austenitic stainless steel used in the steam generator system, weldability is well understood and stress relaxation cracking can be mitigated by design and fabrication. However, the Alloy 800H used in the hottest parts of the system presents unique challenges as the alloy does not have an ASME code-qualified matching filler metal, it's susceptibility to stress relaxation cracking is known but has not been quantified, and degradation in helium gas is a potential concern. This presentation discusses how X-energy is mitigating these gaps to ensure the long term performance of structural alloys and welds in the Xe-100 reactor system.

Session 7: Cladding and Solid State Processes

Thursday AM | October 22, 2026
S226 | Las Vegas Convention Center
Session Chairs: Derek Shaffer, Phoenix Laser Solutions; Jesse Porter, Ohio State University

11:00 AM

Cold Spray Deposition for Fabrication of Interlayers in Stainless Steel – Titanium Dissimilar Metal Laser Welding: *Erin Barrick*[1]; Leah Mills[1]; Michael Kracum[1]; Joseph Padilla[1]; Landon Schnebly[1]; Austin Pisani[1]; Daniel Leseberg[1]; Jack Herrmann[1]; [1]Sandia National Laboratories

Dissimilar metal laser welding of stainless steel (SS) to titanium alloys remains one of the most challenging combinations because when directly joined, brittle intermetallic phases form in the fusion zone, compromising the integrity of the joint. We have addressed this issue by applying interlayers using the cold spray (CS) deposition technique. CS is a solid-state deposition process, therefore there is no melting at the interface, enabling a wide variety of alloys for interlayer use. In this work, the CS interlayer was one of the two alloys in the dissimilar combination (i.e., a third dissimilar interlayer was not used): 304L SS was cold sprayed onto Ti-6Al4V to form a 304L interlayer that was laser welded to 304L sheet; the reverse was also investigated where Ti-6Al-4V was cold sprayed onto 304L SS and the Ti-6Al-4V interlayer was laser welded to Ti-6Al-4V. Different CS processing conditions and post-CS annealing treatments were utilized to influence 1) adhesion of CS interlayer to substrate, 2) density of CS interlayer, and 3) post-CS laser weldability. A wide range of laser welding parameters were explored, including continuous wave and pulse laser welding, to understand processing windows. Microstructure characterization was performed using light optical and scanning electron microscopy. The spatial mechanical properties across the entire dissimilar joints were characterized with microhardness and select interfaces were further characterized with nanoindentation. Overall, many dissimilar welds are defect free; initial high-temperature post-CS annealing treatments promoted diffusion at the CS solid-state interface resulting in interlayer delamination during laser welding. Subsequent annealing times/temperatures were selected to minimize diffusion while facilitating stress relief in the interlayer. These results are significant in that CS is a promising process for facilitating dissimilar joints with careful selection of processing parameters for both CS and laser welding.SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525

11:20 AM

Investigating Processing Space and Performance of Ceramic Reinforced Alloy Laser Powder Cladding: *Derek Shaffer*[1]; [1]Phoenix Laser Solutions

While there are many ways to provide wear and corrosion resistance to metallic components, they often have some negative effects. Some examples of side effects are the environmental and health concerns related to processes like hard chrome plating or the need to put an entire component in a controlled environment to do nitriding or carburizing processes. For these reasons, many industries are looking towards local treatments with laser cladding being one option. Many alloys are used to provide a more wear resistant surface while contributing to corrosion resistance, such as martensitic stainless steels and high hardness nickel alloys. Another area of development that is being used in increasing amounts is the addition of ceramic particles, such as WC, into these cladding overlays. The addition of very hard WC particles which survive the high temperature fusion cladding process has a profound impact on wear resistance while the matrix metal alloy retains its properties. Many commercially available WC metal matrix composite cladding blends that exist today comprise of either austenitic stainless steel or boron silicide strengthened nickel alloy with spherical carbide particles. Some work has delved into the optimization of the WC particle size, morphology, and composition, but this work focusses more on the application of WC particles in different fractions, with different matrix alloys. By comparing the final properties, the most efficient fraction of WC and most applicable matrix material can be selected dependent on the final properties as well as the most suitable processing conditions. Another key insight is the processing parameters and how they may need to change dependent on carbide fraction and the propensity to induce cracking.

11:40 AM

Effects of Cooling Media on Mechanical and Microstructural Properties of Friction Stir Welded AA6061-T6 in a CNC Machine: *Austin Clark*[1]; Ihab Ragai[1]; [1]Pennsylvania State University - Behrend

While friction stir welding (FSW) in a CNC machine is gaining popularity as combining the processes becomes more practical, the effects of thermal input must still be considered. Heat generated from the welding process may negatively affect the machine and components. Machine accuracy, part-life, and warping of components may all suffer some amount of degradation due to elevated levels of thermal input inherent to the welding process. Components such as the spindle and drives may also be negatively affected due to a lack of heat management at the tool. While underwater FSW has previously been researched as a means of continuous cooling, this process is not feasible in a CNC machine. One proposed solution to this issue is to utilize the existing machining coolant, flooded over the tool during welding, to reduce temperature levels at the weld and additionally reducing the amount of heat transferred back into the tool that may damage or warp machine components. Flooding coolant, forced air cooling, and no cooling, as is the case with conventional FSW, were compared. Feed rates varied to study their effect on each cooling method. In this study, 6.35 mm samples of AA6061-T6 were welded in a butt joint configuration and the feed rates were 100, 200, and 300 mm/min. It was observed that the most ideal welding qualities were found by flooding coolant at a feed rate of 100 mm/min. When coolant was implemented during welding, 76% tensile strength was achieved along with increased hardness in the stir zone. Although narrowing of the weld zone occurred along with voids at the surface in samples FSW with coolant. This was due to lower levels of heat for the duration of welding which impeded plastic material flow more so than when no cooling was utilized.

Plenary 3

Thursday PM | October 22, 2026
S225 | Las Vegas Convention Center

Session Chair: Thomas Lienert, T.J. Lienert Consulting, LLC

1:20 PM Plenary
Physics-Dominant Machine Learning for Intelligent Manufacturing: Lessons from Welding: *Hongyan Zhang*[1]; [1]Xi'an Jiaotong-Liverpool University

The rapid adoption of artificial intelligence (AI) in manufacturing has created new opportunities for process modeling, optimization, and quality control. However, many current AI applications rely heavily on data-driven approaches that function largely as black boxes, providing limited physical interpretability and often requiring extensive retraining when process conditions change. For manufacturing processes governed by well-understood physical mechanisms, a fundamental question arises: should machine learning replace physics, or should it complement it? This presentation introduces a physics-dominant machine-learning framework developed for welding operating-window determination. The central premise is that the primary structure of a manufacturing process should be described by governing physics whenever possible, while machine learning should be used selectively to account for secondary effects and residual errors. Physics-informed analytical models are first derived from the dominant heat-generation mechanisms of individual welding processes, establishing physically meaningful operating window boundaries. For processes exhibiting stochastic transition behavior, the framework is extended to probabilistic boundary descriptions that enable risk-based process design. Machine-learning methods are then incorporated only as residual-correction tools, preserving physical interpretability while improving predictive accuracy. The methodology is demonstrated using multiple case studies involving high-frequency induction welding and resistance spot welding. Results show that relatively simple physics-based models capture the dominant operating-window structure, while residual learning provides targeted improvements near process transition boundaries and under conditions exhibiting increased variability. Independent validation studies further demonstrate the adaptability of the framework to new applications and operating conditions. Beyond welding, the proposed approach illustrates a broader paradigm for industrial AI in which physics, domain knowledge, uncertainty quantification, and machine learning are integrated into a unified modeling strategy. The framework provides a practical pathway toward interpretable, transferable, and industrially deployable AI systems for intelligent manufacturing.

Session 8: Properties and Performance of Welded Components

Thursday PM | October 22, 2026
S224 | Las Vegas Convention Center

Session Chairs: Colleen Hilla, SRNL; Andrew Iams, NIST

2:00 PM
Advancing Electrorefining: Corrosion Behavior of Additively Manufactured Tantalum in Molten Salt: *Colleen Hilla*[1]; Gregory Chipman[1]; [1]Savannah River National Laboratory

Tantalum is widely recognized for its exceptional corrosion resistance in aggressive environments, making it a material of choice for components in electrorefining processes that utilize molten salts. Traditionally, tantalum components have been fabricated through wrought processing methods, which produce dense and uniform microstructures but can be limited in terms of design flexibility and manufacturing efficiency. Recent advancements in additive manufacturing (AM) offer the potential to fabricate complex tantalum geometries with reduced material waste and lead time. However, the rapid solidification and layer-wise build nature of AM processes can introduce unique microstructural features—such as anisotropy, residual stresses, and porosity—that may influence corrosion behavior. Molten salt electrorefining, a critical process for the recycling and purification of metals, presents a highly corrosive environment due to the presence of halide salts at elevated temperatures. The long-term performance and reliability of tantalum components in these conditions are essential for process efficiency and safety. Despite tantalum's known corrosion resistance, limited data exist comparing the corrosion performance of additively manufactured tantalum to its wrought counterpart in molten salt environments. This study presents a comparative analysis of the corrosion resistance of LP-DED tantalum and conventional tantalum after exposure to molten salt mixtures used in electrorefining. Microstructural characterization, electrochemical testing, and postexposure surface analysis are conducted to elucidate the influence of manufacturing method on corrosion behavior. The findings aim to inform material selection and processing strategies for advanced molten salt electrorefining systems, assessing the viability of AM tantalum as a high-performance, corrosion-resistant material.

2:20 PM
Evaluating Thermal Fatigue and Creep Resistance in Heat-Resistant Fe-Ni-Cr Alloys Fabricated by Wire Arc Additive Manufacturing: *Giacomo Melaragno*[1]; Michael Gagliano[2]; Alex Bridges[2]; Eeva Griscom[2]; Boian Alexandrov[1]; [1]Ohio State University; [2]Electric Power Research Institute

Pipe components in olefin furnaces produced from cast heat-resistant Fe-Ni-Cr alloys have experienced premature failures during high temperature service by creep fracture, thermal fatigue, and/or thermal shock. Some studies analyzing failures and material susceptibility of these components have suggested that a refined distribution of grain boundary carbides would be beneficial for improving thermal fatigue and creep resistance. As a result, wire arc additive manufacturing (WAAM) has been proposed to produce pipe components that achieve a more refined microstructure. The present study evaluates the thermal fatigue and creep resistance of WAAM heat-resistant Fe-Ni-Cr materials compared to their cast counterparts. Mechanical test specimens were machined from WAAM Fe-35Cr-45Ni (35/45) and Fe25Cr-35Ni

(25/35) builds. Thermal fatigue testing was performed on the WAAM 25/35 and 35/45 materials using a Gleeble-based procedure previously developed on cast heart-resistant Fe-Ni-Cr alloys. Creep testing was performed on the WAAM 35/45 material under constant load at elevated temperatures. Specimens from gravity cast 35/45 components were also tested in creep and the thermal fatigue results were compared to previously collected data on cast materials. Scanning electron microscopy (SEM) was also performed on failed WAAM and cast test specimens to understand differences in performance. The results from this study suggested that WAAM is a potentially viable fabrication method to produce pipe components with improved mechanical performance compared to cast.

