ICSC•2026

International Cold Spray Conference & Expo

SOUVENIR

INTERNATIONAL COLD SPRAY CONFERENCE & EXPO 2026

23-25, JANUARY 2026

IITM Research Park

IIT Madras, Chennai-600036
India

ORGANIZED BY:

Indian Thermal Spray Association

insciin

iTSA
The Indian Thermal Spray Association
ITSA ASSOCIATION FOR THERMAL SPRAY TECHNOLOGY AND RESEARCH

SPRAYCOLD
(COLD SPRAY SYSTEM)

Introducing a metal deposition process that requires no blast cleaning and no oxy-fuel gases. It works solely with air, providing a coating with high bond strength and density. You can apply almost any metal powder, including brass, copper, nickel, aluminum, zinc, tin, bronze, lead, stainless steel, aluminum - silicon carbide, aluminum-copper- zinc, nickel-zinc, copper-tin-lead and many more.

MCS - 23

Cold spray gun with heater installed.

MSC - 500

(MEC cold spray system with trolley, massflow controlled & pressurized powder feeder and PLC controlled panel.)

Advantages

- Green, solid-state process: No combustion flame, fumes, phase change during deposition.
- Ideal for in-situ repair, restoration & AM part correction.
- Delivers high deposition efficiency with minimal thermal impact.
- Enables coating of Al, Mg, Ti, and other reactive

Application of Cold Spray

- Repair, restore & AM part correction.
- Repair bearing seats.
- Cavitiation corrosion protection
- Hermetically seal rediators and air conditioner.
- Add electrical conductive layers to materials.
- Additive manufacturing and many more.

Special Features:

- The detachable type control screen can be removed and positioned on another stand or exterior wall of the spray chamber if user wants to spray using robot/manipulator.
- Working Gas: Air or Nitrogen
- Single Phase Electrical Supply Requirement.
- Operating pressure Temperature: 10 bar at 50 °C

Maximum power consumption:- 3.3kW

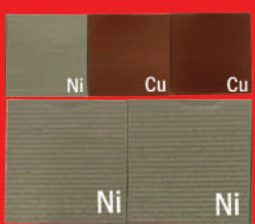
Power supply:- Single Phase 220v, 50/60Hz

Powder consumption:- 10-20 gm/min
(compatible powder will be supplied by MEC)

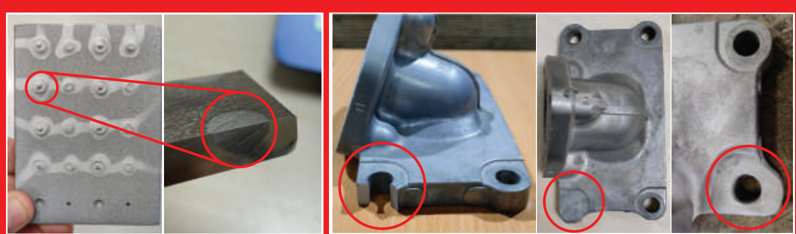
Capacity of Powder Feeder:- 3350 CC (3.3 Liter)

Dimensions and Weight of the System:-
Approx. 600(W) x 500(L) x 1400(H)
Approx. 110 kg
Compressed air consumption:- 0.3 - 0.4 m^3/min

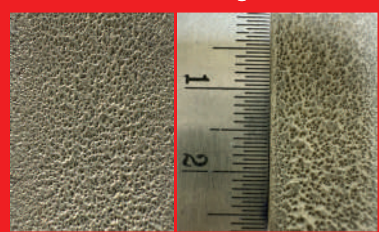
Ni and Cu coatings on CFRP sheet



Repair and Restore Part



Texture Driven Cold Sprayed Ni Coatings



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International Cold Spray Conference & Expo 2026

ICSC·2026
International Cold Spray
Conference & Expo
23-25 Jan. 2026, IITM Research Park, IIT Madras, Chennai-India.

Jan. 23-25, 2026

IITM Research Park

IIT Madras, Chennai-600036, India

Organized by

Indian Thermal Spray Association

iTSA
The Indian Thermal Spray Association
ITSA ASSOCIATION FOR THERMAL SPRAY TECHNOLOGY AND RESEARCH

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Harpreet Singh

President

Indian Thermal Spray Association (iTSA)

Message

It is my pleasure to put on record this message on behalf of *Indian Thermal Spray Association* (iTSA), which is a Standing Committee of the non-profit organisation *"ITSA Association for Thermal Spray and Research (Registered)"* established in the year 2022. iTSA has evolved as an organized association with the support of several academicians, scientists, and industry experts, who have been researching tirelessly on various aspects of thermal spray (TS) including cold spray (CS) for several decades in their respective organizations across India. iTSA has a mandate of realizing a broader TS research, development, and innovation impact, in terms of developing fundamental and applied TS knowledge on one hand, whereas innovative product development for newer applications on the other. The society is also committed to spreading TS awareness across India and developing an ecosystem for research, development, innovation, continuing education, and skill development.

Thermal spray (TS) is a group of coating technologies that are used to deposit materials in the form of molten or semi-molten particles by the application of high thermal and kinetic energy. Being an ever-evolving technology, several technologies such as Arc Spray, Flame Spray, Plasma Spray (PS), Detonation-gun (D-gun) Spray, High-Velocity Oxy-Fuel (HVOF) spray and Cold Spray (CS) have been developed over the years in the quest for developing deposits with superior attributes. CS is a relatively newer addition to the TS family. Unlike other TS processes, where coating deposition is achieved by spraying the molten/semi-molten particles on the substrate, CS uses the kinetic energy of the inflight particles to deposit them as a coating. The ability to produce oxide-free coatings with bulk properties has enabled CS to be considered as a preferred coating technology over other TS processes, especially for deposition of low melting and thermal sensitive materials in healthcare and aerospace applications. Given the ability to produce thick deposits owing to bonding mechanisms, CS is not only limited to surface engineering sectors, rather it is evolving as a competitive tool for additive manufacturing (AM) and repair applications. According to a report from Grand View Research, the global cold spray (CS) market size was estimated at USD 1,047.6 million in 2024 and is projected to reach USD 1,559.7 million by 2030, growing at a CAGR of 7.0% from 2025 to 2030. This shows the potential of CS as a viable technology for several industry sectors. The report also predicted that rising demand of CS from the aerospace industry as a repair technique for lightweight aerospace alloys is expected to drive the market over the forecast period. In this context, technical conferences and exhibitions such as ICSC are destined to play a pivotal role.

With wonderful support from IIT Madras as conference host, we are excited to witness the first edition of *the International Cold Spray Conference (ICSC 2026),* which has received overwhelming participation from several National and International organizations. The technical program of the conference is excellent with contributions from several well-accomplished cold spray-related academicians, scientists, and industrialists, in addition to fresh ideas from several student delegates. The industry exhibition is an icing on the cake.

I hope the delegates will enjoy the conference and benefit from the high-quality technical sessions/interactions and industry exhibits. Networking opportunities offered by ICSC are amazing in terms of connecting with global CS fraternities for research, innovation, and commercial collaborations. Young researchers will have an excellent platform to showcase their skills and connect for furthering their research and development aspirations. Lastly, I would take it as an opportunity to invite the existing and prospective CS industry and academia to join iTSA so that we can nurture this common vehicle for self-sustaining growth of thermal spray in the country and the world at large. Thank you very much to all the delegates and industrial sponsors/exhibitors for supporting ICSC 2026.

Looking forward to welcoming and interacting with the esteemed ICSC 2026 delegates in Chennai.

Best regards

(Harpreet Singh)

M Kamaraj

Senior Member

Indian Thermal Spray Association (iTSA)

Message

I am glad to invite you to the International Cold Spray Conference & Expo (ICSC2026), which will be held on January 23-25, 2026, at IITM Research Park, IIT Madras, in Chennai, India. Cold spray is an advanced process gaining popularity across industries for its ability to deposit materials without damaging the substrate. Unlike thermal spray methods, it accelerates powdered particles to supersonic speeds with high-pressure gas, impacting them onto a substrate to bond through plastic deformation, not melting. This "solid-state" process preserves material properties, reduces oxidation, and avoids thermal distortion. Its applications are broad: in aerospace for repair and corrosion protection; in automotive for wear-resistant and conductive coatings; in marine and energy sectors for corrosion protection and refurbishment; and in additive manufacturing for near-net-shape fabrication and multi-material deposition. Recent trends include advanced feedstock powders, hybrid systems, better process modeling, and digital control. Cold spray supports sustainable manufacturing due to low energy use, minimal emissions, and less waste. Emerging uses in alloys, electronics, and biomedical coatings show its expanding potential. This event unites global experts to share insights, offering valuable solutions for industry problems.

