CSAT Cold Spray Action Team

SOLVUS GLOBAL

CSAT Meeting AGENDA

Tuesday, June 11, 2024, Meeting Time: 8:00am-6:00pm

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

Presenter	Presentation Topic	Time
Session 1: Advancements in Equipment (Moderator: Rob Hrabe, VRC Metal Systems)		
1. Marc Sharp, NCMS	Commercial Technology Maintenance Activities (CTMA)	0830-0850
2. Aaron Nardi, VRC Metal Systems	Cold Spray Property Data For Repair and Additive Mfg.	0850-0915
3. Steve Camilleri, SPEE3D	Achieving Beyond-Wrought Properties With Cold Spray	0915-0940
4. Neil Matthews, Titomic	Titomic - Leveraging Cold Spray for Success	0940-1000
5. Dr. Julio Villafuerte, CenterLine	Practical Implementation of Helium-Nitrogen In-Line Gas Mixing for Enhanced CS Performance and Cost Optimization	1000-1020
Exhibit Area	**BREAK AND NETWORKING**	1020-1120
Session 2: Powder (Moderator: Joseph Heelan, Solvus Global)		
6. Brad Richards, Powders on Demand	High Performance Cold Spray AM Materials	1120-1140
7. Nickolas Sotiropoulos, ARL	Shot Peen Assisted CS - Nitrogen 'Helium Performance'	1140-1200
8. Kyle Tsaknopoulos, WPI	A Through-Process Experimental Approach to Optimization of Aluminum Feedstock Powder for Cold Spray AM	1200-1220
Exhibit Area	**LUNCH**	1220-1330
Session 3: Quality Assurance/ Quality Control (Moderator: Dr. Arash Parsi, Westinghouse)		
10. Jean-Nicholas Robert, Tecnar	The Future of Spray Sensors	1330-1350
9. Tatu Leppanen, Oseir	User Benefits and Application Examples of HiWatch CS-Q	1350-1410
10. Dr. Ozan Ozdemir, Northeastern	Model Informed In-Situ Process Monitoring for 3D Printing	1410-1430
Exhibit Area	**BREAK AND NETWORKING**	1430-1500
Session 4: Projects & Programs (Moderator: Michael Nicholas, U.S. Army Research Laboratory)		
11. Dr. Tim Eden, PennState	Spray Technology at the Point of Need	1500-1520
12. Fred Laguines, ES3	CS Laser Processing and Advancements throughout the DoD	1520-1540
13. Dan Stanley, NNSY	NAVSEA Cold Spray Program – A Year in Review	1540-1600
RECEPTION	**DCU Center Concourse (Poster Session–Exhibits)**	1600-1800

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***Wednesday June 12, 2024,* Meeting Time: 8:00am-5:30pm**

Session 5: Additive Manufacturing (Moderator: Dr. Tim Eden, Pennsylvania State University)			
1.	Michael Schmitt, HAMR	Fundamentals and Applications for Cold Spray AM	0800-0825
2.	Michael Nicholas, ARL	CS Developments at ARL in Large Area & Hydrogen	0825-0855
3.	Michael Eff & Sam Bedard, EWI	Developments in Cold Spray	0855-0920
	Exhibit Area	**BREAK AND NETWORKING**	0920-1000
Session 6: Aerospace/ Aviation (Moderator: Dr. James Castle, Boeing Research & Technology (BR&T))			
4.	Sarah Galyon Dorman, SAFE Inc.	Cold Spray for Aircraft Structural Repair	1000-1020
5.	Bruno Zamorano, Boeing	Metals Affordability Initiative BA24, Bridging the Gap	1020-1050
6.	Kirstyn Roberts, Eaton Corporation	Composition & Microstructure Tailored Al CS Deposits	1050-1110
Session 7: Applications (Moderator: Dr. Ozan Ozdemir, Northeastern University)			
7.	Ben Peterson, Honeywell	Cold Spray Structural Repair Roadmap at Honeywell	1110-1130
8.	Dr. Arash Parsi, Westinghouse	Cold Sprayed Chromium Use in Pressurized Water Reactors	1130-1150
9.	Markus Brotsack, Impact Inn.	Impact Hybrid Brake Disc Coating	1150-1220
	Exhibit Area	**LUNCH**	1220-1330
Session 8: Science & Technology (Moderator: Dr. Arvind Agarwal, Florida International University)			
10.	Dr. Tanaji Paul, ColRAD FIU	Can Novel CS Al Alloys Surpass Al 7075 Deposits in Strength?	1330-1350
11.	Andrew Duguid, SPEE3D	Fracture Mechanics & Defect Typology of CS Material	1350-1410
	Exhibit Area	**BREAK AND NETWORKING**	1410-1440
12.	Dr. Gregory Kubacki, U. of Alabama	Feedstock Composition Performance of CS Al-Mg Alloys	1440-1500
13.	Dr. Peter Lucon, Montana Tech	Pioneering Swift Strategies in Mechanical Plasticity	1500-1520
14.	Chris Smith, PNNL	Measurement of Forces Related to CS Coatings	1520-1540
	Dr. Victor Champagne	**Wrap-Up & CSAT 2024 Poster Awards**	1540-1600
	RECEPTION	**Solvus Global cSIM Leominster Facility Reception**	1600-2000