2:40 PM

Optimal Charpy V-Notch Placement for Heat-Affected Zone Toughness Evaluation in Welded Steel: *Stephen Kenny*[1]; [1]University of Alberta

The Charpy V-notch (CVN) impact test is the primary method for evaluating fracture toughness in welded steels; however, current qualification standards provide inconsistent guidance for notch placement within the heat-affected zone (HAZ). Recommendations vary between placement at the fusion line, a specified offset, or to maximize HAZ inclusion, leading to uncertainty in whether minimum HAZ toughness was obtained. This study quantifies the effect of notch-tip location on measured CVN toughness and evaluates whether a standardized placement can reliably identify the lowest-toughness region of a welded joint. Three submerged arc welds were produced in 25 mm (1") ASTM A36 plate using a 45° single-V groove geometry with a 1/4" root opening, no land, and backing. Welding was performed in nine passes using 3/32" LA-12K wire and Blue Shield LA-59 flux at 30 V, 500 A, and 10 ipm travel speed. Metallographic examination and microhardness testing confirmed weld-to-weld consistency and characterized weld metal, HAZ subregions, and parent microstructure prior to impact testing. Charpy specimens were prepared such that notch-tip locations progressed in 1 mm increments through the weld metal and HAZ. Five notch locations were evaluated on the vertical fusion boundary and fifteen across the 45° fusion boundary. Specimens were etched using 4% Nital to identify notch-tip position. Five specimens were tested at each location in accordance with AWS D1.1, Option B. Results will establish the relationship between notch placement and measured impact energy and assess whether a single notch placement can consistently capture the minimum HAZ toughness. Fracture initiation behavior will be correlated with specific HAZ subregions to determine their influence on CVN response. Findings are expected to provide practical guidance for HAZ toughness testing and inform future revisions to welding qualification standards, including AWS D1.1, ASME Section IX, and other codes governing impact testing of welded structures.

3:00 PM Refreshments Break (S227)

3:20 PM Plenary 4: See Information Below

4:00 PM

Machining-Driven Microstructure and Hardness Control in Additively Manufactured P91-316L Graded Materials: *Rangasayee Kannan*[1]*;* Thomas Feldhausen[1]; Miguel Hoffmann[1]; Andres Rossy[1]; Peeyush Nandwana[1]; Yukinori Yamamoto[1]; [1]Oak Ridge National Laboratory

Hybrid additive+subtractive manufacturing offers a route to control not only component geometry but also near-surface microstructure. This study examines the influence of machining conditions on microstructure evolution and hardness in additively manufactured P91, 316L, and compositionally graded P91+316L deposits. Following deposition, surfaces were machined using varied spindle speeds, coolant conditions, and part-temperature conditions to determine how machining-induced deformation modifies local microstructure and property response across ferritic/martensitic, austenitic, and intermediate compositions. Microstructural characterization was performed using optical microscopy, scanning electron microscopy (SEM), electron backscatter diffraction (EBSD), and microhardness mapping. Emphasis was placed on the machined surface and subsurface region, where deformation-induced lattice misorientation, quantified using kernel average misorientation (KAM), and hardness gradients were evaluated as functions of alloy composition and machining condition. The results show that machining produces a localized deformation layer whose severity depends strongly on spindle speed, cooling condition, part temperature during machining, and composition. In general, higher spindle speed and reduced cooling increased KAM-inferred stored deformation near the machined surface and produced higher hardness, suggesting important implications for post-fabrication heat-treatment response and recrystallization behavior. Deposit composition also influenced the degree of stored deformation. Ferrite-/martensite-forming compositions generally exhibited lower KAM-inferred stored deformation after machining than austenite-forming compositions. These findings highlight machining as an active microstructure-control step in hybrid manufacturing rather than only a finishing operation. By tailoring machining conditions, localized hardness, deformation gradients, and heat-treatment-responsive near-surface microstructures can be engineered in additively manufactured P91+316L graded materials for high-temperature nuclear and fossil energy components.

4:20 PM

Mechanical Property Sensitivity to Sampling Location in Wire Arc Additive Manufacturing for Pressure Component Qualification: *Mia Abdulla*[1]; J. Eduardo Rocha[1]; Patricio Mendez[1]; [1]University of Alberta

The energy sector relies on scheduled shutdowns to maintain operational integrity, but completing these processes efficiently within time and budget constraints remains a challenge. Unexpected component failures, without readily available replacements, can significantly extend downtime and escalate costs. Wire Arc Additive Manufacturing (WAAM) is being explored as a potential solution. This presentation showcases a case study on the fabrication and qualification process of a 2" CL150 flange using WAAM. Qualification walls were first produced in accordance with the requirements outlined in ASME Section IX, QW-600, following the procedure intended for the fabrication of the flange. The components were produced with ER70S-6 welding wire, classified under SFA 5.18. Deposition was performed using the Lincoln Electric Sculptprint RND WAAM system and its associated modeling software. Following deposition, the flange was machined to meet the geometric requirements specified in ASME B16.5 and was designed to meet the mechanical property requirements associated with SA-105 forged material specifications. However, a knowledge gap remains in how mechanical testing should be performed to reliably qualify WAAM components for pressure service applications. Existing code frameworks separate mechanical testing requirements, particularly Charpy V-notch (CVN) impact testing, between weld metal and the heat-affected zone (HAZ) in traditional welded joints. In additive manufacturing (AM), however, the entire component consists of deposited weld metal. Despite this fundamental difference, there is currently little guidance on selecting representative mechanical test locations within WAAM components. This raises questions regarding how sampling location influences measured mechanical properties and whether conventional qualification assumptions remain valid. This work specifically examines the influence of sampling location, with particular focus on Charpy V-notch (CVN) toughness and tensile properties. This work demonstrates the qualification procedure for WAAM components, and questions conventional testing assumptions derived from traditional welding, particularly regarding Charpy notch placement.

4:40 PM

Fatigue Improvement of Welded Cover-Plates Using High Frequency Mechanical Impact (HFMI) Post-Weld Treatment: *Reza Haghani*[1]*;* Michael Neher[2]; Jeong K. Hong[3]; Mohammad Al-Emrani[4]; [1]HiFIT LLC; [2]HiFIT GmbH; [3]Thornron Tomasetti; [4]Chalmers University of Technology

Many existing steel bridges in the United States require upgrading to support increasing load demands. A widely adopted method for enhancing the flexural capacity of beams is the application of cover plates. The application of High-Frequency Mechanical Impact (HFMI) post-weld treatment for improving the fatigue strength of welded cover-plates to steel beams subjected to cyclic loads is discussed. Additionally, results of numerical analyses conducted to assess the risk of root cracking at the welded terminations are presented. The results demonstrate that HFMI treatment significantly enhances fatigue performance, improving their fatigue strength by more than four detail categories according to International Institute of Welding (IIW) recommendations. Notably, no root cracking is observed in any tested specimens. These findings highlight HFMI treatment as a viable alternative to bolted connections and an effective method for reinforcing and extending the service life of existing structures with welded cover-plates.

5:00 PM

Mechanisms of Vibration-Induced Residual Stress Relief in Large Welded Structures: *Zhe Lyu*[1]; Xincheng Li[1]; Yajing Wang[1]; Shaofeng Sun[1]; Leijun Li[1]; [1]University of Alberta

Vibratory stress relief (VSR) is an emerging technique for mitigating welding-induced residual stresses through controlled mechanical vibration. Compared with conventional post-weld heat treatment, VSR requires substantially less energy and treatment time and can be more readily applied to large or in-situ structures. However, the mechanisms governing vibration-induced stress redistribution remain less understood, and most past studies have been limited to laboratory-scale specimens. This study experimentally and numerically investigates the effectiveness and underlying mechanisms of VSR in largescale welded steel structures. Preliminary trials were conducted on an industrial-scale overlay-welded plate to establish the treatment and measurement procedures. VSR was then applied to an industrial-scale butt-jointed steel plate at frequencies selected from its measured vibration-response spectrum. Residual stresses before and after successive VSR treatments were quantified using the hole-drilling method, while the local vibration response was measured using accelerometers. The results show that VSR effectively reduced peak residual stresses near the weld fusion line, with the majority of the stress relief occurring during the first few vibration cycles. Additional vibration primarily caused localized stress redistribution rather than a uniform reduction across the entire plates. Importantly, regions exhibiting greater displacement amplitudes during vibration generally showed more pronounced residual-stress reduction, indicating that VSR effectiveness is strongly governed by the vibrational mode shape and local dynamic response. A series of coupled thermal–mechanical and dynamic finite element models was also developed to simulate weldinginduced residual stresses and their subsequent redistribution during VSR. The simulations reproduced the experimentally observed stress-redistribution behaviour and provided a framework for evaluating the effects of vibration frequency, amplitude, loading position, structural constraints, and treatment duration.

Session 9: American Council of IIW

Thursday PM | October 22, 2026
S225 | Las Vegas Convention Center

Session Chairs: Pat Hochanadel, LANL; Robert Shaw, Steel Structures Technology Center, Inc.

2:00 PM

The IIW Global Perspective on the Key Trends in Welding and Allied Processes: *Luca Costa*[1]; [1]IIW - International Institute of Welding

The International Institute of Welding was founded in 1948 by Welding Institutes and Associations in 13 Countries, with the goal “to allow exchange of knowledge in the field of welding”. Since then, welding technologies have developed, widened, and embraced allied technologies and related approaches. IIW followed this development and enlarged in membership, having now more than 50 members on the 5 continents, and considered a widened scope to include all welding processes as applied to metallic and polymeric materials, from the nano- to the full-scale, and approaching design, fabrication, repair and life extension, quality management and also covering training and certification. The science and technology excellence in research and industrial institutions constitute the IIW community of experts with over 2000 individuals, meeting at least twice every year to discuss research topics, construction and failure cases and to develop collaborative work in the form of books, ISO standards, recommendations, statements, training guidelines and other industrial tools.The presentation will focus on the welding sector from the IIW’s wide-angled view. Topics covered are updated regularly based on the latest discussions of the IIW Community and deliverables produced.