The Conference will feature plenary discussions and keynote lectures by eminent professionals and experts from leading international and national academic and research organizations, as well as industrialists and exhibitors. As the Convener of the conference, I recognize that the success of the event ultimately relies on the significant individuals who have contributed to the development and organization of the technical program and exhibition. I express my gratitude to all, especially our technical committee for their meticulous and prompt examination of the papers, as well as our sponsors, exhibitors, and advertisers who have facilitated the successful execution of the program. Appreciation should go to the local organizing committee members and volunteers who have worked extremely hard for the finer details of important aspects of the conference programs and exhibition. I express my sincere gratitude for their relentless efforts and prompt assistance.

I anticipate a productive gathering with delegates, emerging researchers, and company representatives from several nations, focusing on the exchange of innovative findings in Cold Spraying and industry requirements.

Best regards

M. Kamaraj

Prof. M. Kamaraj

Dr. Srinivasa Rao Bakshi, FASM

Vice President

Indian Thermal Spray Association (iTSA)

Message

It is with great pleasure that I invite all the participants for International Conference on Cold Spray & Expo – 2026. The Indian Thermal Spray Association was started in 2022 by a group of professionals from Industry, Research organizations, and Academia to promote thermal spray technology in India. It has been less than 5 years and ITSA has emerged as the foremost organization for Thermal Spray in India.

I am very happy to be associated as the founding member of the society. ITSA has organized successfully 2 editions of National Thermal Spray conference, first at Jodhpur (2023) and second at Bhubaneshwar (2025). ITSA was organizing partner for the 12th Asian Thermal Spray Conference held in 2023 at IIT Madras. One of the goals of ITSA is education and training in Thermal Spray. We organize monthly technical talks by experts for the benefit of the members. We also organize certified training programs on Thermal Spray with Hands-On Practical Sessions in association with Metallizing Equipment Company for practicing engineers. ITSA has seen steady growth in membership. We are proud to have 50 Life Members, 44 Student Members, 8 Regular Members, and 16 Corporate Members. The efforts of ITSA are highly appreciated by the industries which were largely disconnected. ITSA aims to see the use of thermal spray to its maximum potential in India.

The International Conference of Cold Spray & Expo (ICSC – 2026) is an effort to introduce and popularize the latest addition to the family of thermal spray technologies, cold spray, in India. We are happy to see the enthusiastic participation from leading experts in this area participating from various countries to share their knowledge. I hope that ICSC-2026 is successful in forging new collaborations among the researchers and helps create the dialogue with end-users to adopt cold spray for potential application. I wish the participants a pleasant stay in Chennai.

Best regards

Prof. Srinivasa Rao Bakshi

Satish Tailor | PhD

General Secretary, iTSA

The Indian Thermal Spray Association (iTSA)

Message

It is a privilege to share this message on behalf of the Indian Thermal Spray Association (iTSA), a Standing Committee of *ITSA Association for Thermal Spray and Research (Registered)*, established in 2022. iTSA represents a growing national platform driven by academicians, scientists, and industry experts committed to advancing thermal spray technologies, including cold spray, through research, innovation, skill development, and industrial outreach.

Cold spray has emerged as a transformative solid-state deposition technology, enabling oxide-free coatings, bulk-like properties, and thick deposits without thermal degradation. Its expanding role in aerospace repair, additive manufacturing, energy systems, healthcare, and sustainable manufacturing highlights its strategic importance for future engineering solutions. As cold spray transitions from laboratory research to industrial-scale deployment, focused international forums such as ICSC play a vital role in shaping its technological direction and industrial adoption.

We are delighted to witness the inaugural **International Cold Spray Conference & Expo (ICSC 2026)** at **IIT Madras Research Park, Chennai**, hosted with the strong support of IIT Madras. The conference features an excellent technical program with contributions from leading global experts, industry practitioners, and young researchers, complemented by a vibrant industry exhibition.

On behalf of iTSA, I sincerely thank the local organizing committee at IITM, technical committee, reviewers, sponsors, exhibitors, and volunteers for their dedicated efforts. I am confident that ICSC 2026 will foster meaningful technical exchanges, inspire innovation, and strengthen global collaborations. I invite the wider cold spray and thermal spray community to engage with iTSA and contribute to building a resilient and future-ready ecosystem for advanced coating and manufacturing technologies.

Best regards

(Satish Tailor)

About ICSC

The International Cold Spray Conference & Expo 2026 (ICSC 2026) marks a significant milestone for the global thermal spray fraternity as the first international event dedicated exclusively to Cold Spray technology. Scheduled to be held during 23–25 January 2026 at the IIT Madras Research Park, Chennai, India, ICSC 2026 will serve as a focused platform for researchers, technologists, industry leaders, and manufacturers to exchange knowledge, showcase innovations, and discuss emerging trends in Cold Spray science, engineering, and applications. Conceived as a biannual conference series, ICSC aims to provide a sustained and evolving forum for the Cold Spray community worldwide. The conference seeks high-quality technical contributions spanning fundamental research, process development, materials, characterization, and industrial deployment. Bringing together over 300 delegates from across the globe, ICSC 2026 will feature a vibrant technical program, distinguished keynote lectures, an industry-focused expo, and rich networking opportunities—collectively fostering collaboration and shaping the future of Cold Spray technology.

About IITM Research Park

IIT Madras Research Park, India's first university-based research park is a Sec 8 not for profit company promoted by IIT Madras and conceived by Prof. Ashok Jhunjhunwala in the spirit of breaking traditional barriers. We aspire to build a knowledge and innovation ecosystem where industry leaders and scholars can collaborate with state-of-art technology to integrate and apply advancements in knowledge to real-time products or services. By fostering partnerships and assisting new ventures, we are determined to transform and exceed the global standards of the research and development industry. For more info please visit
https://respark.iitm.ac.in/about-us/

About iTSA

The Indian Thermal Spray Association (iTSA), a standing committee of "ITSA ASSOCIATION FOR THERMAL SPRAY TECHNOLOGY AND RESEARCH [ITSA-ATSTR]". ITSA-ATSTR is founded and constituted in June 2022 under the visionary leadership of several dynamic and prominent academicians and industrialists. iTSA is a professional association dedicated to expanding the use of Thermal Spray Technology in India. The main mission of the iTSA is to promote the advancements of research & developments and industrial applications of thermal spray technology in India as well as in the world through establishing an information exchange platform and the involvement of experienced professionals and young researchers and students in thermal spray R&D.

