CSAT Meeting AGENDA

Tuesday, June 20, 2023, Meeting Time: 8:00am-6:00pm

Dr. Victor Kenneth Champagne, Jr. (Welcome & Keynote Address) 0800-0830

- Dr. Grace Wang, President of WPI
- Eric Batista, City Manager of Worcester

Session 1: Advancements in Equipment, Materials & Applications (Moderator: Dr. Tim Eden, PennState)

Presenter	Presentation Topic	Time
1. Aaron Nardi, VRC Metal Systems	New Materials and Applications in High Pressure Cold Spray	0845-0915
2. Steven Camilleri, SPEE3D	Value Metrics of Metal "Additive Mfg." For Production	0915-0945
3. Alex Finch, Titomic	Cold Spray AM: Integrated Spray Booth Systems	0945-1015
Exhibit Area	**BREAK AND NETWORKING**	1015-1100
Session 2: Powder (Moderator: Noah Lieb, Jensen Hughes)		
4. John Barnes, Metal Powder Works	Direct Powder Process for CS Additive Manufacturing	1100-1120
5. Joe Heelan, Powders on Demand	Engineered Powders for Cold Spray	1120-1140
6. Casey Jones, ES3	Effects of Gas, Powder & Substrate on CS Performance	1140-1200
Exhibit Area	**LUNCH**	1200-1330
Session 3: Quality Assurance/ Quality Control (Moderator: Daniel Stanley, Norfolk Naval Shipyard)		
7. Emily Lee, NIOSH	Exposures, Health Effects, & Controls of Cold Spray Coating	1330-1350
8. Jussi Larjo, Oseir	Novel Online Particle Sensor for CS Process Monitoring	1350-1410
9. Dr. Tim Eden, PennState	Eliminating Nozzle Clogging in Cold Spray	1410-1430
Exhibit Area	**BREAK AND NETWORKING**	1430-1500
Session 4: Applications (Moderator: Howie Marotto, EWI)		
10. Isaac Nault, ARL	Cold Spray AM of Leading Edges for Extreme Environments	1500-1520
11. Dr. Julio Villafuerte, Centerline	Polyamide (PA) Thermal Barrier Profiles for Window Mfg.	1520-1540
12. Sascha Bernhardt, Impact	Advancement in high-pressure CS equipment & Applications	1540-1600
RECEPTION	**DCU Center Concourse (Poster Session–Exhibits)**	1600-1800

THANK YOU TO OUR PLATINUM SPONSORS

Wednesday June 21, 2023, Meeting Time: 8:00am-5:30pm

Session 5: Science & Technology (Moderator: Dr. Danielle Cote, WPI)

	Presenter	Presentation Topic	Time
1.	Dr. Ozan Ozdemir, Northeastern U.	In-Situ and Ex-Situ Means for Through-Process Control in CS	0800-0820
2.	Dr. Luke Brewer, U. of Alabama	CS & In-Situ Laser Heating for Repair of High Strength Steel	0820-0840
3.	Tanaji Paul, ColRAD FIU	Composition & Microstructure Tailored Al CS Deposits	0840-0900
4.	Richard Thuss, TTEC	Brittle Particle Cold Spray	0900-0920
5.	Sridhar Niverty, PNNL	Localized Surface Modification of HPDC AZ91 Mg Alloy	0920-0940
Exhibit Area		**BREAK AND NETWORKING**	0940-1030

Session 6: Aerospace/ Aviation (Moderator: Marcel Van Wonderen, KLM Engineering & Maintenance)

6.	Benjamin Bedard, RTRC	Elevated Temperature Mechanical Behavior of CS 5056 Al	1030-1050
7.	Sarah Galyon Dorman, SAFE Inc.	Cold Spray for Aircraft Structural Repair	1050-1110
8.	Benjamin Peterson, Honeywell	Cold Spray Repair Development at Honeywell	1110-1130
9.	Bruno Zamorano, Boeing	Cold Spray Aluminum Structural Repair Development	1150-1210
10.	Hugues Francois-Saint-Cyr, ThermoFisher	Functionally Gradient Bimetallic Ni-Cu CSAM Alloys	1210-1230
Exhibit Area		**LUNCH**	1230-1330