2:20 PM Invited

Welding Without Redundancy: Evolving ISO 15608 Toward True Weldability-Based Material Grouping: *Michal Bernasek*[1]; [1]C-spec

In fabrication, significant time and cost are often driven by repeated qualification of welding procedures for materials that exhibit essentially the same weldability and performance. While grouping systems are intended to reduce this redundancy, their effectiveness depends on how well they reflect real-world weldability. ISO 15608 established a globally harmonized framework for material grouping, primarily based on chemical composition, with mechanical properties as a secondary consideration. While this approach provides structure and international consistency, it does not always align with demonstrated weldability equivalence observed in qualification testing and industry practice, and in some cases may exclude materials with proven similar performance. This lecture examines the evolution of material grouping systems and compares practical approaches used worldwide, including the long-standing ASME Section IX P-Number system. Emphasis is placed on the need to move beyond rigid composition-based grouping toward systems that better incorporate weldability, qualification test results, and industry experience.Now established as an International Standard, ISO 15608 provides a foundation for further development. Ongoing efforts to consolidate global material listings present an opportunity to evolve the system toward greater technical accuracy, reduced redundancy, and improved efficiency in welding qualification worldwide.

2:40 PM

IIW Structured Efforts for Intelligent Manufacturing: *Yuming Zhang*[1]; Edward (Peng) Wang[2]; [1]University of Kentucky; [2]CASE Western Reserve University

This talk presents the structured efforts of the International Institute of Welding in advancing intelligent manufacturing for welding and allied processes through realtime monitoring, adaptive control, and artificial intelligence. The presentation reviews how IIW has systematically promoted this emerging field through coordinated international activities, including annual symposia on intelligent manufacturing, tutorial and keynote presentations, workshops, panel discussions, topical collections in Welding in the World, and the establishment of dedicated working units. These efforts aim to strengthen collaboration among researchers, industry, and standards communities while accelerating the integration of sensing, data analytics, machine learning, and intelligent control into modern manufacturing systems. The talk also discusses the evolving role of IIW in fostering global cooperation and shaping the future development of intelligent welding and manufacturing technologies.

3:00 PM Refreshments Break (S227)

3:20 PM Plenary 4: See Information Below

4:00 PM

Non-Epitaxial Nucleation in High Energy Density Welds: *Joris Hochanadel*[1]; Boyd Panton[2]; Carolin Fink[2]; Johan Westraadt[2]; John Lippold[2]; [1]Los Alamos National Laboratory; [2]Ohio State University

Iron and nickel alloy systems are commonly joined using dissimilar metal welding techniques. These systems undergo non-epitaxial nucleation where the grains in the weld metal do not share the same orientation as the base metal. It is necessary to analyze this behavior to assist in failure prevention as well as microstructural engineering. This study investigated the role of crystal structure and solidification rate on the nucleation behavior of dissimilar metal welds between iron-nickel electron beam welds and 439 stainless steel-nickel laser welds. The electron beam welds exhibited crystal structure as the main factor contributing to nucleation behavior. When the crystal structures were the same upon solidification, epitaxial nucleation occurred. Dissimilar crystal structures resulted in a potential orientation relationship with the base metal. The laser welds displayed a relationship between solidification rate and average grain size, where higher solidification rates resulted in a higher nucleation rate and therefore finer weld metal grains. A mechanism of nucleation and growth related to undercooling was proposed.

4:20 PM

Curriculum Redesign in Welding Engineering: Industry Endorsements and CWI Exam Preparation: *David Phillips*[1]; [1]Ohio State University

The Welding Engineering program at The Ohio State University is one of only 14 engineering degree programs offered by the institution and is unique nationwide. Although graduates of the program have historically been in high demand across diverse industrial sectors, the program has consistently experienced student enrollments that are disproportionately low relative to workforce needs. This persistent enrollment challenge is largely attributed to negative or limited perceptions prospective students associate with the term welding when evaluating engineering degree options.In response, the Welding Engineering program is implementing two strategic curricular modifications aimed at improving student recruitment and enhancing alignment with contemporary industry requirements. These modifications include the introduction of industry-focused tracks (or endorsements) and the incorporation of curricular content designed to prepare students for the fundamentals portion of the newly redesigned AWS Certified Welding Inspector (CWI) examination. This presentation provides an overview of these two program enhancements.

4:40 PM Invited

Weld Microstructure in Duplex Stainless Steels Using a Novel Waveform-Gas Combination: *Corey Cox*[1]; Andres Fischdick Acuna[1]; [1]Lincoln Electric

Duplex stainless steels (DSS) exhibit distinctive properties which require precise chemical composition and thermal history. Additionally, porosity is a challenge in GMAW of DSS; however, a new gas ($69.75Ar/30He/0.25CO_2$) has emerged for porosity mitigation. The effect of this gas on metal transfer and arc stability was investigated. Consequently, a new waveform was developed to improve operability. This study evaluates the new waveform-gas combination using three DSS filler wires. One-inch-thick plates were welded using austenitic and duplex stainless base materials. Mechanical testing followed ISO 17781, including Charpy V-notch testing at −46°C and ductile-to-brittle-transition-temperature (DBTT) characterization.Weld metal ferrite-austenite phase balance and austenite grain size were analyzed. Results demonstrated that austenite grain area was the primary parameter controlling DBTT, while austenite fraction and grain continuity governed upper shelf energy. These features were strongly influenced by the welding process and base material selection, highlighting the critical role of process control in optimizing toughness.

5:00 PM

An Overview of New Technologies for Joining Dissimilar Materials in the Automotive Industry: *Murali Tumuluru*[1]; [1]Tumuluru Welding Consulting

Sustainability has become a primary driver of changes in automotive design, as countries tighten emissions requirements and broader sustainability targets. To meet the EU goal of climate neutrality by 2050, automakers have spent the past two decades reducing greenhouse gas output both by improving near-term fuel efficiency through mass reduction and accelerating investment in electric vehicle technologies.To cut emissions in the near term, the industry is prioritizing weight reduction without sacrificing passenger safety or manufacturability, using approaches such as advanced high-strength steels (AHSS) and multi-material lightweighting that combines AHSS. These material shifts are also changing how structures are joined. Mixed material designs increasingly rely on non-fusion welding methods to support joining dissimilar material combinations. As alternative lightweight materials continue to expand, joining methods have evolved further. In this talk a review of the predominant joining methods in use today and outlines likely trends based on projected material usage

---

Session 10: Honorary Symposium for Prof. Stephen Liu

Thursday PM | October 22, 2026
S226 | Las Vegas Convention Center

Session Chairs: Zhenzhen Yu, Colorado School of Mines; Juan Carlos Madeni, Johns Manville

---

2:00 PM Invited

New Multi-Principal Element Alloy Brazing Filler Material with Reduced Joint-Clearance Sensitivity: *Zhenzhen Yu*[1]; Benjamin Schneiderman[1]; [1]Colorado School of Mines

Over the past decade, efforts to develop multi-principal element alloys (MPEAs) as brazing filler metals have accelerated, largely because their broad single-phase fields offer exceptional flexibility for melting point control and ductile solid-solution matrices. However, MPEA brazing studies rarely address joint clearance, despite its critical influence on void formation, triaxial stress states, and secondary phase evolution. For traditional nickel-base fillers containing boron or silicon melting point depressants, wide joint clearances often limit solute diffusion, leading to continuous centerline eutectic constituents that are brittle and therefore severely degrade joint performance. This work systematically investigates the joint clearance sensitivity of a new face-centered cubic (FCC) MPEA filler—designed as a boron- and silicon-free alternative—and compares it to a commercial BNi-5 filler brazed under identical thermal cycles on 316L stainless steel. Microstructural characterization revealed that the MPEA filler exhibited an FCC matrix with minor secondary phases whose fraction remained constant regardless of joint clearance, but centerline voids were observed when the clearance exceeded 140 µm. Conversely, the BNi-5 joints exhibited centerline silicide phases that grew progressively extensive with increasing clearance. In single-lap-joint mechanical testing at a 50 µm clearance, the MPEA filler showed improvements of 65% in engineering shear stress, 82% in base material tensile stress, and 460% in elongation over BNi-5. At a wider 100 µm clearance, these relative advantages expanded significantly to 99%, 86%, and 620%, respectively. Crucially, the MPEA-brazed joints consistently shifted the failure location, always failing in the base material at 50 µm and occasionally at 100 µm, whereas all BNi-5 specimens suffered brittle failure at the braze interface. These findings demonstrate the exceptional wide-gap capability of the MPEA filler over traditional nickel-base alternatives.

2:20 PM Invited

From the Metal Transfer Concepts to Industrialized Closed-Loop Control for Laser Wire AM: *Wesley Wang*[1]; [1]GKN Aerospace

The fundamental study of metal transfer in arc welding has been instrumental in the evolution of automated robotic welding. Through welding signals acquisition, real-time data processing, and control algorithms that monitor arc stability, the welding industry successfully implemented closed-loop control system and A.I.based process control. As a variant of welding technology, laser wire additive manufacturing (LWAM) has successfully adopted these control philosophies to achieve industrial-scale manufacturing reliability. Modern LWAM systems employ multiple closed-loop control algorithms to ensure consistent metal deposition, process stability, and robust deposit materials properties. GKN aerospace hot-wire LWAM process incorporates three (3) closed-loop control systems: 1. Laser monitored layer height control by dynamically adjusting wire feed rate; 2. In-situ molten pool size monitoring by an infrared camera and control by regulating the laser power; 3. Interlayer temperature monitoring and control by a scanning infrared pyrometer to manage thermal history and microstructure of deposits. With the assistance of the three closed-loop control systems, engineered Ti-6Al-4V structures can be manufactured while maintaining a stable bridging-mode metal transfer. The deposits exhibited a uniform microstructure dominated by the desirable acicular α-phase, smooth and flat beads, and clean surfaces free from discoloration. The resultant tensile property dataset was subjected to rigorous statistical assessment by Battle's MIDAS methodology, confirming a high level of process robustness and material performance consistency. These results provided crucial support to the development of AMS7009 for LWAM. This progression, from fundamental understanding of metal transfer in welding to the industrialization of closed-loop controlled LWAM, demonstrates how welding science has enabled the large-scale LWAM systems capable of delivering both process stability and certifiable material performance.