Executive Committee

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Sergi Dosta
University of Barcelona (Spain)

Sinan Muftu
Northeastern University (USA)

Tanaji Paul
Florida International University (USA)

Prof. Tanvir Hussain
Univ. of Nottingham, UK

Yuji Ichikawa
Tohoku University (JP)

LOCAL ORGANIZING COMMITTEE

Technical Organizing Committee

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Indian Institute of Technology Madras

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Indian Institute of Technology Madras

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Indian Institute of Technology Madras

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Indian Institute of Technology Madras

Exhibition

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Indian Institute of Technology Madras

Anup Kumar Maurya
Indian Institute of Technology Madras

Ganta Mohith Yadav
Indian Institute of Technology Madras

KEYNOTE SPEAKERS

Prof. Andrew Ang
Swinburne University of Technology, Australia

Prof. Tanvir Hussain
University of Nottingham, Nottingham, UK

Prof. Kazuhiro Ogawa
Tohoku University, Sendai, Japan

Prof. Sinan Muftu
Northeastern University, USA

Prof. Heli Koivuluoto
Tampere University, Finland

Mr. Jean-Félipe Henri
tecnar, Canada

Prof. Ozan Ç. Özdemir
Northeastern University, USA

Prof. Sara Bagherifard
Politecnico di Milano, Italy

Prof. Mario Guagliano
Politecnico di Milano, Italy

Dr. Thorsten Stoltenhoff
Linde AMT, Europe

Markus Brotsac
Impact Innvo. Germany

Prof. Suresh Palanisamy
Swinburne University of Technology, Australia

Dr. Patrizio Lomonaco
TU-Delft, Netherlands

Dr. Jussi Larjo
Oseir Oy

Dr. Reeti Singh
Impact Innvo. Germany

KEYNOTE SPEAKERS

Dr. Dheepa Srinivasan
Ramaiah University of Applied Sciences, Bangalore

Dr. Gopi Chandran,
IIT Madras (ex-GE & Applied Materials)

Dr. Eklavya Calla
GE Vernova, India

Prof. Harpreet Singh
Indian Institute of Technology Ropar

Dr. Satish Tailor
Metallizing Equipment Company Pvt Ltd, Jodhpur

Chiragkumar Raval,
Hannecard Roller Coatings Inc., USA

Dr. Jeganathan Karthikeyan
ASB Industries, Barberton, USA

Prof. S Rao Bakshi
IIT Madras, India

Prof.Kesavan Ravi
IIT ISM Dhanbad, India

Prof. AYAN BHOWMIK
IIT Delhi, India

Prof. Jayabal K
IIITDM, Kancheepuram

Dr. Meenu Srivastava
CSIR-NAL Bangalore, India

Dr. Sisir Mantry
CSIRIMMT, Bhubaneshwar, India

INDUSTRIAL PANEL DISCUSSION

Moderator

Dr. Dheepa Srinivasan

Baker Hughes, Bangalore, India

Dr. Thorsten Stoltenhoff
Linde AMT Europe

Dr. Reeti Singh,
Impact Innvo. Germany

Prof. M. Kamaraj
Indian Institute of Technology Madras

Dr. Jeganathan Karthikeyan
ASB Industries, Barberton, USA

Ankur Modi
Metallizing Equipment Company Private Limited, Jodhpur

Prof. Andrew Ang
Swinburne University of Technology, Australia

Prof. Tanvir Hussain
University of Nottingham, Nottingham, UK

International Cold Spray Conference & Expo-2026

23rd – 25th January 2026, IITM Research Park, IIT Madras

Technical Program

Day 1: 23rd January (Friday) – Forenoon			
Time	**Event**		
08:30 - 09:15	**Registration**		
09:15 - 10:00	**Inauguration**		
10:00 - 10.30	**Tea/Coffee** *Dining Hall*		
Technical Session I *Raman Hall* *Session Chair:* **Prof. Kamaraj M**			
10:30 – 11:00 Keynote lecture (KL1)	Unlocking the Potential of High-Entropy Alloys for Cold Spray Processing **Andrew Siao Ming Ang** *Swinburne Univerisity of Technology, Australia*		
11:00 – 11:30 Keynote lecture (KL2)	The application of cold spray for structural repair: current status and next challenges **Mario Guagliano** *Politecnico Milano, Milan, Italy*		
11:30 – 12:00 Keynote lecture (KL3)	Cold Spray Deposition of Martensitic Nickel Aluminum-Bronze (NAB) for Repair and Coating Applications **Harpreet Singh** *Indian Institute of Technology Ropar, India*		
12:00 – 13:00	**Panel Discussion** **Cold Spray – Opportunities -Challenges & Future Directions** ***Raman Hall*** **Moderator: Dr. Dheepa Srinivasan,** *Ramaiah University of Applied Sciences, Bangalore*		
	Dr. Thorsten Stoltenhoff *Linde AMT, Europe*	**Dr. Reeti Singh,** *Impact Innvo. Germany*	
	Prof. M. Kamaraj *Indian Institute of Technology Madras*	**Dr. Jeganathan Karthikeyan** *ASB Industries, Barberton, USA*	
	Prof. Tanvir Hussain *University of Nottingham, Nottingham, UK*	**Prof. Andrew Ang** *Swinburne University of Technology, Australia*	
	Ankur Modi *Metallizing Equipment Company Private Limited, Jodhpur*		
13:00 – 14:00	**Networking Lunch** *Dining Hall*		

Day 1: 23rd January (Friday) – Afternoon	
Technical Session II *Raman Hall* *Session Chair:* **Prof. Tanvir Hussian**	
14:00 – 14:30 Keynote lecture (KL4)	Cold Spray – Coating Technology to Integrated Manufacturing **Thorsten Stoltenhoff** *Linde AMT, Ratingen / Schluechtern, Germany*
14:30 – 15:00 Keynote lecture (KL5)	Enhancements in cold spraying through laser assistance **Heli Koivuluoto** *Tampere University, Tampere, Finland*
15:00 – 15:30 Keynote lecture (KL6)	Exploring the Mechanical Performance of Multi-Material Cold Spray Additive Deposits **Sara Bagherifard** *Politecnico di Milano, Milan, Italy*
15:30 – 16:00 Keynote lecture (KL7)	Nitrogen-Sprayed Al-6061 for Load-Bearing Applications **Sinan Müftü** *Northeastern University, Boston, MA USA*
16:00 – 16:30 Keynote lecture (KL8)	Cold Spray on polymers and polymer-based composites. **Patrizio Lomonaco** *Tu-Delft, Delft, Netherlands*
16:30 – 17:00 Keynote lecture (KL9)	Niobium alloy C-103 for high-performance space applications – first results with using Cold Spay Additive Manufacturing – CSAM **Markus Brotsac** *Impact Innovations GmbH, Germany*
17:00 – 17:30 Keynote lecture (KL10)	A Review on Cold Spray Coating Technology in Gas Turbine Repair **Dheepa Srinivasan** *Baker Hughes, Bangalore, India*
17:30 – 17:45	**Tea/Coffee** *Dining Hall*
17:45 – 18:45	**POSTER SESSION**
19:00	**DINNER**

Day 2 - 24th January (Saturday) – Forenoon		
Technical Session III		
	Technical Session III A Fundamentals/Research & Development - NEW coating developments **Raman Hall** *Session Chair:* ***Prof. Andrew Ang***	**Technical Session III B** Cold Spray Repair and Additive Manufacturing **Leelavati Hall** *Session Chair:* ***Prof. Harpreet Singh***
09:00 - 09:30 Keynote lecture	**KL-11:** Cold Spray Deposition: Bridging Dissimilar Materials for Advanced Manufacturing **Kazuhiro Ogawa** *Tohoku University, Sendai, Japan*	**KL-13:** Powder modification and feedstock engineering for repair and additive manufacturing with Cold Spray: from Al to Ti via Ni **Tanvir Hussian** *University of Nottingham, UK*
09:30 - 10:00 Keynote lecture	**KL-12:** Cold Spray Deposition of Pure Metallic Al, Cu and Ni Coatings on Carbon Fiber Reinforced Polymer Substrates: Adhesion, Microstructure, and Functional Performance **Satish Tailor** *MECPL Jodhpur, India*	**KL-14:** Air Cold Spray Additive Manufacturing Capabilities and Challenges **Suresh Palanisamy** *Swinburne Univerisity of Technology, Hawthorn, Australia. Additive Manufacturing CRC, Hawthorn, Australia*