Session 7: Power & Energy (Moderator: Jack Lareau, PNNL)

13.	Chris Smith, PNNL	Cavitation Damage in Hydropower Turbines	1330-1350
14.	Carl Friant, Constellation Energy	Mitigation of Flow Acceleration Corrosion in Nuclear Power	1350-1410
15.	Arash Parsi, Westinghouse	Nuclear Power Applications of Cold Spray	1410-1430
16.	Jon Tatman, EPRI	Residual Stress Analysis Corros. Cracking Mitigation & Repair	1430-1450

Session 8: Additive Manufacturing (Moderator: Aaron Nardi, VRC Metal Systems)

17.	Samuel Bedard, EWI	Rapid CS Additive Manufacturing of Robot End Effectors	1450-1510
18.	Michael Schmitt, HAMR	R&D & Sustainment Efforts for CS Additive Manufacturing	1510-1530
Exhibit Area		**BREAK AND NETWORKING**	1530-1550
19.	Leo Ajdelsztajn, GE	LCF Of Cold Spray Ni Superalloys for AM Applications	1550-1610

Session 9: Manufacturing at Point of Need (Moderator: Janice Bryant, NAVSEA)

20.	Daniel Stanley, NNSY	CS Process Qualification in Support of Shipboard Repair	1610-1630
21.	Dr. Tim Eden, PennState	Conducting Shipboard Repairs in Today's Naval Environment	1630-1700
	Dr. Victor Champagne	**Wrap-Up & CSAT 2023 Awards**	1700-1730
RECEPTION		**Polar Park – Worcester Red Sox – Gates Open/ Buffet**	1745-2000

THANK YOU TO OUR HOSTS, CONFERENCE STAFF MEMBERS, SPONSORS & ADVISORY BOARD

Executive Director, Dr. Victor Kenneth Champagne, Jr.
Email: vchampagnejr@gmail.com, Mobile: (774) 334-0842

Associate Executive Director, Dr. Aaron Birt
Solvus Global, 104 Prescott Street, Worcester, MA, 01605
Email: aaron.birt@solvusglobal.com, Mobile: (717) 602-5158

Conference Organizers

Nicole Boyson, Meeting Coordinator
Annette Langan, Sponsorship Coordinator
Andrew McShane, Sponsorship Coordinator
Dr. Caitlin Walde, Conference Director
Dr. Aaron Birt, Associate Executive Dir.
Dr. Victor Champagne Jr., Executive Dir.

CSAT Advisory Board Members

Michael Nicholas	Army Research Lab. ARL-Northeast, MA	DoD Member
Janice Bryant	NAVSEA, Washington, DC	DoD Member
Brian James	Ellsworth Air Force Base, SD	DoD Member
Daniel Stanley	Norfolk Naval Shipyard	DoD Member
Aaron Nardi	VRC Metal Systems, SD	Industry Member
Byron Kennedy	SPEE3D, Australia	Industry Member
Howard Marotto	EWI, Columbus, OH	Industry Member
Dr. Bruno Zamorano	Boeing, AR	Industry Member
Dr. Julio Villafuerte	CenterLine Windsor Limited, Canada	Industry Member
Noah Lieb	Jensen Hughes, MD	Industry Member
Marcel van Wonderen	KLM Engineering & Maintenance, NL	Industry Member
Leonhard Holzgaßner	Impact Innovations, DE	Industry Member
Dr. Danielle Cote	Worcester Polytechnic Institute, MA	Academic Member
Dr. Tim Eden	Pennsylvania State University, PA	Academic Member
Neil Matthews	Titomic, Australia	Emeritus Member
Jack Lareau	Pacific Northwest National Labs, WA	Emeritus Member
Dr. Dennis Helfritch	Survice Engineering, MD	Emeritus Member