2:40 PM Invited

Reducing Cooling Rates in Underwater Wet Welding Through Slag- and Resistance-Based Process Transitions: *Ezequiel Pessoa[1]*; [1]LeTourneau University Underwater wet welding (UWW), particularly flux-cored arc welding (FCAW), is widely reported to produce welds with degraded mechanical properties due to elevated cooling rates and reduced arc stability. These deficiencies arise primarily from bubble dynamics at the arc/weld pool interface, which extract heat rapidly and destabilize the process. Prior work in this research program demonstrated that incorporating submerged arc welding (SAW)-style fluxes into the underwater FCAW process can mitigate these effects. Using a Lincoln Power Wave 455/STT system with CORESHIELD 8 (1/16") wire, over 150 bead-on-plate welds were performed across multiple flux formulations, including commercial fluxes (Lincoln P2000, Sandvik 35WF/15W), crushed electrode coatings, and custom flux-to-epoxy resin blends (35/65 ratio) containing varying CaF_2 content. Results showed that the optimized flux formulation (Data 2) improved voltage stability, reduced cooling rate by 11%, and improved reinforcement-to-penetration width ratio by 36% relative to the unfluxed baseline.Building on these findings, current work investigates electroslag welding (ESW) as a further evolution of this process pathway. ESW eliminates the arc entirely, relying on resistive heating through a molten slag bath rather than direct arc/water contact. This research examines the transition from gas-shielded (FCAW) to slag-shielded (flux-assisted FCAW) to fully resistive (ESW) heat generation as a strategy to progressively suppress bubble-driven heat extraction and arc instability in underwater conditions. By removing the arc as the primary heat source, ESW is hypothesized to further reduce cooling rates and improve weld bead geometry and mechanical performance beyond what flux addition alone can achieve. This work aims to establish ESW as a viable underwater welding process for applications requiring improved metallurgical quality in submerged repair and construction environments.

3:00 PM Refreshments Break (S227)

3:20 PM Plenary 4: See Information Below

4:00 PM Invited

Weld Cracking Susceptibility and Field Performance of High-Chromium Ni-Base Filler Metals for Nuclear Repair Applications: *Davis Wilson[1]*; Eun Jang[2]; [1] Framatome; [2]EPRI

Nickel-base filler metals with approximately 30 wt% chromium are required for nuclear weld repair applications to ensure resistance to primary water stress corrosion cracking (PWSCC), but these higher chromium filler materials have introduced persistent metallurgical challenges related to weldability performance such as cracking (DDC, solidification and liquation cracking) and inconsistent wetting behavior. These challenges have driven successive development from Alloy 52 to 52M and most recently 52MSS-Ta. This presentation reviews the historical weldability issues that prompted each alloy refinement, supported by Framatome's field experience with associated weld failures and weldability testing data, then examines where academic and industry R&D has effectively guided field repair practice and where meaningful gaps remain between laboratory findings and field applications. Drawing on Framatome's ongoing development program with Alloy 52MSSTa, residual shortcomings in weld cracking resistance are discussed alongside additional factors with direct consequences for multipass weld repairs including the influence of deposit cleanliness on welding efficiency, and the effects of dilution with both vintage and modern base materials. Together, these topics illustrate the complex interplay between alloy chemistry, welding process variables, and field conditions that define the current state of practice in nuclear weld repair and the path forward for next-generation nickel-base consumables.

4:20 PM Invited

Electron Beam Brazing of Stainless Steel using Nioro Filler Metal: *Cheryl Hawk[1]*; Amber Black[1]; Andrew Duffield[2]; [1]Los Alamos National Laboratory; [2]Los Alamos National Lab

Furnace brazing offers two advantages which are a protective atmosphere and repeatability. However, it requires the entire components to be placed in the furnace regardless of the braze location. This research compared furnace brazing and electron beam brazing of a 316L stainless steel component. This component required multiple electron beam welds and one small braze. One issue that arose was one of the joint locations was close to the braze hole, which, if the weld was too wide, could plug the braze hole. Furnace brazing after welding was a concern as residual stress built up in the component could cause dimensional changes (distortion). Electron beam welding is a promising method as it locally heats up the area of interest, thus reducing the chance of distortion. Electron beam brazing proved to be more successful than furnace brazing, due to the geometry of the component. The electron beam weld required to join the component was close to the braze hole. Furnace brazing before welding caused the electron beam weld to pick up the NIORO filler metal resulting in cracking due to saturation of gold in the weld and the tubes became plugged. Since furnace brazing was not an option after welding, electron beam brazing proved to be more successful. Electron beam brazing could be conducted after all the welds were made thus no NIORO filler metal was picked up by the weld and cracking was not observed.

4:40 PM Invited

Advances in Deployment of Electron Beam Welding for Heavy Section Components: *Stephen Tate[1]*; [1]Electric Power Research Institute

Electron beam welding shows potential time savings for fabrication of heavy section components. Successful demonstrations have been completed by industry on 200 mm thick cylindrical low alloy steel materials. Significant research has shown the technology is ready for deployment, but we need to address a few remaining topics to fully realize the potential of EB welding. This presentation will cover work on transferring weld parameters between machines and options for repair of potential defects. The transfer of weld parameters between low kV and high kV equipment was performed for both steady state condition and the slope out region of circumferential welds with SA-508 Grade 3 and Grade 4N low alloy steels. Different oscillation strategies were required for high kV and low kV equipment. Evaluation of repair methods was performed by metallography and mechanical property testing for both arc welding and electron beam welding repairs.

5:00 PM Invited

High-Speed Double-Sided Friction Stir Welding of Automotive AHSS: Process Development and Practical PCBN Tool Life: *Muneo Matsushita[1]*; Rinsei Ikeda[2]; Branislav Džepina[3]; Richard Townsend[3]; [1]Jfe Steel Corporation; [2]Osaka University (Formerly JFE Steel Corporation); [3]Element Six (UK) Limited

Double-sided friction stir welding (FSW) with a preheating process using high-frequency induction heating was investigated to enhance the travel speed for welding of automotive advanced high-strength steel (AHSS). Butt joints of 1.6 mm-thick, 1180 MPa-grade steel sheets were employed. A maximum welding speed of 6.0 m/min was achieved without weld defects or lack of fusion, representing a 50% increase compared with the process without preheating and approaching the speed of laser beam welding, one of the primary joining methods in the automotive industry. Metallographic observations revealed that plastic flow in the stir zone was reduced under steep thermal gradients, which became more pronounced at higher travel speeds. The preheating process effectively homogenized the temperature distribution, thereby promoting stable plastic flow and increasing the attainable welding speed. Tool life evaluation was conducted for double-sided FSW without preheating using tools made of polycrystalline cubic boron nitride (PCBN). The tools operated without fracture up to 200 m, demonstrating robust durability. Stable weld quality was maintained up to approximately 100 m, indicating a practical tool life under the present conditions, while progressive wear beyond 120 m gradually affected weld appearance. These results demonstrate the technical feasibility and industrial potential of double-sided FSW for high-speed, high-quality joining of AHSS, while the tool life evaluation highlights the applicability of PCBN tools.

Plenary 4

Thursday PM | October 22, 2026
S225 | Las Vegas Convention Center

Session Chair: Thomas Lienert, T.J. Lienert Consulting, LLC

3:20 PM Plenary

A Robust Framework for Systematic Study of Hydrogen Susceptibility in High-Strength Low-Alloy Steel Welds: *Zhenzhen Yu*[1]; Lydia Hines[1]; Jackson McCloskey[1]; Chen Ni[1]; Matthew Connolly[2]; May Martin[2]; Gregory Ebel[3]; Joe Bundy[3]; Andres Acuna[4]; Ravi Menon[5]; Anoop Samant[5]; Jorge Penso[6]; [1]Colorado School of Mines; [2]NIST; [3]CBMM North America; [4]Lincoln Electric; [5]ESAB; [6]Shell Global

A lack of understanding persists in literature regarding how individual subzone microstructures within complex high-strength low-alloy (HSLA) welds influence hydrogen susceptibility, largely due to the difficulty of isolating these narrow regions for mechanical testing. To address this gap, a robust framework was established for the systematic study of X-series pipeline multipass welds by separating evaluations into the heat-affected zone (HAZ) and weld metal (WM). A comprehensive methodology utilized Gleeble thermomechanical simulation, finite element modeling (FEM), and metallurgical characterization to design specialized single-edge bend (SE(B)) specimens, successfully isolating bulk coarse-grained, fine-grained, intercritical, and reheated HAZ subregions (CGHAZ, FGHAZ, ICHAZ) from X65M and X70M pipes. Fracture toughness tests in 21 MPa gaseous hydrogen revealed that the final thermal cycle dictates toughness, with the final CGHAZ cycle averaging the lowest toughness among all conditions. Complementing the HAZ framework, a systematic WM testing matrix evaluated variations in welding technologies, heat inputs, and filler chemistries. SE(B) specimens from X65 and X70 plates were notched parallel to the welding (WD) and normal (ND) directions to assess microstructural anisotropy impacts. The hydrogen fracture toughness of most WM conditions was comparable to the base metals and consistently exceeded the CGHAZ subzones, with WD notches yielding higher toughness than ND notches. To support both tracks, a robust multi-scale metallurgical characterization procedure implemented targeted etching, optical microscopy, and electron backscatter diffraction. This framework definitively identified that coarser martensite-austenite (M-A) constituents drive toughness degradation in both the WM and HAZ, while the influence of grain boundary ferrite and acicular ferrite depended on notch orientation. Ultimately, this systematic framework provides a foundational methodology for optimizing weld designs tailored to in-service crack paths in hydrogen infrastructure.

Plenary 5

Friday AM | October 23, 2026
S225 | Las Vegas Convention Center
Session Chair: Thomas Lienert, T.J. Lienert Consulting, LLC

8:00 AM Plenary

Advances in Computational Fluid Dynamics Based Welding Process Modeling of Residual Stress, Solidification Cracking, Thermal Damage and Electrode Cooling: *Wei Zhang*[1]; Aryan Aryan[1]; Andrew Tong[1]; Tarasankar DebRoy[2]; Todd Palmer[2]; Tuhin Mukherjee[3]; [1]Ohio State University; [2]Pennsylvania State University; [3]Iowa State University

Many welding process models in the literature consider solely heat conduction and do not directly treat the effect of liquid convection on heat transfer. Instead, such effect is indirectly accounted for using a prescribed heat flux distribution such as the ever-popular Goldak double-ellipsoidal heat source. However, the heat source parameters require calibration against experimental data, thus decreasing the models' predictive capability. This talk first reviews the fundamentals of weld pool convection such as how it affects the fusion zone shape focusing on the role of dimensionless numbers. Then, recent advances in Computational Fluid Dynamics (CFD) based welding process models are discussed using several examples. In Example 1, a well-tested heat transfer and fluid flow model is used to accurately calculate temperature history during laser additive manufacturing. The temperature field is mapped into a mechanical model to predict the residual stress and distortion. The effect of material properties and printing parameters on the residual stress is evaluated. The same approach is used in Example 2 where the susceptibility to unusual occurrence of horizontal fusion zone cracks in laser welds of Inconel 740H and 690 is compared. Example 3 studies the thermal damage to electrical insulation coating during keyhole laser welding of copper hairpins in electric motors. A local CFD melt pool model is used to predict the net laser energy absorbed via Fresnel absorption, which is then used in a global heat conduction model where the temperature evolution in the enamel coating is analyzed. Example 4 studies electrode cooling in resistance spot welding, where thermo-electro-mechanical finite element simulation is coupled with fluid-structure interaction simulation. Taken together, these examples illustrate how the advanced CFD based welding process models can significantly enhance the predictive capability, which are crucial for computer aided engineering and optimization to achieve defect free and sound welds.