10:00 - 10:15 Contributory lecture	**CL-01:** Preliminary Deposition Behaviour of an In-House Developed Co-Axial Laser-Assisted Cold Spray System **Anirban Naskar** *Indian Institute of Technology Hyderabad, Hyderabad, India*	**CL-04:** Micromachinability Analysis of Cold-Sprayed Additively Manufactured Al-6061 Alloy. **MD Shad Ali** *Indian Institute of Technology Ropar, Rupnagar, India.*
10:15 - 10:30 Contributory lecture	**CL-02:** Evaluation of inter-splat bonding in cold spraying using scratch test **Mohd Nadeem Akhtar** *Indian Institute of Technology Ropar, Rupnagar, Punjab*	**CL-05:** Evaluation of Cold-Sprayed IN718 Coating Properties on IN718 Substrate for Repair Applications **Aviral Bisht** *Indian Institute of Technology Madras, Chennai, India*
10:30 - 10:45 Contributory lecture	**CL-03:** Self-Peening Assisted Cold Spray Deposition for Enhanced Properties of 316L Stainless Steel Using Nitrogen Gas **Srinivasan Nagarajan** *South Dakota School of Mines and Technology, Rapid City, United States*	**CL-06:** Deposition and characterization of cold sprayed compositionally graded multilayer SiC-Al based metal matrix composite (MMC) coatings on Al-6061 alloy **Gaurav Rai** *Indian Institute of Technology Ropar, Rupnagar Punjab, India.*
10:45 - 11:00	**Tea/Coffee** *Dining Hall*	
	Technical Session IV	
	Technical Session IV A Advanced Cold Spray Applications **Raman Hall** *Session Chair:* ***Prof. Srinivasa Rao Bakshi***	**Technical Session IV B** Cold Spray Application in Defense, Space Industries; Tribology Applications **Leelavati Hall** *Session Chair:* ***Dr. Sisir Mantry***
11:00 – 11:30 Keynote lecture	**KL-15:** Cold Spray for Industrial Applications **Reeti Singh** *Impact Innovations GmbH, Rattenkirchen Germany*	**KL-17:** Innovative High-Pressure Cold Spray Aluminum Solutions for Enhanced Solid-State Repair of Gas Turbine LPC Components **Chiragkumar Raval** *Hannecard Roller Coatings Inc, Barberton, Ohio, US*
11:30 – 12:00 Keynote lecture	**KL-16:** Cold spray Relevant Industrial Speciality Processing (CRISP) **Gopi Chandran** *Indian Institute of Technology Madras, India.*	**KL-18:** Tailoring cold spray deposited Ni-superalloys coating to suit various applications by post-processing **Ayan Bhowmik** *Indian Institute of Technology Delhi, India*
12:00 - 12:15 Contributory lecture	**CL-07:** Effect of TiO_2 Content on the Corrosion Behavior of Cold Sprayed Cu-Based Composite Coatings in Marine Applications **Saminderpreet Singh** *Indian Institute of Technology Roorkee, India*	**CL-11:** Strength Restoration in Aircraft Grade AA2014-T6 Alloy Using Cold Spray- An Experimental Tensile Study **Mohanbabu** *CSIR-National Aerospace Laboratories, Bangalore, India.*
12:15 - 12:30 Contributory lecture	**CL-08:** Corrosion Analysis of Cold-Sprayed Copper-Based Composite Coatings **Abhishek Kumar Grain** *Indian Institute of Technology Ropar, Rupnagar, India*	**CL-12:** Cold Spray Deposition for the next generation applications **Jitendra Kumar** *Indian Institute of Technology Ropar, India*
12:30 - 12:45 Contributory lecture	**CL-09:** Cold Spray Deposition of Sn with Ag Overlayers on CFRP as a Replacement for Stainless Steel Solar Mirrors **RPS Chakradhar** *CSIR-National Aerospace Laboratories, Bangalore, India.*	**CL-13:** Microstructure and Tribological Behaviour of Cold Sprayed Tribaloy 400 Reinforced IN718 Coating **Alwin Balasundaram** *Sri Sivasubramaniya Nadar College of Engineering*
12:45 - 13:00 Contributory lecture	**CL-10:** Low Pressure Cold Spray of Al-Al_2O_3 Coatings for Mining Pipeline Repair **Chaitanya Gullipalli** *Indian Institute of Technology (Indian School of Mines), Dhanbad, India*	**CL-14:** Enhancing the Mechanical and Tribological Properties of Cold-Sprayed Nickel-Aluminum Bronze Coatings through Heat Treatment **Unnikrishnan P D** *Indian Institute of Technology Madras, Chennai, India.*
13:00 -14:30	**Networking Lunch** *Dining Hall*	

Day 2 - 24th January (Saturday) – Afternoon		
Technical Session V		
	Technical Session V A Equipment, Consumables and Economics **Raman Hall** *Session Chair:* ***Prof. Anup Keshri***	**Technical Session V B** Quality Assurance: Spray Diagnose Equipment **Leelavati Hall** *Session Chair:* ***Prof. Ayan Bhowmik***
15:00 – 15:30 Keynote lecture	**KL-19:** Process gas and its influence on cold spray process **Eklavya Calla** *GE Vernova, Bengaluru, India*	**KL-22:** Online monitoring of the cold spray process: coverage for full plume width and full process duration for optimal results **Jussi Larjo** *Oseir Ltd., Tampere, Finland*
15:30 – 16:00 Keynote lecture	**KL-20:** Reminiscences on cold spray technology **Jeganathan Karthikeyan** *Thermal Spray Consultant, Sea Ranch Lakes, United States*	**KL-23:** Bridging Research and Industry: Real-Time Diagnostics for Cold Spray **Jean-Félipe Henri** *Tecnar, Canada*
16:00 – 16:30 Keynote lecture	**KL-21:** Empowering Low-Pressure Cold Spray: Pathways for Industrial Adoption in India **Kesavan Ravi** *Indian Institute of Technology (Indian School of Mines) Dhanbad, Dhanbad, India*	**KL-24:** An overview of Cold Spray coating activities at CSIR-NAL for Functional Applications and Component Repair **Meenu Srivastava** *CSIR-National Aerospace Laboratories, Bengaluru, India*
16:30 - 16:45 Contributory lecture	**CL-15:** Introduction to SPRAYCOLD ®: India's First Cold Spray Unit **Vasu K** *MECPL Jodhpur, Jodhpur, India*	**CL-17:** Cold Spray-Assisted Digital Manufacturing of Functional Polymer Architectures **Balasubramanian K** *Defence Institute of Advanced Technology (DU), Pune, India*
16:45 - 17:00 Contributory lecture	**CL-16:** Design and Experimental Validation of a Novel Cold Spray Nozzle for Enhanced Particle Acceleration and Thermal Management **Amit Kumar Sharma** *Titomic Europe B.V, Heerenveen, Netherlands. South East Technological University, Ireland*	**CL-18:** Significance of in-flight powder energy on cold-sprayed coatings **Neelima Devi Guduru** *National Institute of Technology, Andhra Pradesh, Tadepalligudem, India*
17:00 – 17:15	**Tea/Coffee** *Dining Hall*	
17:15 – 18:15	**POSTER SESSION**	
19:00	**Gala DINNER & NETWORKING** **IITM (Alumni club D Block 10th FL)**	

Day 3 -25th January (Sunday) – Forenoon		
Technical Session VI		
	Technical Session VI A Feedstock & coating Characterization and New Repair Evaluation Techniques. **Raman Hall** *Session Chair:* ***Prof. Keshvan Ravi***	**Technical Session VI B** Cold Spray modelling and simulation, Fundamentals/Research & Development. **Leelavati Hall** *Session Chair:* ***Prof. SB Arya***
09:00 - 09:30 Keynote lecture	**KL-25:** Cold spray deposition of copper based alloys **Srinivasa Rao Bakshi** *Indian Institute of Technology Madras, Chennai, India*	**KL-27:** Advancing Cold Spray Through Varying-Fidelity Physical Models, Integrated Sensors, and Engineered Data **Ozan Cagatay Ozdemir** *Northeastern University, Boston, United States*