THANK YOU TO OUR GOLD SPONSORS

THANK YOU TO OUR SILVER SPONSORS

THANK YOU TO OUR BRONZE SPONSORS

CSAT Meeting *ABSTRACTS*

Cold Spray AM: Integrated Spray Booth Systems

Speaker: Alex Finch
Organization: Titomic

Through its attributes, cold spray has a unique ability to address the large format additive manufacturing need in the market. However, progress is limited by the relative lack of industry familiarity, high learning curve, high infrastructural requirements, and ease of use and implementation. To address this, we at Titomic, a worldwide leader in cold spray technology, have taken an all-encompassing approach to making cold spray accessible and optimized for end-user applications. Through our Integrated Spray Booth (ISB) systems, we created both standard and highly customized systems that allow the benefits of cold spray to be easily inserted into customer operations and facilities. Often new to cold spray, our users require easy-to-use systems with high reliability for the application of novel coatings, repair of high-value components, and additive manufacturing of large parts. With the ISB approach, we are able to meet the customer where they are in regard to their needs for system capabilities, size, and price point. The result is a line of products that cover the entire spectrum of cold spray needs, from the ISB-10 for small-scale coatings applications and research to the TKF5000 providing production-level additive manufacturing up to 175 cubic feet build volume.

Engineered Powders for Cold Spray

Speaker: Joe Heelan
Organization: Powders on Demand (Solvus Global)

Cold Spray and other additive manufacturing (AM) technologies now recognize the importance of high-quality powder feedstock for augmented performance and reliability of the manufacturing process. At Powders on Demand, powders are engineered at the microstructural level to best serve the requirements of specific applications. In the present work, value added, novel processing techniques are applied to raw materials to improve properties of the powder that are crucial to cold spray performance. A series of experiments were conducted which demonstrate the spectrum of corrosion and wear resistance that can be achieved by cold spraying coatings through powder recipe optimization. In addition to coatings, bulk parts were fabricated via cold spray additive manufacturing (CSAM) using powders that were carefully selected and tuned to maximize part quality. New efforts to both standardize data tracking and accelerate commercialization of powders designed specifically for cold spray are also covered which will expand the toolbox the cold spray industry needs for continued growth.

Effects of Gas, Powder & Substrate on CS Performance

Speaker: Casey Jones
Organization: ES3

ES3 has been evaluating multiple cold spray systems, carrier gases, powders and substrates in efforts for the US Air Force and Navy. ES3 has also retrofitted a cold spray system with a 4 kW laser to perform laser assisted cold spray and developed a mixed gas system for enhanced coating properties while reducing helium dependency. This presentation will review results of these projects to show how coating performance varies using different gases and powder/substrate combinations applied with three different cold spray systems, as well as how integrating laser energy during the cold spray deposition process enhances coating performance.

NIOSH research: Exposures, Health Effects, and Controls of Chemicals from Cold Spray Coating

Speaker: Emily Lee
Organization: NIOSH - National Institute for Occupational Safety and Health
Authors: **Eun Gyung Lee, Daniel J. Hardt, M. Abbas Virji**

Thermal spray coating (TSC) processes, particularly cold spray processes, are fast-growing and emerging technologies that potentially generate hazardous inhalation exposures. However, the actual exposure profile and potential health effects from mixed exposures to metal fumes, particles, and gases generated during TSC processes have not yet been characterized. Thus, NIOSH is conducting a research study to 1) assess these exposures and describe the respiratory health effects of workers using TSC technologies in various industries; 2) evaluate the existing exposure controls being used at TSC workplaces; and 3) make appropriate recommendations to improve TSC work environments. NIOSH will focus on TSC processes that are performed manually, such as electric arc-, flame-, and cold-spraying.