Session 11: High Energy Density Welding

Friday AM | October 23, 2026
S224 | Las Vegas Convention Center

Session Chairs: Todd Palmer, Pennsylvania State University; J. Eduardo Alvarez Rocha, University of Alberta

8:40 AM

Optimizing Pulsed Laser Beam Welding Parameters for Stainless Steel Turbine Shaft Repair: *Andrew Iams*[1]; Derek Shaffer[2]; [1]National Institute of Standards and Technology; [2]Phoenix Laser Solutions

Worn turbine components often require costly replacements with long lead times. Pulsed laser beam welding (PLBW) provides a low-heat-input repair approach that can minimize distortion while reducing repair time and cost relative to conventional methods. A computational and experimental approach was used to optimize PLBW parameters for repairing a 422 stainless steel turbine shaft using 410 stainless steel filler metal. The processing conditions were tailored to achieve the desired microstructure and properties without requiring post-weld heat treatment.

9:00 AM

Advancements in Handheld Laser Welding (HLBW) for Multi-Pass Butt Joint Applications: *J. Eduardo Alvarez Rocha*[1]; Ivan Pigozzo[1]; Felipe Castro Cerda[2]; Patricio Mendez[1]; [1]Canadian Centre for Welding and Joining; [2]University of Santiago de Chile

Multi-pass butt joints for pressure-retaining equipment have traditionally been produced using conventional arc welding processes such as SMAW, GMAW, and GTAW. In contrast, handheld laser beam welding (HLBW) has so far been primarily associated with single-pass welding of thin sections. This perception limits the consideration of HLBW for thicker components typically found in pressure-service applications. However, recent work indicates that multi-pass HLBW can be used to weld thicker sections with unprecedented high impact properties in comparison to arc welding. This study presents a comprehensive assessment of multi-pass HLBW for pressure-service applications by combining laser beam characterization, mechanical testing, and microstructural characterization to provide insights to the strengthening mechanisms at play. The influence of key variables including power, beam angle, travel speed, spot size, and shielding gas is evaluated in relation to penetration mechanism, weld bead profile, and mechanical properties. The parameters examined are linked to ASME Sec. IX qualification requirements, which define essential and non-essential variables for laser beam welding (LBW) and low-power-density laser beam welding (LLBW). LBW encompasses both keyhole and conduction-mode welding, while LLBW is restricted to conduction mode. These defined penetration modes are not explicit to HLBW since the penetration mode can transition between keyhole and conduction modes depending on power, spot size, travel speed, and beam orientation. Practical concerns are also raised regarding the applicability of existing variables to a handheld process. The results aim to demonstrate the process, microstructure, and property relationships to support the identification of the essential and non-essential variables in HLBW.

9:20 AM

Vacuum Chamber Wobble Laser Welding Development for Purge-Tube Seals and Lunar Regolith Affected Aluminum Welds: *Jonah Duch*[1]; Brett Tucker[1]; Jack Herrmann[1]; Andrew O'Connor[2]; [1]Sandia National Labs; [2]NASA

Laser welding of aluminum under vacuum or an inert gas atmosphere requires an enclosed chamber with laser transparent windows. Such chambers enable both final seal welds for controlled atmosphere hardware and realistic space welding simulations. However, the altered pressure environment from vacuum pumping and pressure spikes from vaporization produces unexpected changes in weld physics that must be studied. To address these needs, we developed two scalable vacuum chamber laser welding rigs, a smaller one for spot wobble welds on purge tube seals, and a larger chamber for linear welds. The smaller chamber was used to develop spot wobble laser welds on purge tubes, which are typically sealed using an arc weld. These final seals do an excellent job of containing a controlled atmosphere, but the high heat input, large weld size, and limited re-usability of traditional arc welds can be improved with laser welding. In our experiments, this chamber enabled laser welds that surpassed conventional arc welds in heat input, bead size, and potential for reuse. However, process control must be altered to address shock from laser welds. The larger chamber utilizes a 125mm window for linear welds, and offers a versatile testbed for realistic space welding scenarios, specifically for aluminum welds in lunar conditions. Laser welding in space is an active research space, but the effect that lunar regolith has on aluminum weld quality is unknown. We used various simulated lunar and Martian regolith samples to emulate these environments and determine the effect of extraterrestrial soil on aluminum weld quality, morphology, and cracking behavior. The weld setup, experiments, and analysis will be discussed. Overall, this platform establishes a foundation for further investigations into laser welding under extraterrestrial environment constraints necessary for future lunar and Martian habitats.

9:40 AM

Laser Hybrid Tack Welding of HSLA Steel Fillet Weld Joints: Microstructure Influence in Final Weldments: *Benjamin Schneiderman*[1]*;* Jonathan Roberts[2]; Kevin Roossinck[2]; Zhenzhen Yu[1]; [1]Colorado School of Mines; [2]Ingalls Shipbuilding

Handheld laser welding systems can produce small fillet welds with deep penetration, offering a convenient alternative to conventional methods for shipbuilders looking to eliminate oversized tack welds when joining large sections of high-strength low-alloy (HSLA) steel plate. This technique is particularly beneficial because the low heat input minimizes part distortion while providing highly localized joint restraint prior to the main welding pass, e.g., with flux cored arc welding (FCAW). However, the influence of handheld laser tack welding on the final weldment microstructure and impact toughness has not been fully explored. This work investigated laser tack fillet welds of HSLA-65 that were subsequently over-welded by conventional FCAW. While the high heat input of the FCAW process successfully consumed and re-melted the vast majority of the laser tack weld metal, certain joint geometries and local variations in fit-up led to the retention of a re-heated but un-melted zone of tack weld metal near the weld root, spanning 1–2 mm2 in cross-sectional area. Optical microscopy identified this unconsumed zone as the primary region of interest for potential debits to weldment impact toughness. Metallurgical characterizations revealed that while the unconsumed laser tack weld displayed microhardness similar to equivalent FCAW heat-affected zone regions in untacked base material, it exhibited distinct microstructural features. Specifically, higher fractions of upper and lower bainite along with a 50–70% increase in the area fraction of martensite-austenite (M-A) constituents were observed. These localized microstructural features suggest a heightened susceptibility to embrittlement within the small unconsumed tack zones. The absence of unconsumed tack weld metal in majority of the specimen sets suggests strategic manual positioning of the handheld laser may mitigate the unconsumed zone. Alternatively, within the identified laser parameter windows, increasing the wobble parameter may create shallower and wider pool geometries more likely to be completely re-melted by FCAW.

10:00 AM Poster Session 2 (Location: TBD) & Refreshments (S227)

10:30 AM Invited 2: See Information Below

11:00 AM Invited

New Opportunities for Laser Welding: From Thin Sheet to Heavy Fabrication: *Zack Sanders*[1]; [1]Civan Lasers

For many years, laser welding has been primarily associated with thin-gauge materials and high-volume manufacturing industries such as automotive production. While laser systems offered advantages in speed, precision, and automation, limitations in penetration depth, process stability, gap tolerance, and weld quality restricted broader adoption in heavy fabrication industries. Recent advances in laser technology are changing this landscape. The availability of high-power laser systems, combined with new beam delivery and dynamic beam shaping capabilities, has significantly expanded the application space for laser welding. These developments enable improved control of keyhole behavior, melt pool dynamics, heat distribution, and penetration characteristics, allowing laser welding to address challenges traditionally managed by arc welding, laser hybrid welding, and electron beam welding processes. This presentation reviews the technological advancements that are driving the transition of laser welding from thin-sheet applications to heavy manufacturing environments. Industrial welding examples covering carbon steel, stainless steel, aluminum, and copper will be presented, including applications in structural steel fabrication, shipbuilding, energy infrastructure, transportation, and defense manufacturing. Representative results include thick-section welds, reduced heat input fabrication, low-distortion joining, and high productivity welding solutions for demanding industrial applications. The discussion will focus on how increased laser power and advanced beam control influence process stability, weld quality, productivity, and manufacturing economics. The presentation concludes with an outlook on the future role of laser welding in heavy fabrication and examines how recent technological developments are enabling laser-based joining solutions in applications that were previously considered beyond the practical limits of laser welding.

11:20 AM

A Study of Distortion in Handheld Laser Welding of SS304L: *Brett Tucker*[1]; Jonah Duch[1]; Adam Youtzy[1]; [1]Sandia National Laboratories

Handheld laser welding is becoming an increasingly popular advanced manufacturing technology. This technology utilizes a wobble laser to weld a larger area than traditional laser welding. The portability and ease of use with no formal welding training make handheld laser welding highly approachable and a great substitute for arc welding. Handheld laser welding also touts benefits such as lower heat input and smaller weld profiles than arc welding resulting in lower distortion. Weld distortion is a common problem with low thermal conductivity metals such as stainless steel. As such, handheld laser welders are not only useful for their ease of use, but as important tools in welding difficult metals. However, little work has been done to quantify the difference in distortion between arc welds and these handheld laser welders, which use a high powered gaussian (“single-mode”) beam. In this work, handheld laser welding of SS304L plate was studied and compared to handheld gas metal arc welds. A process parameter map of weld power, travel speed, and plate thickness was performed. A press brake was used to manufacture 12” x 6” plates into “Z” shapes. The “Z” shaped plates were scanned with a Creaform Handyscan Black Elite high-resolution 3D scanner before and after welding to quantify distortion. Resulting microstructure and properties were studied and compared to arc welds. Temperature data collected during the tests also provided insight into heat input differences. Differences in distortion will be discussed as well as the practical considerations that must be made to implement this technology for production. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy’s National Nuclear Security Administration under contract DE-NA0003525.

11:40 AM

Electron Beam Welding of Ultra-Pure Niobium Structures for Superconducting Radiofrequency Cavities: *Richard Li*[1]; Boyd Panton[1]; [1]Ohio State University

Electron Beam Welding (EBW) is the primary joining process in the fabrication of superconducting radio frequency (SRF) cavities from ultra high purity niobium. In order to produce target accelerating gradients and quality factors in SRF cavities, stringent metallurgical and surface conditions are required to maintain the superconducting effect in niobium. This work presents a characterization of EBW process parameters and its effect on weld geometry across three different joint configurations: edge, fillet, and pipe welds. Weld characteristics including penetration, crown width, root width, and area were evaluated along with the effect of thermal preheat accumulation during circumferential welds. The EBW process was simultaneously modeled on Simufact Welding to simulate thermal history and benchmarked against experimental results.