09:30 - 10:00 Keynote lecture	**KL-26:** Repairing AA2524 fuselage using cold spray coating **Jayabal K** *Indian Institute of Information Technology, Design and Manufacturing, Kancheepuram, Chennai, India.*	**KL-28:** Deposition of Ceramic Coatings on Metallic Substrates by Low-Pressure Cold Spray: Experimental Validation and Numerical Modeling **Sisir Mantry** *CSIR-Institute of Minerals & Materials Technology, Bhubaneswar, India*
10:00 - 10:15 Contributory lecture	**CL-19:** Cold spray processing of AA2024/Al2O3 coating on magnesium AZ91D alloy: Process parameters optimization, microstructure and adhesive strength performance of coating **Mathivanan K** *Priyadarshini Engineering College, Vaniyambadi, India.*	**CL-26:** Thermal Stability and Oxidation Resistance of NiCrAl Substrate –AlCoCrFeNi HEA Interface **Nabila Tabassum** *Shiv Nadar Institution of Eminence, Greater Noida, India*
10:15 - 10:30 Contributory lecture	**CL-20:** A Comparative Analysis for Al-TiO_2 Composite Coatings Fabricated using Cold Spray, Flame Spray, and HVOF **Nitesh Kumar** *IIT Roorkee, Roorkee, India*	**CL-27:** Computational Analysis of Flow and Acoustic Proxy Characteristics in Cold Spray Nozzle Configurations **Mayank Jately** *Maharaja Agrasen Institute of Technology, Delhi, India.*
10:30 - 10:45	**Tea/Coffee** *Dining Hall*	
10:45 - 11:00 Contributory lecture	**CL-21:** Influence of Substrate Surface Roughness on the Microstructure and Mechanical properties of Cold-Sprayed Ti-FeCoCuNbMo Coatings on SS316l **J Sharath Kumar** *Dr B R Ambedkar National Institute of Technology Jalandhar, Jalandhar, India*	**CL-28:** Numerical Investigation of Low-pressure Cold Spray Operations with Back-pressure Control **Samanyu Raina** *South East Technological University, Carlow, Ireland.*
11:00 - 11:15 Contributory lecture	**CL-22:** Insights into the Fracture and Fatigue Behavior of Cold-Sprayed Al–Fe Bimetallic Structures **Kiran Tulasagiri Raddi** *Politecnico di Milano, Milan, Italy.*	**CL-29:** Inner-Diameter Cold Spraying: Optimization and Toolpath planning **Yaman Sahu** *Tampere University, Tampere, Finland*
11:15 - 11:30 Contributory lecture	**CL-23:** High-Temperature Tribological Behaviour of Cold Sprayed Coating on Die Steel **Sanjeev Kumar** *IKGPTU, Kapurthala, India.*	**CL-30:** Investigation on the effects of bilayer sequential cold spray deposition on coating properties in cold-sprayed Ni-base superalloys **Malar Vadani** *Indian Institute of Technology, Delhi, India.*
11:30 - 11:45 Contributory lecture	**CL-24**: High-Temperature Degradation Behaviour of Cold-Sprayed Inconel 718 Coatings **Milan Shahana S** *Indian Institute of Technology Madras, Chennai, India*	**CL-31:** Identifying the reliable Johnson-Cook model parameters and developing the modeling procedure to cold spray AA2524 alloy for repairing fretting wear in Aircraft application **Rajendra Kumar R T P** *Indian Institute of Technology Madras, Chennai, India.*
11:45 - 12:00 Contributory lecture	**CL-25:** Cold-Sprayed ZrC–Cu Composite Coatings: Processing–Structure–Property–Tribology Relationships and Laser Damage Resistance **Saiful Wali Khan** *Indian Institute of Technology Ropar*	**CL-32:** A Comprehensive Literature Review on the Mechanical and Tribological Properties of Cold-Sprayed High-Entropy Alloy Coatings. **Pawan Kumar** *Indian Institute of Technology, Rupnagar, India.*
12:30 - 13:30	**Valedictory Ceremony**	
13:30 - 14:30	**Networking Lunch** *Dining Hall*	
Day 3 -25th January (Sunday) – Afternoon		
15:00 - 17:00	**Lab Visit to IIT Madras**	

Poster Session

Day 1: 23rd January (Friday) *17:45 - 18:45*   **Day 2: 24th January (Saturday)** *17:15 - 18:15*

Poster Code	Poster Details
P01	A Critical Review of High Velocity Oxy Fuel (HVOF) Coating Techniques: Materials, Processes, and Applications. **Vishal Bathrinath M** *Chennai Institute of Technology, Chennai, India*
P02	Influence of Twin Wire Arc Spraying Parameters on Coating Thickness of Copper Coating on Ferrous Metals **Khader C,** Thirumalai Kumarasamy D, Thirumal D *Government College of Engineering Bargur, KRISHNAGIRI, India*
P03	**Development of empirical relationship to predict the porosity level of Twin Wire Arc Sprayed Coatings on stainless steel** **Thirumalaikumarasamy D**, Khader C *Government College of Engineering, Bargur, India*
P04	**Evolutionary Optimization of Cold Spray Deposition: Genetic Algorithm Approach for AA2024–YSZ Composite Coatings** Ashokkumar Mohankumar, Arunkumar Thirugnanasambandam, **Vishal bathrinath Manikandan**, Anbuselvam Thilaharaj *Chennai institute of technology, Chennai, India*
P05	**Process Development and Qualification of Ceramic Coatings on Copper Coils by Plasma Spray Technique** **Ravi Pandey** *Institute for Plasma Research, Gandhinagar, India*
P06	**Cold Spray Additive Manufacturing: A Material-Specific Review** **Mathanbabu Mariappan[1]**, Rajamurugu N[2], Yaknesh S[2], Ashokkumar Mohankumar[3] *[1]Indian Institute of science, bangalore, Bengaluru Urban, India. [2]KCG College of Technology, chennai, India. [3]chennai Institute of Technology, chennai, India*
P07	**Identifying the optimal HVOF spray parameters to attain minimum porosity and maximum hardness in Tungsten Carbide 12 % Cobalt + Self-Fusing Nickel Alloy (WC12Co +Ni Ally + NiAl Blend) coatings on naval materials** **Anbarasu M[1,2]**, Anand R B[1], Thirumalaikumarasamy D[3] *[1]National Institute of Technology, Trichy, India.* *[2]thanthai Periyar Government Institute of Technology Vellore, Vellore, India.* *[3]Government College of Engineering, Bargur, Krishnagiri, India*
P08	**Machine Learning in Surface Coating Engineering: Current Trends, Challenges, and Future Directions: A Comprehensive Review** Anbarasu M[1], Anand R. B[1], Thirumalaikumarasamy D[2], **Anantha Babu M[3]** *[1]National Institute of Technology, Trichy, Trichy, India.* *[2]Government College of Engineering Bargur, Krishnagiri, India.* *[3]Thanthain periyar government institute of Technology vellore, Vellore, India*
P09	**Effect of Traverse Scanning Speed on the Microstructure and Mechanical Properties of Cold-Sprayed Cu/Graphene Composite Coatings** **S Akhil Teja[1]**, Saiful Wali Khan[1], Harpreet Singh[1], Navaneeth K M[1], Vinay Gidla[1], Malkeet Singh[2] *[1]Indian Institute of Technology Ropar, Rupnagar, India.* *[2]Swinburne University of Technology, Victoria 3122, Australia*
P10	**Cold Spray as a Viable Repair Route for AA2014-T6 Airframe Materials-Evidence from NDT Studies** **M Muruganandam**, RPS Chakradhar, I Mohanbabu, Meenu Srivastava, Harish C Barshilia *CSIR-National Aerospace Laboratories, Bangalore, India*
P11	**Tribological and Corrosion Behaviour of Al_2O_3-Based Coatings** **Khushneet Singh** *Shri Mata Vaishno Devi University, Katra, India*
P12	**Repair of H13 Die Steel using Cold Spray Coating** **Vanjangi Abhisheak Naidu[a]**, Unnikrishnan P D[a], Srinivasa Rao Bakshi[a], Giridhar Gopal[b], TVLN Rao[a,b] & M. Kamaraj[a] *[a]Indian Institute of Technology, Madras, Chennai – 600 036, Tamil Nadu, India.* *[b]Sundaram Clayton Pvt. Ltd., Chennai*

BOOK OF ABSTRACTS

Keynote Lecture Abstracts

KL-01: Unlocking the Potential of High-Entropy Alloys for Cold Spray Processing

Andrew Siao Ming Ang
Australian Research Council (ARC) Industrial Transformation Training Centre on Surface Engineering for Advanced Materials (SEAM), Swinburne University of Technology, Australia

High-entropy alloys (HEAs), particularly the CoCrFeNi-based system, have gained significant attention for their exceptional toughness and resistance to wear and corrosion. However, processing these complex alloys through traditional melting methods can often lead to undesirable phase changes or oxidation. Cold spray technology offers a unique solution by depositing materials in a solid state, allowing the CoCrFeNi-based alloy to retain its superior properties without the heat-related degradation typical of other coating methods.