This study will characterize TSC emissions and determine emission rates for each TSC process in laboratory-controlled conditions; assess TSC worker exposures at their individual worksites; and perform comprehensive respiratory health assessments. The expected outcomes will be to 1) determine worker inhalation exposures to chemical hazards; 2) recommend appropriate selection and use of engineering controls and personal protective equipment for each TSC technology; and 3) determine potential health effects in TSC workers from mixed exposures to the particles and gases generated during TSC processes. The success of this study relies upon establishing strong partnerships with multiple TSC workplaces to conduct the study, which would enroll TSC operators and allied workers. NIOSH has a strong history of partnering with different workplaces and private sector companies for the mutual benefit of all parties and to enhance the health and safety of workers. Successful completion of this study will positively impact thousands of workers and generate information about personal exposure and respiratory health effects, which can lead to effective interventions to mitigate occupational health hazards associated with these TSC processes.

Novel Online Particle Sensor for Cold Spray Process Monitoring

Speaker: Jussi Larjo
Organization: Oseir

Cold Spray Additive Manufacturing (CSAM) is an emerging manufacturing technology with great potential in many application fields. For successful employment of CSAM, high levels of reliability and reproducibility for the cold spray equipment, feedstock material properties and process control are needed. In particular, degradation in spray nozzle condition and powder feeder instability are found to cause unexpected, often intermittent variation in the resulting spray deposit properties that may cause serious quality issues in the end product. A rapid and reliable quality assurance (QA) solution is essential in establishing timely user detection and response to these issues. Existing sensor solutions have required an interruption of the process for a measurement cycle, leaving the majority of the process time unmonitored. We present a novel imaging sensor solution for continuous online monitoring of the spray plume during CSAM process. The sensor measures particle properties such as speed and position as well delivers instantaneous measurement data for the user. Experimental results are presented using various cold spray gun types, nozzles and powders. Sensor integration with the spray gun control system and data collection for extended QA purposes are discussed.

Eliminating Nozzle Clogging in Cold Spray

Speaker: Dr. Tim Eden
Organization: Pennsylvania State University

Nozzle clogging is a prevalent problem for all cold spray systems that can limit the spray-ability of certain materials and cause sub-standard properties and porosity for others. Although prevalent, the mechanism and progression of nozzle clogging in cold spray is not well understood. Largely anecdotal evidence and simple solutions (i.e. nozzle cooling) that only limit the problem currently exist. Many analytical studies have been completed without experimental evidence to support findings. In order to better understand this problem, PSU/ARL has completed solid and split nozzle experiments to elucidate and characterize mechanisms and progression of nozzle clogging in cold spray.

Polyamide (PA) Thermal Barrier Profiles For Window Mfg.

Speaker: Julio Villafuerte
Organization: CenterLine

Thermal efficiency is one of the most important aspects of industrial and residential construction. Climate change and ever-increasing costs of energy have driven special attention to a building's thermal efficiency. Aluminium is by far the most widely used material for window profiles used in windows and facades frames. The production of aluminium and other materials profiles for windows and facades is a multibillion-dollar well-established global industry. The major downside to aluminium is its low thermal insulation capability. For decades, one of the most commercially viable and popular solutions has been the addition of a thermal barrier in the form of a profile, made of polyamide (PA), inserted between the outer and inner parts of the aluminium frame. Polyamide has excellent thermal dimensional stability, ensuring thermal barrier profiles that offer unlimited possibilities in terms of windows aesthetics and design. Despite the advantages as the best polymer for aluminium assembly, electrostatic powder coating, and anodizing processes, the use of Polyamide profiles has opportunities for improvement in areas such as finishing as well as reliable building adhesion to other substrates.