12:00 PM Invited

Integrated Modeling and In-Situ Strain Validation of Solidification Cracking in Laser Welding of High-Strength Aluminum Alloy: Wei Zhang[1]; *Zenan Zhang*[1]; Paul Blackhurst[1]; Boyd Panton[1]; Calvin Stewart[1]; [1]Ohio State University

Solidification cracking is strongly influenced by the local thermo-mechanical response in the mushy zone during welding. Although there exist several criteria to evaluate cracking susceptibility based on composition variation and liquid feeding, the applications of these criteria are largely qualitative. A reliable prediction of solidification cracking requires a quantitative description of the process-related local stress-strain evolution. This study performs Houldcroft weldability tests with autogenous laser welding at different travel speeds on Al 7075 fishbone samples. In-situ Digital Image Correlation (DIC) is used during welding to measure the transient strain field. A molten pool fluid flow calculation is integrated with a thermo-mechanical finite element model to obtain the mushy-zone thermal history and stress-strain behavior. Existing cracking criteria are applied within this integrated framework to quantitatively assess the local tendency of crack formation. The numerical simulation results are validated against post-weld metallography and DIC-measured strain history, providing guidance for improving model predictions of cracking under local restraint and thermal gradient variations.

12:20 PM

Evaluating Conduction and Beam-Oscillated Keyhole Modes in Hot Wire Laser Welding of AA6061-T6 Thin Sheet: *Paul Blackhurst*[1]; Boyd Panton[1]; [1]Ohio State University

Joining of thin sheet metals has traditionally had challenges with melt-through, distortion, and cracking. These issues are accentuated with aluminum alloys due to their high coefficient of thermal expansion and susceptibility to solidification and liquation cracking. Hot wire laser welding (HWLW) is a novel joining method that achieves acceptable fusion for thin sheet aluminum while minimizing heat input and distortion. In this study, conduction mode HWLW and beam-oscillated keyhole mode HWLW were investigated for use in HWLW of thin sheet AA6061-T6. The oscillated keyhole mode beam had a spot diameter of 0.560 mm, and the conduction mode beam had a spot diameter of 3 mm with no beam oscillation. Process windows for beam-oscillated keyhole mode were developed. The keyhole mode welds produced deeper penetration with less power than conduction mode. Keyhole mode welds exhibited greater performance in strength, elongation, and processing efficiency compared to the conduction mode welds.

Session 12: Wire-Arc Additive Manufacturing

Friday AM | October 23, 2026
S225 | Las Vegas Convention Center

Session Chairs: Gentry Wood, Apollo Machine & Welding Ltd.; Eun Jang, EPRI

8:40 AM

Development of Grain Refinement Technologies in Ti-6Al-4V using Advanced Pulse GTAW and Inter-layer Ultrasonic Peening: *Garrett Anders*[1]; Boian Alexandrov[1]; [1]Ohio State University

Titanium and its alloys, namely Ti-6Al-4V, are commonly utilized in aerospace applications because of their high strength-to-weight ratio, corrosion resistance, and elevated temperature performance. Additive manufacturing (AM) is experiencing rapid growth in industry. Gas tungsten arc welding direct energy deposition (GTAW-DED) is one method to produce AM Ti-6Al-4V components. Additively manufactured Ti-6Al-4V components and multi-pass Ti-6Al-4V weldments exhibit large columnar β grains that grow epitaxially and exhibit coarse texture. It is difficult to achieve comparable properties to wrought and forged components. Significant effort is spent to explore methods of microstructural refinement in Ti-6Al-4V components. Previous research into grain refinement methods in titanium fusion welding includes beam and arc pulsation, inter-layer deformation, and alloying additions such as boron, beryllium, silicon, and yttrium. This research is aimed at evaluating advanced pulse gas tungsten arc welding and inter-layer ultrasonic peening to mitigate the negative effects of multi-pass welding and AM on Ti-6Al-4V. For this study, single-pass thick Ti-6Al-4V walls were deposited using GTAW and 0.045" Ti-6Al-4V wire on a matching Ti-6Al-4V substrate. The welding current was pulsed with varying conditions to explore the effects of amplitude and pulse frequency. Data acquisition of arc current and voltage was taken. Metallographic analysis was conducted transverse and longitudinal to the welding direction. Experimental testing found that advanced pulse waveforms had little improvement on mechanical properties and microstructure in Ti-6Al-4V weldments. The negative effects of epitaxial nucleation and growth were not obstructed. Inter-layer ultrasonic peening was investigated as an additional approach, with further exploration of its effects on microstructure ongoing. Future work will include a deeper study into ultrasonic peening parameters and the addition of inter-layer compressive rolling.

9:00 AM

Case study: Applicability of Wire-Arc Additive Manufacturing (WAAM) in the Replacement of Water Intake Pump Rotor on Oil Platforms: *Diandro Fernandes*[1]; Elias de Lima[1]; Louriel Vilarinho[1]; [1]Federal University of Uberlândia

Aluminum is an indispensable material in the offshore sector, valued for its unique combination of properties that make it ideal for diverse applications, such as high strength-to-weight ratio, corrosion resistance, and recyclability. In this sector, it is commonly used in housings for sensors, control systems, and other components. The advent of Additive Manufacturing, combined with reverse engineering techniques, enables the on-demand production of commercially unavailable replacement parts in a customized way, increasing cost efficiency and sustainability in the oil, gas, and biofuel industry by reducing lead time. Therefore, this work aims to demonstrate the applicability of Wire-Arc Additive Manufacturing (WAAM) through a case study developed for the replacement of a water intake pump rotor manufactured from an aluminum-magnesium alloy.Through a reverse engineering process, which included 3D scanning of a similar unit available on-site and its modeling using Design for Additive Manufacturing (DfAM) techniques, an appropriate methodology was established for the printing, joining, and post-processing stages. This made it possible to obtain a component with 97.8% similarity to its digital twin, proving the applicability of WAAM in the manufacture of obsolete components and replacement parts.

9:20 AM

Estimation of Thermokinetic Parameters in WAAM-Fabricated ER308L Stainless Steel Using Infrared Thermography: *Karem Tello*[1]; Martin Cisternas[1]; Fernanda Sotelo[1]; Felipe Sandoval[1]; Mauricio Solis[1]; Felipe Soto[1]; Manuel Olivares[1]; [1]Universidad Tecnica Federico Santa Maria

Wire Arc Additive Manufacturing (WAAM) involves complex thermal cycles that strongly influence solidification conditions and the resulting microstructure. Understanding how these thermal conditions evolve during multilayer deposition is important for establishing relationships between processing parameters and material response. This work evaluates the use of infrared thermography to estimate thermokinetic parameters during the fabrication of ER308L stainless steel walls produced by WAAM. Thermographic data were collected during the deposition of a 15-layer wall. Python-based scripts were developed to extract temperature profiles at the center of each deposited layer and process the corresponding cooling cycles. The experimental thermal histories were analyzed using Rosenthal's analytical solution for a moving point heat source on a thin plate to estimate the effective thermal power (Q) associated with each deposited layer. In addition, thermal gradients in the liquid region (GL) and solidification rates (R) were estimated from melt pool dimensions and transverse temperature profiles for selected layers located at the bottom, middle, and top of the wall.The results showed a progressive increase in effective thermal power from 874 J/s in the first layer to 2256 J/s in the fifteenth layer, indicating the cumulative effect of heat accumulation during multilayer deposition. At the same time, the thermal gradient decreased from 61.7 K/mm to 31.8 K/mm between the first and last analyzed layers. Solidification rates also decreased with wall height, from 3.21 mm/s in the first layer to 1.47 mm/s in the upper region of the wall. These trends are consistent with the reduction in cooling conditions caused by progressive substrate preheating during the WAAM process. The proposed methodology demonstrates that infrared thermography combined with analytical thermal models can provide quantitative information regarding thermal conditions and solidification behavior during WAAM.

9:40 AM

Impact of Weld Wire on WAAM Parameter Development: *Jeff Kikel*[1]; John Ryan[1]; [1]AML3D

Wire Arc Additive Manufacturing (WAAM) has seen significant growth across the Navy industrial supply base in an effort support the Navy's accelerated ship building plan. Due to long lead times and poor quality, shipyards and their supplier have turned to WAAM. Meeting required quality and mechanical property requirements consistently has been a challenge across the industrial supply base. As the leading supplier of WAAM systems and software in North America, AML3D has found that weld wire from different manufactures perform differently and require parameters to be tuned to the specific weld wire being used to obtain consistent arc stability and puddle characteristics. Depending on the alloy being used parameter tuning may require minor adjustments to arc length or pulse frequency correction. In extreme cases, different synergic lines or shielding gas composition may be required to achieve the required arc stability and puddle characteristics.

10:00 AM Poster Session 2 (Location: TBD) & Refreshments (S227)

10:30 AM Invited 2: See Information Below

11:00 AM

Microstructure and Strength–Ductility Behavior of Layered Multi-Material Steels Deposited by Wire Arc Additive Manufacturing: *Bishal Silwal*[1]; Christin Stibitz[1]; [1]Georgia Southern University

Wire Arc Additive Manufacturing (WAAM) was utilized to fabricate a dissimilar steel composite—comprising three layers of LA-100 high-strength low-alloy (HSLA) steel and one layer of 316L stainless steel to investigate the system's combined strength–ductility behavior. A defect-free wall structure (approximately 206 mm × 15 mm × 150 mm) was successfully deposited with sound metallurgical bonding. To assess anisotropic mechanical properties, including yield strength, ultimate tensile strength, and elongation, tensile specimens were tested in both horizontal and vertical orientations. Furthermore, microstructural characterization and hardness mapping were conducted to analyze phase evolution, grain morphology, and interfacial diffusion. This study provides foundational insights into the mechanical performance and interfacial characteristics of layered, multi-material WAAM structures.