This keynote examines the performance and microstructural evolution of CoCrFeNi-based during the cold spray process. We explore how the high-velocity impact of particles leads to plastic deformation, resulting in coatings or deposits that can be suitable for industrial applications. By analyzing the correlations between material phase, deposition parameters and the resulting mechanical behavior, this research demonstrates how cold-sprayed CoCrFeNi-based alloys can be designed for cold spray processing. The findings provide a pathway for utilizing HEAs to create more durable and reliable surface solutions for the future of engineering.

KL-02: The application of cold spray for structural repair: current status and next challenges

Mario Guagliano
Politecnico Milano, Milan, Italy

Cold spray is a solid-state deposition technique for metallic powders that exhibits several peculiarities making it attractive for many engineering applications.

The cold spray process consists of accelerating metallic powders through a converging-diverging nozzle to supersonic velocities, such that, upon impact with the substrate, adhesion of the particles occurs due to the high plastic deformation and high strain rate.

Thanks to the few limitations regarding sprayable materials (the only required property being a certain ductility), the wide range of possible powder–substrate combinations, the

ability to spray mixtures of different materials, the absence of restrictions on the thickness of the achievable deposits, and the high deposition rate (up to 15 kg/h), cold spray is today considered a very attractive technique for repair and remanufacturing, with the aim of extending the service life of worn and/or damaged components.
In the present work, after introducing the process and discussing the advantages and critical aspects of cold spray as a repair/remanufacturing technique, some structural repair applications developed by the authors are described, the results are critically discussed and the current challenges outlined.

KL-03: Cold Spray Deposition of Martensitic Nickel-Aluminum-Bronze (NAB) for Repair and Coating Applications

Vinay Gidla, Ravi Kant, **Harpreet Singh**
IIT Ropar, Rupnagar, India

Nickel-Aluminium Bronzes (NAB) are copper-based alloys containing aluminum, iron, and nickel, known for their excellent corrosion resistance due to the formation of a protective aluminum oxide layer in corrosive environments. Typically, NAB alloys contain 8–10% aluminum, with the addition of nickel and iron further enhancing their strength and corrosion resistance, making them well-suited for cavitation and biofouling applications. Corrosion and wear lead to material deterioration, often necessitating repairs. Given their desirable properties, NAB alloys are advantageous for use as coatings. Traditional repair techniques such as welding and laser cladding, as well as thermal spray methods like flame spray and High-Velocity Oxy-Fuel (HVOF) spraying, are commonly used for material restoration. However, these methods induce phase changes in the deposited material, requiring extensive heat treatment to restore mechanical properties. Additive manufacturing (AM) techniques, particularly Selective Laser Melting (SLM), have gained attention for fabricating NAB components. While SLM addresses some challenges related to phase transformations, it still necessitates post-processing and has limitations in terms of part size and repairability. Other AM techniques like Directed Energy Deposition (DED) and Wire Arc Additive Manufacturing (WAAM) offer repair solutions but involve high substrate temperatures due to material melting. Cold Spray technology presents a promising alternative, overcoming several of these challenges. As a solid-state deposition process, Cold Spray relies on the plastic deformation of particles to create coatings or repair damaged components without inducing phase changes. However, NAB's inherent martensitic nature makes it difficult to deposit using Cold Spray. To improve deposition efficiency, researchers have explored heat treatment of the feed-stock powder to reduce martensite content, thereby enhancing deposition behavior. This work investigates a novel hybrid approach that combines particle size selection with heat treatment to optimize the Cold Spray deposition of NAB. NAB powder was heat-treated to reduce martensitic phases and then segregated into three size ranges for deposition. Heat treatment significantly improved deposition efficiency (DE) from 20% to nearly 100%. Mechanical (hardness, scratch) and electrochemical corrosion tests were conducted to evaluate inter-splat bonding. Results indicated that as-received (AR) NAB powder exhibited superior mechanical properties despite its lower DE. Among heat-treated powders, the coarser size demonstrated better inter-splat bonding due to its particle size and surface oxide characteristics.

KL-04: Cold Spray – Coating Technology to Integrated Manufacturing

Thorsten Dr Stoltenhoff
Linde AMT, Ratingen / Schluechtern, Germany

From its first mentions more than 30 years back, Cold Spraying has developed to a mature technology for material deposition. In the mid-nineties it was of scientific interest for the process characteristics, particularly the corresponding coating properties, that drove the research in this new coating method. With the development of the first industrial-grade system at the beginning of the 2000s, the interest among coating companies in this novel process also arose.

Linde Advanced Material Technologies (formerly known as Praxair Surface Technologies) is a market leader in the coating technologies segment. In 2005 – still the very early industrialization phase of cold spraying – the company decided to add this new technology to its process portfolio and was the first company that did apply cold spraying for the repair of aircraft parts in an industrial production.Other applications, in particular high-volume production in the automotive business, as well as an outlook on future fields of applications apart from the surface coatings will be discussed in this presentation.

KL-05: Enhancements in cold spraying through laser assistance

Heli Koivuluoto, Leo Suomalainen, Jyrki Latokartano, Reza Jafari
Tampere University, Tampere, Finland

Laser-assisted cold spraying has emerged as a promising technique for enhancing coating properties and structure by promoting thermal softening of powder particles upon impact with the substrate. This facilitates the formation of protective barrier coatings suitable for various corrosive environments. Moreover, the process expands the range of usable coating materials by improving the deformation behavior of challenging powder materials. Additionally, laser assistance can serve as an in-situ heat treatment, thereby influencing the mechanical properties of the resulting coatings. This study explores recent advancements in laser-assisted cold spray technology, with a particular focus on quality control during coating fabrication and additive manufacturing applications.

KL-06: Exploring the Mechanical Performance of Multi-Material Cold Spray Additive Deposits

Sara Bagherifard

Politecnico di Milano, Milan, Italy

Cold spray technology enables the fabrication of multi-phase composite structures, such as bimetallic systems, ceramic-metal composites, and two-dimensional metal matrix composites. This capability remains largely unachievable or is significantly constrained within fusion-based additive manufacturing methods, owing to their intrinsic technical and physical restrictions.

This distinctive advantage positions cold spray as a transformative process, especially for additive manufacturing, expanding its potential for engineering applications that require customised mechanical and functional properties. However, realising this potential and broadening the applicability of multi-material cold spray deposits requires meticulous control over the deposition process and thorough evaluation of the resulting mechanical performance.

To meet these requirements, a comprehensive set of experimental and numerical methods has been adopted to investigate the properties of cold spray additively manufactured multi-material deposits covering a wide range of combinations. These investigations encompass microstructural characterisation, mechanical testing, and predictive modelling, collectively advancing our understanding of the interplay between processing parameters, chemical composition, deposit microstructure, and performance characteristics. Through these integrated approaches, cold spray composites can be optimised for specific applications, thereby improving their reliability and extending their use in advanced engineering settings.

KL-07: Nitrogen-Sprayed Al-6061 for Load-Bearing Applications

Sinan Müftü
Northeastern University, Boston, MA USA

This work focused on using various heat-treatment methods to improve the load-bearing characteristics of N 2 -sprayed Al-6061 deposits and on seeking correlations between easily measurable physical properties, such as thermal and electrical conductivity, and material properties. In its as-sprayed condition, this material is brittle. We implemented a series of post- spray treatments, including hot isostatic pressing, solutionizing, annealing, and warm rolling. We demonstrated that these methods can achieve up to 6% ductility and finite fatigue strength. The most significant improvement was achieved when a 5 kW laser was used during the spraying. This laser-assisted cold spray process resulted in a 16% increase in ductility in the as-sprayed material. Microstructural analysis showed that non-heat-treated Al-6061 deposits fail due to interparticle fracture. The failure mode becomes a mixture of inter- and intra-particle failure following heat treatments. This was attributed to the observed healing of micro-gaps (crack-initiation sites) following heat treatments and to the natural effects of annealing. Statistical analysis of the results indicated strong correlations between the physical properties (TC, EC, CTE) and the compression strength, as well as among these properties.