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CSAT Meeting *ABSTRACTS*

Impact Hybrid Brake Disc Coating

Speaker: **Markus Brotsack**

Organization: Impact Innovations

The innovative brake disc coating technology that fulfils all technical requirements for the Euro 7 standard. Environmental regulations in many regions all over the world require significant particle emission reduction from braking. At least for conventionally powered cars most OEMs plan to apply a wear and corrosion resistant coating on the brake discs to fulfill these requirements. Recuperation of hybrid and electric vehicles lead to less wear, but even more corrosion. The Impact Hybrid Brake Disc Coating offers the best solution for all these challenges.

With Impact Hybrid BDC®, Impact Innovations combines two technology worlds in two brake disc coating layers: The strong metallurgical bonding of a laser-cladded intermediate layer with the crack and corrosion-resistant cold-spray top layer.

- Highest-performance coating solution by combining the advantages of the two most advanced coating technologies for brake discs
- Highest metallurgical bonding strength to the grey cast iron
- No thermal deformation of the brake disc
- Avoidance of severe cracks by the compressed stress of the cold-sprayed top layer
- Longest corrosion and wear resistance
- Lowest coating and grinding costs due to the benefits of the robust cold spray technology
- Highest particle emission reduction due to optimized available brake pad materials

Composition & Microstructure Tailored Al CS Deposits

Speaker: Kirstyn Roberts

Organization: Eaton Corporation

This work is the result of a team of cold spray users from multiple companies, focused on developing non-destructive inspection to directly inspect deposition quality. Coupons for a variety of adhesive tests were sprayed in aluminum on aluminum substrates, including double-lug shear, C633, and custom testing from bespoke samples. Scan data of each coupon were recorded using a variety of non-destructive techniques, primarily ultrasonic inspection. The scans showed significant correlation to their respective destructive testing results. This presentation discusses some best practices of using non-destructive verification for cold spray depositions, followed by the results of the destructive / non-destructive inspection testing.

The Future of Spray Sensors

Speaker: Jean-Nicholas Robert

Organization: Tecnar

Tecnar has been in the spray sensor industry since 1989. It has developed best-in-the-industry technologies like the DPV and the Accuraspray Series that have been used in thousands of papers worldwide.
Sensors were historically used to achieve great coatings every run and as a go/no-go tools. It helped to process IP archiving, ensure reproducibility, and decrease HR dependency. It measured temperature, velocity, stability, angles, plume width, intensity, and density. The benefits were obvious: less operator dependency,

optimization of gun maintenance, process development, reduction of downtimes, reduction of coupons, savings on powder waste, and more. We now explore new opportunities. We work on in-situ readings, the detection of new indicators, the integration of 3D printers, the use of AI to feed-back to spray controllers, effortless plume optimization, and more.