11:20 AM

Wire Arc Additive Manufacturing Capability Development: Process Evaluation and Software Toolchain Integration: *Tao Dai*[1]; [1]LeTourneau University Wire Arc Additive Manufacturing (WAAM) is an emerging advanced manufacturing technology. In 2024, LeTourneau University acquired two new Yaskawa welding robots to strengthen welding engineering education and training. These robotic platforms provided an opportunity to establish WAAM capabilities within the welding engineering program. To achieve this goal, a senior design project was launched during the 2025–2026 academic year.** The first phase of the project investigated the feasibility of employing three Gas Metal Arc Welding (GMAW) metal transfer modes—Cold Metal Transfer (CMT), Regulated Metal Deposition (RMD), and Surface Tension Transfer (STT)—for WAAM of duplex stainless steel (DSS) 2209. Vertical wall specimens were fabricated and evaluated through visual inspection, metallography, hardness testing, tensile testing, and impact testing. Among the three processes, CMT yielded the highest-quality deposits, exhibiting excellent surface finish and no observable spatter or internal defects. RMD and STT produced deposits with varying levels of spatter but showed no lack of fusion, porosity, or cracking. All walls displayed similar hardness distributions and ferrite numbers near 40. Impact toughness averaged approximately 100 ft-lbs for CMT wall and 82 ft-lbs for both RMD wall and STT wall, while ultimate tensile strengths exceeded 105 ksi for all specimens. No significant anisotropy was observed in either toughness or tensile properties. **The second phase focused on developing an integrated WAAM software toolchain that combines Fused Deposition Modeling (FDM)inspired slicing strategies with industrial robotic welding. A custom WAAM slicer was developed and the RoboDK post-processor was used to address limitations of conventional FDM software and provide enhanced control over heat input, bead geometry, seam placement, and contact-tip-to-work distance. Validation through fabrication of increasingly complex geometries demonstrated improved process stability, reduced programming effort, and repeatable deposition performance. The resulting workflow establishes a practical and scalable foundation for future adaptive and multi-axis WAAM systems.

11:40 AM

Wire Arc Directed Energy Deposition of High-Strength Steels: Ruslan Kim[1]; *Kaue Riffel*[1]; Antonio Ramirez[1]; [1]Ohio State University

Wire-Arc Directed Energy Deposition (DED) is an additive manufacturing process that enables the efficient fabrication of large-scale metallic components due to its high deposition rates and compatibility with existing arc-welding infrastructure. This work presents the ongoing development of wire-arc DED of high-strength steels (HSS), focusing on the initial process-development stage and the planned research pathway. The study is motivated by the growing demand for HSS in structural applications such as defense systems and subsea oil and gas tooling and connectors, where high strength, toughness, and manufacturing efficiency are critical requirements. The project encompasses the evaluation of high-strength filler metals in both metal-cored and solid-wire forms, optimization of deposition parameters and thermal management strategies, and comparison of as-built and post-deposition heat-treated conditions. Performance targets include yield strength exceeding 100 ksi while maintaining adequate ductility, impact toughness, and process productivity. Current efforts are centered on establishing robust deposition conditions, selecting suitable process variants, and generating the experimental foundation for subsequent microstructural characterization, mechanical testing, and heat-treatment optimization. Future activities will include the assessment of residual stresses, proof-of-concept component fabrication, and the development of productivity-enhancement strategies, including active cooling approaches to reduce idle time while maintaining interpass temperature control. The work outlines a pathway toward the implementation of high-performance wire-arc DED of HSS for industrially relevant applications.

12:00 PM

Trailblazing Multi-Material Structure (MMS): Molybdenum Alloy (TZM) to Titanium Alloy (Ti64) Using Wire-Arc Additive Manufacturing: *Sainand Jadhav*[1]; [1]Kennesaw State University

This study presents the fabrication and characterization of bimetallic TZM–Ti6Al4V (Ti64) thin-wall structures produced using Wire Arc Additive Manufacturing (WAAM). The objective was to evaluate the feasibility of joining a refractory molybdenum-based alloy (TZM) with a titanium alloy (Ti64) and to assess the resulting microstructural, mechanical, and corrosion properties of the multi-material system. Optical microscopy and scanning electron microscopy (SEM) revealed the formation of a continuous and defect-free metallurgical interface, free from cracks, porosity, and other processing-induced defects. A narrow transition region was observed at the interface, indicating limited elemental diffusion and effective metallurgical bonding between the dissimilar alloys. Microhardness measurements demonstrated a clear variation across the bimetallic structure. The TZM substrate exhibited relatively uniform hardness values ranging from 225 to 235 HV, whereas the Ti64 deposit showed significantly higher hardness values between 340 and 385 HV. A localized hardness reduction was observed near the interface, followed by a sharp increase within the Ti64 region, reflecting the influence of compositional gradients and microstructural evolution across the transition zone. The absence of excessive hardness peaks suggests that no brittle intermetallic phases formed during deposition. Mechanical testing indicated that the fabricated structure exhibited continuous strain hardening behavior, achieving an ultimate tensile strength of approximately 330 MPa and a total elongation of about 7.5%. Fracture occurred after substantial plastic deformation, indicating a favorable balance between strength and ductility. Electrochemical corrosion testing showed that Ti64 possessed the highest corrosion resistance, while TZM exhibited the highest corrosion rate. The TZM–Ti64 bimetallic structure displayed intermediate corrosion behavior, with improved corrosion resistance compared to TZM due to the presence of a sound metallurgical interface and stable passive oxide films. Overall, the results demonstrate the feasibility of producing TZM–Ti64 multi-material structures by WAAM for potential high-temperature and structural engineering applications.

12:20 PM

Hot Deformation Behavior of Wire-Arc Additively Manufactured 316L Stainless Steel under non-isothermal conditions: *Bishal Silwal*[1]; Christin Stibitz[1]; [1] Georgia Southern University

This study investigates the hot-compression behavior of 316L stainless steel fabricated via Wire Arc Additive Manufacturing (WAAM) to evaluate its viability as a preform for subsequent forging operations. To ensure stable thermo-mechanical boundary conditions, a custom closed-loop, temperature-controlled platen system was utilized. Preheated specimens were compressed at elevated temperatures under strain rates of 0.01 s^{-1} and 0.1 s^{-1}. Flow stress analysis revealed that friction induced barreling led to uneven deformation, causing an 8–10% overestimation of flow stress prior to geometric correction. Furthermore, finite element simulations highlighted pronounced non-isothermal fields: lower strain rates (0.01 s^{-1}) resulted in significant cooling due to prolonged die contact, while higher rates (0.1 s^{-1}) maintained elevated core temperatures via adiabatic heating. Finally, microstructural characterization using EBSD was conducted to investigate the underlying microstructural evolution and deformation mechanisms of the preform under these specific processing conditions.

Session 13: Modeling and Simulation

Friday AM | October 23, 2026
S226 | Las Vegas Convention Center

Session Chairs: Tuhin Mukherjee, Iowa State University ; Ian Wietecha-Reiman, NIST

8:40 AM

Assessment of Critical Phase Transformation Temperatures for Modeling of Welding and Additive Manufacturing: *Nitheesh Kumar Ramasamy*[1]; Felipe Castro Cerda[2]; Patricio Mendez[1]; [1]University of Alberta; [2]University of Santiago de Chile

Phase transformation temperatures are critical input parameters for modeling welding and additive manufacturing. The uncertainty in these temperatures is an important factor in assessing the uncertainty and reliability of process models. In this work, a detailed analysis is performed to determine the uncertainty in the melting range and solid-state transformation temperatures of some key materials of interest. Quantified uncertainty captures the uncertainty from the measurement instrument and the variability in material response. The analysis includes an exhaustive literature survey and computational modeling, including thermodynamics and Scheil-Gulliver models. To provide actionable guidance for process modelers, a novel four-quadrant classification framework is introduced to systematically segregate alloys based on data abundance and statistical variance. The resulting framework helps identify gaps in the data being used in modeling advanced manufacturing processes.

9:00 AM

The Sensitivity of Solidification Cracking Susceptibility Metrics to Modeling Assumptions: *Ian Wietecha-Reiman*[1]; Carelyn Campbell[1]; [1]National Institute of Standards and Technology

One of the critical objectives of alloy selection for welding applications is to minimize the risk of solidification cracking. Various metrics for quantifying solidification cracking susceptibility (SCS) based on thermodynamic simulations have been proposed to facilitate this task. While each metric has been validated to varying degrees, a broader consensus on the application of these tools has yet to be reached. Part of the challenge is a lack of characterization of the sources of variability and uncertainty in these models. A broad evaluation of several prevalent SCS metrics is performed using solidification simulation data generated using the classic Scheil model, fast diffusers, a ferrite to austenite transformation, back diffusion, and solute trapping. These results highlight the need for judicious selection of the solidification model and parameters when designing weldments.

9:20 AM

Computational Alloy Design of P91-Type Steels for Virtual Manufacturing and Qualification: *Yousub Lee*[1]; Bhagya Prabhune[1]; Rangasayee Kannan[1]; Yukinori Yamamoto[1]; William Carter[1]; Chris Masuo[1]; Aslan Nasirov[1]; Andrzej Nycz[1]; Srdjan Simunovic[1]; [1]Oak Ridge National Laboratory

Ferritic-martensitic steels containing 9-12 wt.% Cr are key structural materials for harsh environments in fossil and nuclear energy applications. To optimize F-M steel made using wire-arc Direct Energy Deposition (DED), adjusting the phase transformation temperature and material properties by modifying P91's composition is necessary. Current parameter development and part qualification strategies in wire-arc DED such as operator-driven trial-and-error or extensive experiments are a major bottleneck for rapid adoption of new alloys and scaling of critical parts. Nonlinear physical interactions among alloy composition, energy input, process parameters, and part geometry make a prediction highly complicate and intensive. With broad compositional specifications (13-18 independent elements), AM printability and performance can vary largely. One specification may lead to cracking, poor high-temperature properties, or weak deformation resistance depending on actual composition within the specification window. In this research, we investigated alloy-process-material-microstructure-performance relationships in the high-dimensional composition spaces of P91. Using Latin Hypercube Sampling, more than 1000 candidate compositions were generated within ASME/ASTM specification ranges and evaluated using JMatPro and Thermo-Calc to predict the thermophysical and mechanical properties. Composition-induced variability was quantified using coefficient of variation. The results showed that the coefficient of thermal expansion shows the highest overall sensitivity to composition followed by specific heat. A normalized "composite score" combining distortion score, high-temperature score, and cracking score, ranked candidate alloys for the initial screening of candidate compositions. Based on this score, the top 10 balanced compositions were chosen and evaluated through multi-physics simulations to assess their performance in practical manufacturing scenarios. Noticeable changes in G/R space indicate that composition strongly affects thermophysical behavior and microstructure evolution during wire-arc DED. Ongoing work will evaluate distortion and residual-stress responses using experimentally relevant process parameters.