KL-08: Cold Spray on polymers and polymer-based composites.

Patrizio Lomonaco[1], Francesco Delloro[2]
[1]Tu-Delft, Delft, Netherlands. [2]Mines Paris PSL, Paris, France

This presentation explores the metallization of polymers and polymer-based composites using the cold spray process. An overview of the various attempts in the scientific literature introduces the main challenges, which concern the low adhesion of metal coatings onto polymer-based composites and the risk of damaging the composite during cold spray deposition. The presentation will then move to actual research results. The innovative strategy employed in this study consists in spraying a mixed Al-PEEK feedstock powder with different PEEK proportions within the mixture. Both high-pressure and low-pressure cold spray systems have been compared. The main results are as follows. Low-pressure cold spray can be more effective than the high-pressure for this material combination; the higher the spraying temperature, the higher the adhesion; an increased PEEK content in the feedstock results in higher adhesion, at the expense of lower electrical conductivity. When

PEEK content in the feedstock mixture exceeds a certain threshold, located between 10 and 20 vol.%, the coatings completely lack electrical conductivity. A compromise thus has to be found, depending on the requirement of each application, to achieve a satisfying balance between the antagonist properties of adhesion and electrical conductivity. Finally, two mechanisms leading to the creation and growth of coatings from mixed metal-polymer feedstock powders have been proposed.

KL-09: Niobium alloy C-103 for high-performance space applications – first results with using Cold Spay Additive Manufacturing – CSAM

Markus Brotsack[1], Jan Kondás[1], Dr. Reeti Singh[1], Leonhard Holzgaßner[1]
[1]*Impact Innovations GmbH, Germany*

Space propulsion applications require lightweight materials that can withstand high stresses at elevated temperatures. Niobium has a very low density compared to other refractory metals but high strength, i.e. a high strength-to-weight ratio. The material also shows high thermal conductivity and a low ductile-to-brittle transition temperature. This low transition temperature is advantageous for space applications because it shows excellent resistance to high-frequency vibrations at cryogenic temperatures. Furthermore, C-103, a niobium, hafnium, and titanium alloys used for space propulsion applications, have a high melting point at around 2.350°C and show strong stability at elevated temperatures, too.
Currently, many investigations around C-103 material for in-space propulsion systems for satellites are happening in the space industry. This work shows the feasibility of Cold Spray Additive Manufacturing (CSAM) technology to produce a C-103 test part as a first step for future nozzle designs for different space applications. It is essential for the application to have as thin walls as possible to get down the take-off weight of the satellites. A tube of around 135 mm in length and 2 mm in wall thickness has been manufactured using CSAM. The manufacturing process will be presented in detail, in pictures and videos.
It has been proven that C-103 can be sprayed with high deposition efficiency using cold spray technology. Deposition efficiency of around 92% with a 4 kg/h deposition rate was observed. Both properties make cold spray cost-effective for manufacturing in-space propulsion nozzles with C-103 niobium alloy. Furthermore, microstructural and mechanical properties of cold-sprayed C-103 have also been investigated.

KL-10: A Review on Cold Spray Coating Technology in Gas Turbine Repair

Dheepa Srinivasan
Baker Hughes, Bangalore, India

Cold Spray coatings are seen as a powerful alternative to repair and restoration, as a weld overlay for a number of structural and functional applications in aerospace, Oil and Gas, Power generation and other engineering applications. A number of efforts have gone into using cold spray technology in repair and refurbishment of difficult to weld alloys such as Magnesium, Titanium, Aluminium, Copper and several other 'soft' alloys, for mainly non-structural repair applications, as a buttress layer or a restoration layer. For harder materials, cold spray coatings are also seen as an excellent alternative as a spray on weld of hard, wear resistant materials on steels, in lieu of weld cladding. Stellite6 on steam turbine blade leading edge for erosion protection, IN718/IN625 cold spray coatings for corrosion protection on low alloy steels as well as on rotor rabbet joints are examples of successful qualifications in rotating and stationery parts. However, when it comes to structural repairs of gas turbine components, there are also several aspects that pose a challenge to translation of cold spray technologies owing to possible debits to the mechanical properties. For example, while there are reports of compressive residual stresses in soft metals such as Al alloys, cold spray could result in debits to fatigue and creep behaviour, especially at high temperatures in some Nickel based superalloys.

The present study will showcase examples of hard vs soft alloys using cold spray technologies for gas turbine and oil and gas equipment applications and present a review of the state of art applications that have been successful in using cold spray coatings in production, especially in repair and refurbishment applications.

KL-11: Cold Spray Deposition: Bridging Dissimilar Materials for Advanced Manufacturing

Kazuhiro Ogawa
Tohoku University, Sendai, Japan

Cold spray technology has emerged as a promising solid-state deposition method for integrating dissimilar materials, offering unique advantages such as low-temperature processing, minimal oxidation, and strong interfacial bonding. This keynote presentation explores the challenges and innovations associated with cold spray deposition on diverse material combinations, including metals, ceramics, and polymers.

We present some representative cases that highlight the versatility of cold spray in overcoming conventional limitations of material compatibility. First, the deposition of metallic coatings onto ceramic substrates is examined, focusing on the role of particle velocity, substrate surface treatment, and thermal mismatch. Despite the inherent brittleness and low ductility of ceramics, optimized spray parameters and interfacial engineering enable robust adhesion and functional performance.

Second, we investigate the deposition of ceramic particles onto metallic substrates. This configuration is particularly relevant for applications requiring thermal barrier coatings or wear-resistant surfaces. The study emphasizes the importance of particle morphology, impact dynamics, and post-deposition treatments in achieving dense and adherent ceramic layers without compromising the integrity of the metal base.

Third, we explore the novel application of cold spray for polymer deposition onto metallic substrates. Although polymers are traditionally processed via thermal or chemical methods, cold spray offers a unique route for creating composite surfaces with tailored mechanical and chemical properties. The challenges of particle deformation, adhesion mechanisms, and substrate compatibility are addressed through experimental and analytical approaches.

Across all cases, the integration of dissimilar materials via cold spray is shown to be highly dependent on process optimization, material selection, and interface design. The presentation also discusses recent advancements in nozzle design, powder development, and its diagnostics that contribute to improved deposition outcomes.

By demonstrating the feasibility and adaptability of cold spray for multi-material systems, this work aims to inspire new directions in additive manufacturing, surface engineering, and hybrid material design. The findings contribute to a deeper understanding of cold spray mechanics and open pathways for industrial applications in aerospace, energy, and semi-conductor sectors.

KL-12: Cold Spray Deposition of Pure Metallic Al, Cu and Ni Coatings on Carbon Fiber Reinforced Polymer Substrates: Adhesion, Microstructure, and Functional Performance

Satish Tailor

MECPL Jodhpur, India

Cold spray deposition of pure aluminium, copper, and nickel coatings on carbon fiber reinforced polymer (CFRP) substrates was systematically investigated to enable multifunctional surface properties on lightweight composites. The solid-state nature of the cold spray process allowed metallic coatings to be deposited without exceeding the thermal stability limits of the polymer matrix. Process parameters, including gas pressure and temperature, were optimized to achieve continuous, adherent coatings while preserving substrate integrity. Microstructural characterization using scanning electron microscopy revealed dense coatings with low porosity and minimal oxidation for all three metals. No evidence of matrix degradation or fiber damage was observed. Interfacial analysis indicated that coating adhesion was governed by localized plastic deformation of particles, mechanical interlocking, and anchoring at exposed carbon fibers and surface asperities of the CFRP substrate. Quantitative adhesion strength was evaluated using a modified ASTM C633 tensile test adapted for polymer substrates, yielding adhesion strengths in the range of 3 – 5 MPa, with failure occurring predominantly within the adhesive or near-surface composite region. Functional assessments demonstrated metal-specific performance: aluminium coatings provided lightweight surface protection, copper coatings significantly enhanced electrical conductivity and electromagnetic interference shielding effectiveness, and nickel coatings imparted improved wear resistance and barrier properties. The results establish cold spray as a versatile and effective metallization route for CFRP components in structural and functional applications.