In this presentation we will talk about the ability of low-pressure cold spray to produce controlled coating of polyamide profiles with proprietary powdered materials in a volume production environment to improve the performances of polyamide profiles. This unique and patented implementation has required the cold spray technology to attain, at least, an acceptable level of industrialization including cost-effectiveness, reliability, repeatability, maintainability, and high productivity

Latest Developments in High-Pressure Cold Spray Equipment and Main Applications

Speaker: Dr. Sascha Bernhardt
Organization: Impact Innovations GmbH
Authors: Dr. Sascha Bernhardt, Leonhard Holzgassner, Jan Kondas; Dr. Reeti Singh

The Cold Spray technology is getting established for industrial applications in high volume manufacturing. But not only the market for Cold Spray coatings grows exponentially, also Cold Spray Additive Manufacturing (CSAM) especially in aerospace applications reaches already higher volume. The presentation describes latest developments in the equipment of high-pressure cold spray and which main markets can be served with that. Increased efficiency in the cold spray process and suitability of the equipment for 24/7 operation in the Industrial Internet of Things (IIoT) leads to new applications with tremendous growth potential in the upcoming years. Main future cold spray markets and its applications will be described with the specific advantages over other technologies.

In-Situ and Ex-Situ Means for Through-Process Control in Cold Spray

Speaker: Dr. Ozan Ozdemir
Organization: Northeastern University
Authors: Ozan C. Ozdemir, Rohit Bokade, Kishore Kumar, Mann Patel, Samuel Boese, Xiaoning Jin, Sinan Muftu

In the field of cold spray (CS) and other additive manufacturing (AM) methods, limited number of standards and the lack of quantitative means for assessing the integrity of CS and AM produced products create a bottleneck in broad adaptation of these technologies. Furthermore, the large number of variabilities involved in CS and other AM processes contribute to the unpredictability of the final part properties and the reluctance in leveraging the manufacturing flexibility of these technologies. In addressing these challenges, Northeastern University (NU) has been active in the development of standard methods in powder characterization for CS, aeroacoustics and thermal imaging based in-situ process monitoring and anomaly detection methodologies and means for quantitative non-destructive inspection of CS and AM produced components. Furthermore, in-situ measurement methods are being coupled with physics informed machine learning algorithms to increase their effectiveness in field applications. In this talk, efforts of NU will be detailed in the development of methods for in-situ and ex-situ through-process control in CS. The highlighted efforts will be essential in increasing process repeatability and reliability; will contribute to the establishment of standards; and help expand the applicability of CS and other AM processes.

Cold Spray & In Situ Laser Heating for Repair of High Strength Steel Structures

Speaker: Dr. Luke Brewer
Organization: The University of Alabama
Authors: Luke N. Brewer, C. Jacob Williamson, Christopher M. Roper, and Anita Heczel

In this talk we will share new, promising results demonstrating the ability to repair high strength, martensitic steel with cold spray deposition-based processes. High strength, ferritic-martensitic steels, such as HY80 and 4340, can suffer from corrosion, erosion, and wear damage. As is the case with other metallic alloys, cold spray deposition can be used as a means for dimensional and even structural repair. HY80 steel can be readily deposited using helium-based, high-pressure cold spray deposition with gas atomized powders. The resultant materials are dense and quite hard, twice the value of quench-and-tempered (QT) plate material. We have used in situ laser heating, both during cold spray, i.e. laser assisted cold spray (LACS), and post-deposition, to enhance the mechanical properties of these repaired materials. We applied all three of these processes to fill HY80 material into QT HY80 substrates with machined grooves. Tensile testing of these deposits shows that the cold spray deposition increases the repaired samples' strength back to the QT load capacity. The cold sprayed material fractures as tensile deformation progresses, but the substrate elongation to failure shows no decrement from the cold spray repair process. Post-deposition laser heat treatment produces inconsistent results, but LACS at both 750˚C and 950˚C demonstrates substantial increases in the elongation to failure of the repaired samples without sacrificing their load-carrying capacity.