9:40 AM

Design for Wire Arc Directed Energy Deposition Process Using an Analytical Framework: Birendra Barik[1]; *Amitava De*[2]; [1]Veer Surendra Sai University of Technology Burla; [2]Indian Institute of Technology Bombay

Wire arc directed energy deposition (DED-Arc) process is increasingly attempted for layer-by-layer fabrication of large, near net shape metallic components due to its high deposition rate and flexibility to automation. The ongoing attempts to adopt DED-Arc process for versatile applications are notably dependent on the finite element and finite volume method based numerical simulation models, which are used to compute the transient temperature field, cooling rate, and melt track dimensions for a given DED-Arc process conditions. Although these models have helped in basic mechanistic understanding, they struggle enormously due to massive computational demand. We propose here a three-dimensional analytical heat conduction model with temperature-dependent material properties and volumetric heat source to compute the transient temperature field and reconstruct the DED-Arc deposit profiles reliably and rapidly. The model is validated against experimentally measured results for DED-Arc of multiple filler wire alloys, and a range of process conditions. Most importantly, the analytical model can simulate the temperature field several orders of magnitude faster than the contemporary numerical simulation models. Building on this foundation, the present work proposes further to use the analytical model as a forward evaluator within a parametric design space for identifying suitable process conditions and scanning strategy for part-scale DED-Arc. The analytical model in conjunction with suitable defect predictor metrics can help design part-scale DED-Arc, and select the process condition and scanning strategy. In turn, a seamless generation of the robot code for final printing can be achieved rapidly. Overall, this work demonstrates, through a set of scanning strategy and process parameter combinations, that the analytical framework can meaningfully narrow the design space and serve as a substantive off-line design tool for part-scale DED-Arc.

10:00 AM Poster Session 2 (Location: TBD) & Refreshments (S227)

10:30 AM Invited 2: See Information Below

11:00 AM

Variations in the Thermophysical Properties Used in Welding Simulations of Austenitic Stainless Steels: *Ian Wietecha-Reiman*[1]; Todd Palmer[2]; Tarasankar DebRoy[2]; [1]National Institute of Standards and Technology; [2]Pennsylvania State University

Essential variables for laser and electron beam welding processes are developed and transferred into a production environment through experimental trial-anderror approaches. To achieve high levels of precision and repeatability during production, welding simulations are beginning to be incorporated to accommodate minor variations in processing parameters. However, the thermophysical properties used in these simulations are often not representative of the composition of the incoming material but are instead compiled from numerous sources studying different materials, introducing uncertainty. Alternatively, thermodynamic simulations can be incorporated to predict composition- and temperature driven variations in these properties. Analysis of these results demonstrated that in addition to Cr and Ni composition, the elements Mn, Si, P, S, V, Cu, and Ti may have noticeable or even overwhelming effects on thermophysical properties of interest.

11:20 AM

Rotating-Electrode GTAW for Enhanced Weld Penetration and Pool Convection: *Masoud Paikar*[1]; Daryush Aidun[1]; [1]Clarkson University

Gas tungsten arc welding (GTAW) is widely used for joining metallic materials, but controlling weld penetration and fusion-zone geometry remains challenging, particularly under stationary heat input and in future dissimilar-metal applications. In conventional GTAW, the arc remains fixed relative to the workpiece, which can produce localized heating and limited control of weld-pool circulation. In this study, a rotating-electrode GTAW process is investigated numerically and experimentally to improve weld-pool convection, penetration, and fusion-zone development. A three-dimensional transient model was developed in COMSOL Multiphysics® to simulate stationary spot welding of AISI 1018 steel. The workpiece was modeled as a solid domain with a localized liquid weld-pool region to reduce computational cost while capturing molten-metal flow. Heat transfer was solved in both solid and liquid regions, and fluid flow was solved in the weld-pool domain. Phase change was modeled using the apparent heat capacity method with liquid-fraction tracking. The momentum equation included buoyancy, Lorentz force, Marangoni force, and Carman–Kozeny damping in the mushy and solid regions. The welding arc was represented by Gaussian heat-flux and normal-current-density distributions on the top surface. For rotating-electrode cases, the heat and current input centers rotated around the weld center at prescribed rotational speeds. The electric-current field was solved to obtain current density, and the Lorentz force was calculated from the interaction between current density and magnetic flux density. Temperature-dependent Marangoni shear stress was applied on the top free surface for 0.03 wt.% sulfur steel.Results showed that electrode rotation transforms the weld-pool flow from nearly symmetric circulation to time-dependent rotating flow. The 600 RPM case produced stronger internal convection, deeper penetration, and a larger molten region than the stationary case. Experimental cross-sections from AISI 1018 and AISI 304 welds at 0, 300, and 600 RPM showed increased penetration with rotation, supporting the model predictions.

11:40 AM

Geometry Defect Mitigation and Residual Stress Evolution in Hybrid Directed Energy Deposition–Milling: Chenxing Liu[1]; *Edward Wang[1]*; [1]Case Western Reserve University

Hybrid directed energy deposition (DED) integrated with interlayer milling offers a promising strategy to improve geometric accuracy, process stability, and structural integrity in metal additive manufacturing. This study investigates the hybrid process through a combined experimental and simulation-based framework. On the experimental side, real-world DED trials are performed to identify practical process recipes for reducing geometry defects and improving bead formation. Particular attention is given to process-start behavior and parameter combinations that promote stable liquid-bridge formation, thereby mitigating materialdeposition delay and early-stage geometric inconsistency. On the simulation side, a unified thermo–mechanical finite element framework is developed to analyze residual stress evolution throughout the hybrid DED–milling process. A solver-specific implementation is developed and, for the first time, deployed on the Siemens NX platform. Numerical case studies systematically investigate residual stress formation during deposition, stress redistribution caused by interlayer milling, and the effects of milling frequency and bead removal order on final stress distribution. The results reveal characteristic stress evolution trends, including tensile stress migration during deposition and threshold-like sensitivity to milling frequency.

12:00 PM

Transport Phenomena in Laser Welding in Space: Noshin Tasnim Tuli[1]; Meysam Faegh[2]; Ehsan Setayesh[2]; Andrew O'Connor[3]; Louise Littles[3]; Jeffrey Sowards[3]; Azadeh Haghighi[2]; Tarasankar DebRoy[4]; *Tuhin Mukherjee*[1]; [1]Iowa State University; [2]University of Illinois Chicago; [3]NASA Marshall Space Flight Center; [4]Pennsylvania State University

Laser welding in space presents unique challenges due to the extreme environmental conditions of low gravity, low pressure, and low temperature encountered in near-orbit, lunar, and Martian environments. This work presents a three-dimensional transient numerical model of keyhole-mode laser welding developed to predict weld behavior under such conditions for austenitic stainless steel 316. The governing equations of conservation of mass, momentum, and energy are solved simultaneously, incorporating relevant welding process parameters and thermophysical properties of SS 316 alongside the environmental conditions characteristic of space. The model predicts temperature and velocity fields, keyhole geometry, fusion zone dimensions, thermal cycles, cooling rates, and solidification parameters. Model predictions are validated against available experimental data, demonstrating strong agreement. Parametric studies are conducted to isolate and quantify the individual and combined effects of low temperature, low pressure, and low gravity on weld pool dynamics, keyhole formation, and fusion zone geometry across near-orbit, lunar, and Martian conditions. To provide deeper physical insight into the governing transport mechanisms, the results are further interpreted through key dimensionless numbers, including the Péclet, Marangoni, Fourier, Rayleigh, and Weber numbers, enabling a systematic assessment of the relative contributions of conductive and convective heat transfers and fluid flow. The findings of this work advance the fundamental understanding of laser welding behavior in space and provide a quantitative framework to support the development of in-space manufacturing and repair capabilities for future crewed and robotic space missions.

12:20 PM

Inverse Arc Column Calorimetry Using Feedstock Melt Onset in GTAW: *Nate Sena*[1]; [1]Ohio State University

Accurate prediction of feedstock melting is a practical requirement in wire-fed gas tungsten arc welding (GTAW), especially when metal transfer morphology controls process stability. Existing analytical wire melting models capture the basic heating physics, but they are limited by fixed heat-flux assumptions and simplified process boundary conditions. In real welding conditions, the arc column, filler wire, and melt pool interact such that the effective heat delivered to the wire is not fixed by current and arc length alone. Wire position and wire feed speed also strongly influence the local heating response. This work treats feedstock melt onset as an experimental measurement of local arc heating. Bead-on-plate GTAW experiments were performed across varying current, arc length, travel speed, wire feed speed, wire diameter, and wire entry position. A synchronized imaging and computer vision pipeline was developed to extract the melt-onset datum across a large process dataset. Machine learning-based image segmentation identifies the wire, melt pool, tungsten, and arc region, while downstream geometric parsing measures wire position, melt onset location, melt pool geometry, standoff, and arc geometry on a frame-by-frame basis. In the tested conditions, melt onset shifted by approximately 4 mm in the horizontal direction. Measured melt onset locations were then compared against 2D analytical and numerical feedstock melting simulations. Genetic optimization was used to identify latent arc parameters that best fit the simulated and measured melting behavior. These fitted parameters are used to construct simple geometric representations of arc-column heat flux of amperages ranging from 120A to 240A and arc lengths of 3-8mm. This inverse arc calorimetric approach turns feedstock melting into a datum for heat flux in the GTAW arc column, with direct application to wire placement optimization, dual-wire GTAW control, and real-time melting stability prediction.

Invited 2

Friday AM | October 23, 2026
S225 | Las Vegas Convention Center
Session Chair: Thomas Lienert, T.J. Lienert Consulting, LLC

10:30 AM Invited

A Welder Goes to Washington: Reflections on My Year in the Capitol and a Call to Action: *Todd Palmer*[1]; [1]Pennsylvania State University

In September 2025, I embarked on a year-long sabbatical from my faculty position to become an AAAS Science and Technology Policy Fellow in the Air Force's Operational Energy office. These fellowships are highly sought after and provide hands-on federal policy-making experience to scientists and engineers. My age and experience set me apart from the other fellows, and it was a good time to use my experiences across the national laboratories, industry, and academia to influence policy at a higher level. Even though my fellowship year began with the longest government shutdown in history, I quickly discovered how central materials and welding and joining were to nearly all the policy issues that I encountered. I found materials, joining, and workforce issues, particularly involving the lack of welding professionals across the defense industrial base was a constant theme in staff meetings, congressional hearings, and think tank discussions. There were, however, few experienced and honest brokers available to help the senior civil servants, political appointees, staffers, and elected officials identify policy mechanisms that would address these shortages or help rebuild the domestic manufacturing base. Engaging experts and knowledgeable advocates in policy discussions is critically needed to overcome the paralysis that is afflicting policy makers and to avoid implementing poorly conceived initiatives that are doomed to fail. Welding and joining professionals need to take their place at the table and contribute to the conversation in meaningful ways. Professional organizations can fill some of these roles but are not effectively engaging the different branches of government or the public in a strategic and approachable manner. Well-placed and effective advocacy that is rooted in intellectual expertise can be effective in informing decision makers and ensuring that sound decisions with the long-term interests of the country are made.

Poster Session 1

Thursday AM | October 22, 2026
S227 | Las Vegas Convention Center

Session Chair: To Be Announced

To Be Added

Poster Session 2

Friday AM | October 23, 2026
S227 | Las Vegas Convention Center

Session Chair: To Be Announced

To Be Added