Feedstock Composition Performance of CS Al-Mg Alloys

Speaker: Dr. Gregory Kubacki

Organization: University of Alabama

This talk will highlight the influence of feedstock chemistry on the mechanical and corrosion properties of cold sprayed Al-Mg alloys. Cold spray deposition is a promising in-situ repair technology; however, its application to marine-grade Al alloys, such as AA5083-H116, for structural repairs has been limited. We show that the complex microstructure of cold spray deposited AA5083 effects strengthening mechanisms and corrosion processes, which leads to poor performance compared to its wrought counterpart. In this program, custom feedstock alloys were explored that allow target mechanical properties to be met while simultaneously improving deposition efficiency and corrosion resistance compared to cold sprayed AA5083.

Practical Implementation of Helium-Nitrogen In-Line Gas Mixing for Enhanced CS Performance and Cost Optimization

Speaker: Dr. Julio Villafuerte

Organization: CenterLine Windsor Limited

Pure helium can be utilized as a carrier gas in cold spray processes due to its ability to triple supersonic gas jet velocity, thereby enhancing deposition efficiency and overall cold spray deposit properties. However, the high cost and limited availability of pure helium, compounded by the capital-intensive nature of helium recovery systems, pose challenges, particularly for portable cold spray setups.

Original research at the University of Ottawa introduced an innovative in-line gas mixing technology capable of blending nitrogen and helium at user-defined ratios. Extensive investigations, including particle velocity measurements, deposition efficiency assessments, and evaluations of coating properties, demonstrated that even minimal helium concentrations result in significant improvements in coating quality and performance. Initial cost analysis identified optimal nitrogen-helium ratios (dependent on material selection), offering a practical approach for cost-effective cold spray applications.

Real-world implementations of the mixing system showcased operational mechanisms and tangible cost benefits in industrial settings. Engineering optimization work at ES3 USA affirmed the industrial viability of gas mixing delivery systems, showcasing equivalent or superior coating performance compared to pure helium or nitrogen applications, leading to cost savings in gas usage. Initial demonstrations and optimization of gas mixtures utilized previous test results and optimized parameters, focusing on aluminum 7075 powder on 7075-T6 and 6061-T6 aluminum substrate combinations. Cost-wise, employing the gas mixing delivery system with high-pressures resulted in significant savings, particularly at helium to nitrogen ratios of 75:25 and 67:33. Additionally, at low pressures, helium and nitrogen gas utilization were further optimized, reducing overall gas costs and the cost of gas mixing. Metallurgical results indicated that helium/nitrogen mixed-gas ratios of 75:25 and 67:33 outperformed pure helium applications on aluminum substrates, exhibiting ASTM C633 bond strengths equal to or greater than pure helium baselines, with a uniform microstructure and less than 1% porosity.

Measurement of Forces Related to CS Coatings

Speaker: Chris Smith

Organization: Pacific Northwest National Laboratory (PNNL)

Many of the hydropower dams in the United States are in excess of 50 years old and have challenges related to aging infrastructure. One issue that is plaguing industry is cavitation damage and its repair. Cavitation damage can occur in multiple locations within the turbines and degrades the performance of turbines, eventually necessitating repair. In many cases, it is impractical or impossible to remove equipment, so repairs must be performed in-situ. Repairs using current approaches are costly, have significant safety and health hazards, and cause significant lost revenue resulting from the downtime associated with effectuating the repairs. In addition, the current repair approach, gas metal arc welding, has a heat affected zone with inferior cavitation performance compared to the base materials, resulting in ever increasing need for repair. As an alternative repair process, the cold spray technology is being developed and has been demonstrated to be able to achieve multiple factor improvements in cavitation performance. For early implementations, it has been assumed that cold spray would be performed manually. However, for the longer term, automated solutions are more desirable, but access is very limited in certain cases. For this reason, it is important to develop an understanding of the level of effort required to react the process loads, as well as the static and dynamic equipment loads. This is not only important for ergonomics when performing the process manually, but for implementation of an automated solution. To this end, a study was commissioned to develop an understanding of the cold spray process loads and the static and dynamic loads related to the hardware. The presentation will present the results of these force measurements.