Composition and Microstructure Tailored Aluminum Alloy Deposits Manufactured by Cold Spray

Speaker: Tanaji Paul
Organization: ColRAD – Florida International University
Authors: Tanaji Paul, Denny John, Anil Lama, Kazue Orikasa, Arvind Agarwal

Aluminum alloys with novel composition and structure are cold spray deposited to thicknesses of 5 millimeters to surpass the mechanical performance of state-of-the-art Al 7075 deposits. A two-pronged approach, consisting of aluminum-based high-entropy alloy (Al-HEA) mixed with Al 6061 and scandium (Sc) containing Al (Al-Sc) alloys are deposited using nitrogen and helium process gases. Structural hierarchy of these deposits, consisting of amorphous and nanocrystalline aluminum, and intermetallic precipitates of Al-Sc are revealed. The role of these structural features on the mechanical behavior of the deposits are evaluated at length scales ranging from individual splats to bulk deposits.

Brittle Particle Cold Spray

Speaker: Richard Thuss

Organization: TTEC

The Brittle Particle Cold Spray (BPCS process refers to the kinetic impact adhesion and densification of powder materials composed of 100% brittle material particles. Previous efforts have demonstrated the process viability using a wide compositional range of thermoelectric semiconductor and magnetic materials. Impact adhesion and densification has been shown to require irregular shaped particles and specific particle size distributions that span from approximately 100nm to 10 µm in equivalent spherical volume. More recent research has demonstrated that particles as small as 5nm, nanotubes, and microfibers can be added to the powder mix in significant quantities without disruption of the kinetic adhesion and deposition process. Progress on extending this process to high temperature capability ceramic materials, random fibre reinforced composite materials and extra-terrestrial soil simulants will be presented by TTEC LLC with supporting data from Northeastern University.

Localized Surface Modification of HPDC AZ91 Magnesium Alloy using Cold Spray to Enhance Surface Properties

Speaker: Sridhar Niverty
Organization: Pacific Northwest National Laboratory (PNNL)
Authors: Sridhar Niverty, Rajib Kalsar, Li Lei, Ayoub Soulami, Glenn Grant, Darrell R. Herling, Vineet V. Josh

Magnesium (Mg) alloys have immense potential in automotive applications due to their high specific strength and light weight. However, their poor corrosion performance limits their commercial application. In this study, we have utilized cold spray coating technology to improve the surface properties of high pressure die cast Mg-alloys. Commercially pure zinc (CP-Zn) powders were coated onto AZ91 substrates using several combinations of carrier gas (Nitrogen) pressure, gas temperature, and powder size parameters. Microstructural characterization of the optimized coatings showed negligible porosity (less than 0.5% by area) and no unwanted intermetallic formation at the coating-substrate interface. Wear tests on the coating surfaces showed more than a 50% decrease in wear rate over uncoated AZ91 substrates, and coating adhesion tests (ASTM 4541) showed promising strengths of greater than 25 MPa. Electrochemical impedance spectroscopy and Potentiodynamic polarization showed a notable increase in the corrosion resistance and corrosion potential of the Zn coated samples as compared to the uncoated substrates. Finally, the optimized Zn coating parameters were utilized to coat curved Mg alloy automotive parts to demonstrate their commercial viability.

Elevated Temperature Mechanical Behavior of Cold Spray 5056 Aluminum

Speaker: Benjamin Bedard
Organization: Pacific Northwest National Laboratory (PNNL)

As Cold Spray continues to advance as a structural repair technology, understanding the behavior of cold spray deposits at relevant operating conditions has become increasingly important. In the current study, a decrease in tensile ductility was discovered during elevated temperature tensile tests of aluminum 5056 cold spray deposits. This is opposite the traditional behavior discussed in literature for conventionally produced 5056. This behavior appears to be related to dynamic strain aging, appearing only active whilst the specimen is held and tested at elevated temperatures. Heat treatment methods were studied to explore the effect and suggest strategies to mitigate the behavior.

- Al 5056 tested at elevated temperature and room temperature
- Mechanical property change observed at elevated temperature
- Mechanical property change appears only active at elevated temperature

Cold Spray for Aircraft Structural Repair

Speaker: Sarah Galyon Dorman
Organization: SAFE Inc.
Authors: Sarah Galyon Dorman, Justin Rausch, and Anthony Naccarelli

Cold spray (CS) is being use in both civil aviation and military aircraft fleets as a method for repairing obsolete or damaged parts mainly for dimensional repair. There is ongoing research by the United States Office of Naval Research examining the corrosion and mechanical property equivalency of CS repairs on aluminum alloys for structural applications on aircraft. Testing has shown that CS repairs of fatigue sample geometries with 15-30% depth blend outs are able to improve fatigue life to near that of undamaged fatigue samples at two stress ratios. Tensile coupons with 15% CS repairs have also shown tensile properties within 90% of wrought material for two alloy systems. Work continues transitioning cold spray to aircraft part repair with updated tensile and fatigue geometries. Various other material properties for cold spray repairs have been developed including compression, fatigue crack growth rates and bending. Further understanding has been developed on how to appropriately design samples for cold spray repair material property evaluation.

Functionally Gradient Bimetallic Ni-Cu CSAM Alloys

Speaker: Hugues Francois-Saint-Cyr
Organization: ThermoFisher Scientific
Authors: John Yorston, Mark Riccio, Hugues Francois-Saint-Cyr, Helmut Hoell, Marius Ellingsen, Joseph Rinck, and Kristen Batte

Weight reduction and improvement in efficiency of rocket engine components, are highly desirable in aerospace to reduce payload, lower launch costs, increase specific impulse, and enable their reuse in successive launches.

We focused in this study on functionally gradient Ni-Cu alloys, which offer both high-temperature strength and high heat flux properties to combustion liners, jackets, and nozzles. The microstructures of those bimetallic alloys prepared by nitrogen-based cold spray additive manufacturing (CSAM), have been evaluated using 3D X-ray microscopy, large-scale automated scanning electron microscopy, and energy dispersive spectroscopy. Information such as grain size, shape, distribution, porosity, and chemical maps will help guide researchers in their understanding of the mechanical properties of that material.

Cavitation Damage in Hydropower Turbines

Speaker: Chris Smith
Organization: Pacific Northwest National Laboratory (PNNL)

Cavitation damage is a significant wear mechanism experienced in hydropower turbines. Current cavitation damage repair approaches are time consuming, cause excessive downtime and lost revenue, and represent significant risks from an environmental, safety, and health perspective. In addition, the current repair process leads to ever increasing frequency of follow-up repair. To help alleviate these challenges, the cold spray coating process is being developed as an alternative cavitation damage repair solution. To determine the efficacy of the cold spray process and optimal parameter conditions, accelerated cavitation testing of cold spray coatings and various base materials is being performed per ASTM G134. To aid in determining optimal cold spray parameter settings, cold spray deposits were created with a variety of input conditions, including variation in carrier gas pressure and temperature, powder type, powder flow rate, travel speed, nozzle orientation, and nozzle stand-off distance. These cold spray deposits were then subjected to accelerated cavitation testing. Efforts were also completed to understand if cavitation performance can be correlated with other output characteristics of cold spray deposits, such as adhesion strength and porosity. If cold spray can enable improved cavitation erosion resistance, this will provide the opportunity for hydropower facilities to operate more flexibly and in less optimal times, yielding an improved ability for the hydropower industry to adapt to the changing electrical generation market.