Fundamentals and Applications for Cold Spray AM

Speaker: Michael Schmitt

Organization: HAMR

Cold spray additive manufacturing (CSAM) leverages the benefits of a solid-state fabrication technique in an additive capacity. One major advantage is the ability to process 6xxx and 7xxx series aluminum alloys which are otherwise not feasible in alternative melt-based additive manufacturing methods. Traditionally, cold spray of these alloys utilizes helium to produce ductile deposits, however, in CSAM the ability to post process with heat treatments enables usage of low-cost compressed air and nitrogen. This work explores the impact of temperature, process gas, powder, heat treatment, and location on mechanical properties. This understanding then provides a path of available applications for cold spray.

User Benefits and Application Examples of HiWatch CS-Q

Speaker: Tatu Leppanen

Organization: Oseir

No invention is of value for the users unless it can provide tangible benefits. Normally it means direct benefits in the form of monetary savings but it could also mean indirect benefits e.g. improved reputation being a trusted high quality manufacturer. Typically both of which generate the same final results characterised by short payback and improved customer satisfaction. This time the presentation is not so much about the science, it is about what we have done with the science to ensure that you can provide the best of products to your customers as cost effectively as possible.

Can Novel CS Al Alloys Surpass Al 7075 Deposits in Strength?

Speaker: Dr. Tanaji Paul

Organization: ColRAD – Florida International Laboratory

Absence of understanding correlations between composition control, post-processing heat treatment, and multi-scale mechanical properties is a critical obstacle to cold spraying aluminum alloys with strengths surpassing that of state-of-the-art Al 7075 deposits. This presentation establishes the role of cold spray on the as-deposited structure of ordered polycrystalline and disordered composite Al alloys. Formation of precipitate phases and redistribution of elements during post-deposition heat treatment is delineated. The effect of this structural evolution on the mechanical behavior of the deposits is unraveled through a combination of high-load-based novel indentation plastometry and conventional tensile testing techniques. Comprehension of these correlations, gained from this study, provide strategies to engineer novel Al deposits and enhance their plasticity for broader cold spray and additive manufacturing applications.

Cold Spray for Aircraft Structural Repair

Speaker: Sarah Galyon Dorman

Organization: SAFE Inc.

Cold spray (CS) is being used 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.

A Through-Process Experimental Approach to Optimization of Aluminum Feedstock Powder for Cold Spray AM

Speaker: Kyle Tsaknopoulos

Organization: Worcester Polytechnic Institute (WPI)

This work employs a Through Process Experiment (TPE) systematic approach to study the relationship between powder properties, cold spray (CS) processing parameters, and consolidated specimen behavior through a combination of characterization and computational models. This and TPE approach allows for the systematic isolation of variables that can affect powder and CS properties. In this study, various heat treatments were applied to Al 6061 powder and used as CS feedstock using industry-standard processing parameters to study the effect of thermal pre-treatment of Al 6061 powder on cold spray properties. Techniques including SEM, EDS, XRD, nanoindentation and particle compression, tensile testing, and corrosion testing were used to characterize the properties of both the feedstock powder and CS deposits. Computational thermodynamic modeling was used to guide microstructural interpretation.

Model Informed In-Situ Process Monitoring for 3D Printing

Speaker: Dr. Ozan Ozdemir

Organization: Northeastern University

In-situ process monitoring is emerging as a powerful and necessary tool for quality control and quality assurance in additive manufacturing, repair, and coating applications of cold spray and directed energy deposition methods. However, due to the large parameter space and the complexity of the multi-physics phenomena that occur in these processes, mixed scale models are necessary for making sense of the in-situ data for process monitoring, anomaly detection, and closed loop control for optimizing and predicting properties as well as geometrical accuracy. In tackling this problem, Northeastern University, in collaboration with ARL and NIST, has been investigating the use of thermal cameras, aeroacoustic sensors, and positional sensors and the development of solid mechanics, thermofluids, and geometrical models for physics informed machine learning in cold spray. While introducing the current state of the project, this talk will provide insights in its application in industry and translation into other methods such as wire-DED.