Mitigation of Flow Acceleration Corrosion in Nuclear Power

Speaker: Carl "Lee" Friant
Organization: Constellation Energy
Authors: Lee Friant, Kyle Johnson, Jack Lareau, and Ken Ross

Constellation has been developing and deploying cold spray for mitigation of corrosion in various nuclear applications since 2014. The largest benefit identified would be to apply Cold Spray's unique capabilities to mitigate various forms of corrosion on installed components during refueling outages. However, the nuclear in-plant cold spray presents many new challenges not encountered in a shop environment including working from scaffolding, deploying cold spray equipment through limited access openings and in confined spaces, stringent controls on foreign material (including excess powder removal), chemical contamination and lastly, limited time windows available to perform cold spray. One high risk / high reward application Constellation and VRC Metal Systems are currently pursuing is to apply protective cold spray coatings to non-removable moisture separating carbon steel components inside the steam drums of steam generators found in pressurized water reactors designed by Westinghouse and B&W Canada. High flow regions of these components, over time, are subject to wastage via a flow accelerated corrosion (FAC) mechanism. The details of the challenges encountered to applying a FAC-resistant Cold Spray coating and the significant progress toward addressing these challenges will be presented in this paper.

Residual Stress Analysis of Cold Spray Deposition for Stress Corrosion Cracking Mitigation and Repair

Speaker: Jon Tatman
Organization: EPRI - Welding and Technology Repair Center

Mitigation and repair technology development efforts are currently in progress to proactively address concerns for potential dry cask storage system (DCSS) canister degradation. Cold spray technology is a process of primary consideration for canister mitigation and repair and has recently been developed and demonstrated for in-service canister deployment. Studies are currently being performed to determine the long-term ability of cold spray deposits to resist initiation of chloride-induced stress corrosion cracking (CISCC). A primary factor that contributes to CISCC initiation in susceptible materials is the presence of high residual tensile stress conditions. A detailed analysis was performed in this study to determine the effect of cold spray deposition on existing weld residual stresses in highly restrained configurations. To evaluate this effect, contour and shallow hole drilling residual stress measurements are performed on cold spray build-ups deposited on highly restrained AISI 304L stainless steel weld mockups. These mockups were conservatively designed and fabricated to produce weld residual tensile stress levels higher than those previously predicted on welds performed on canisters during manufacturing. The results provide data that indicate the cold spray process introduces a substantial residual stress reduction during deposition comparable to peening surface stress improvement techniques typically used in the nuclear industry.

R&D and Sustainment Efforts for Cold Spray Additive Manufacturing

Speaker: Michael Schmitt
Organization: HAMR Industries, LLC
Authors: Michael P. Schmitt, Bryer C. Sousa, Jeremy M. Schreiber, Anthony J. Naccarelli, Kiran Judd, Jake G. Keiper, Timothy J. Eden, Danielle L. Cote

There has been significant growth in the adoption of cold spray (CS) as an additive manufacturing technique, however, numerous fundamental aspects of CS still have not been fully described in the literature. This study seeks to provide a stronger understanding of factors contributing to mechanical property development during CS. Novel nano- and micro-mechanical measurements on single-, few-, and multi-splat buildups at varying velocities are compared to simulated finite element counterparts based on Preston-Tonks-Wallace plasticity descriptions. As a conclusion, components and alloys that have been successfully printed via CSAM will be presented, along with future directions for this technology.

Cold Spray Process Qualification in Support of Shipboard Repair

Speaker: Daniel Stanley
Organization: Norfolk Naval Shipyard

The first shipboard Cold Spray repair required rapid development of qualified spray procedures. Corrosion, microstructure, adhesion, tensile and wear testing was required. To meet the tight timeline, efforts of several different groups had to be coordinated. The team had to make decisions based on UIPI requirements, the timeline and the amount of testing actually needed. The process and test results will be presented.

Conducting Shipboard Cold Spray Repairs in Today's Naval Environment

Speaker: Dr. Tim Eden
Organization: Pennsylvania State University

Recently a team of government, academic and private partners completed the first shipboard cold spray repair in US Navy history. The focus of this presentation will examine the risk assessments/decisions, logistics and lessons learned as the team approached this high visibility repair with a truncated timeline filled with many "first time use cases". Presentation will highlight multiple considerations an individual or group will encounter that are applicable to cold spray as well as other innovative processes.