KL-13: Powder modification and feedstock engineering for repair and additive manufacturing with Cold Spray: from Al to Ti via Ni

Tanvir Hussian
University of Nottingham, UK

Cold Spray Additive Manufacturing (CSAM) is now a well-established solid-state large-scale additive manufacturing process where solid particles, upon impact at high strain rate (10^6-9 /s), bond with another material where thermal softening dominates over work hardening. This unique phenomenon allows CSAM to be used from dimensional restoration now to structural repair and load-bearing additive manufacturing. One of the fundamental limitations in the CSAM process is the feedstock powder, which was not designed for high-strain-rate deformation. Over the past decade, the team at Nottingham has done extensive work on solution heat treatment and ageing of difficult-to-spray powder feedstock, starting with precipitation hardenable aluminium alloys such as Al6061, Al7075, to beta titanium Ti5553 alloys via Inconel 718. The common feature in all these alloys is the difficulty to process the gas atomised powder in CSAM due to poor deformability to produce a pore free deposit. In addition to various feedstock engineering, a substantial amount of work took place on the post-deposition trials using laser and heat treatment to improve the mechanical

performance of these AM parts. Finally, the talk will showcase some AM build strategies for CSAM and their corresponding mechanical performance.

KL-14: Air Cold Spray Additive Manufacturing Capabilities and Challenges

Suresh Palanisamy

Swinburne Univerisity of Technology, Hawthorn, Australia. Additive Manufacturing CRC, Hawthorn, Australia

Within the Metal AM space, Cold Spray Additive Manufacturing (CSAM) has emerged as a transformative solid-state technique for fabricating metallic components without melting, making it particularly advantageous for materials with complex microstructures, oxidation tendencies, and difficult-to-weld characteristics. This presentation offers a comprehensive review of our research team's extensive experience with CSAM, focusing on the printability of various metallic powders, the impact of powder feedstock properties, challenges encountered during deposition, optimized post-processing strategies, and the resulting physical and mechanical properties of the fabricated components. Most research works focus on high-pressure inert gas CS (HPCS), neglecting the potential of air-based CS which is often overlooked because of its poorer deposit qualities. Despite this, air-based CS presents advantages in terms of cost and energy savings and has recently gained attention as a promising new CS additive manufacturing method. This review contrasts HPCS and air-based CS, identifying key differences and bonding modes. Then, state-of-the-art air-based CS research is captured and reviewed revealing a diverse range of application areas including functional coatings, machine tool manufacture, and metal-to-ceramic interfacing. Additionally, research efforts to improve air-based CS quality and bonding, which mainly centre around feed-stock morphology optimisation, print pathing, and post-treatment techniques, are captured. Literature is grouped into three main research categories: metal feed-stocks, metal matrix composites and powder mixes, and novel applications.

Our studies have primarily explored the printability of Al6061, Al7075, copper, and aluminium bronze using CSAM. The investigation of powder feedstock characteristics, including morphology, particle size distribution, and pre-treatment techniques, has revealed their critical influence on deposition efficiency, porosity, and mechanical integrity. We have demonstrated that feedstock with irregular or highly oxidized surfaces often results in lower deposition efficiency and mechanical performance due to limited inter-particle bonding. Pre-treatment strategies such as heat treatment and ball milling have been explored to improve powder flowability and reduce hardness prior to deposition, leading to enhanced bonding during the spraying process. Our work also addresses the challenges

associated with process parameter optimization in CSAM, particularly regarding nozzle temperature and spray angles. The impact of build orientation has been systematically studied by printing both horizontally and vertically oriented test coupons. Findings indicate that build orientation significantly influences mechanical anisotropy, with vertically oriented samples exhibiting weaker inter-particle bonding and lower tensile strength due to directional porosity. To mitigate the inherent porosity and mechanical limitations of as-sprayed components, our team has focused on post-spraying heat treatment strategies such as annealing, solution heat treatment, and liquid-phase sintering. These treatments have demonstrated substantial improvements in mechanical performance by facilitating grain refinement, eliminating porosity, and promoting inter-particle metallurgical bonding. For instance, in copper and aluminium bronze components, sintering led to a remarkable increase in tensile strength and ductility, achieving near-wrought performance for structural applications. All these works successfully showcases the capabilities of air based cold spray additive manufacturing.

KL-15: Cold Spray for Industrial Applications

Reeti Singh, Jan Kondas, Leonhard Holzgassner
Impact Innovations GmbH, Rattenkirchen, Germany

In recent years, the focus of research on cold spray technology has shifted from theoretical exploration to practical innovations, resulting in applications that have successfully transitioned to mass production. The concept of cold spray systems is both intuitive and powerful: metal particles are propelled into a heated gas stream through a de Laval nozzle, resulting in a highly effective coating process. For industrial applications requiring precise temperatures and pressures tailored to specific feedstock materials, it is crucial to develop robust systems capable of uninterrupted 24/7 operation.

This work presents a compelling overview of the advantages of cold spray technology, the diverse range of materials it can utilize, and the advancements implemented in Impact Innovations' cold spray systems. We will explore inspiring examples of cold spray applications across various critical sectors, including aerospace, automotive, energy, and others. In addition, this study illustrates how cold spray technology can deliver significant cost savings while enhancing performance in industrial settings, making it an invaluable solution for modern manufacturing challenges.

KL-16: Cold spray Relevant Industrial Speciality Processing (CRISP)

Gopi Chandran R[1], Hemaprabha E[2], Srinivasa Rao Bakshi[1], Kamaraj M[1]

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In this talk, we will explore materials of critical importance to semiconductors and other specialty industries, with a focus on the potential of Cold Spray technology. While Cold Spray offers unique advantages in additive processing, its industrial adoption has been constrained by the high cost of consumables. Developing sustainable approaches that lower input costs is essential to unlocking its broader utility. Such advancements will not only extend the reach of Cold Spray beyond its current niche applications but also open new pathways for widespread exploitation across diverse high-value sectors.

KL-17: Innovative High-Pressure Cold Spray Aluminum Solutions for Enhanced Solid-State Repair of Gas Turbine LPC Components

Chiragkumar Raval

Hannecard Roller Coatings Inc, Barberton, Ohio, United States

The durability and performance of gas turbine Low-Pressure Compressor (LPC) components are vital to turbine efficiency and lifespan. Traditional repair methods, including thermal spray and welding, often face issues like thermal distortion, delamination, degraded mechanical properties, and extended downtime. This presentation explores innovative high-pressure cold spray aluminum solutions as a solid-state repair method for LPC components damaged by wear and erosion-corrosion. High-Pressure Cold Spray accelerates metal particles to supersonic speeds via a high-pressure gas stream, depositing coatings without melting. This minimizes thermal distortion and maintains the metallurgical integrity of the base material. The resulting coatings offer superior adhesion, tailored microstructures, and enhanced wear resistance, significantly extending service life. Additionally, these coatings improve the machinability of repaired parts, enabling efficient post-repair processing. We will discuss process mechanics, material characterization, and performance improvements supported by experimental results. Real-world industrial case studies demonstrate the practical benefits, cost efficiency, and sustainability of this technology. This discussion highlights how high-pressure cold spray aluminum solutions are set to advance the reliability and efficiency of gas turbine maintenance practices.

KL-18: Tailoring cold spray deposited Ni-superalloys coating to suit various applications by post-processing

Ayan Bhowmik
New Delhi, New Delhi, India

Cold spray (CS) additive manufacturing is capable of depositing high-performance Ni-based superalloys repair coatings without melting, thereby retaining feedstock integrity and avoiding phase transformations and formation of deleterious oxidation products. However, the as-sprayed coatings often exhibit limited inter-particle bonding, high porosity, and residual stresses, which are known to adversely affect the coating adhesion and properties. This work investigates various post-processing routes, including heat treatment, introduction of second phase, hot isostatic pressing (HIP)among others, to tailor the microstructure and performance of as-cold-sprayed Ni-superalloy coatings for diverse applications. The influence of these treatments on microstructural evolution, phase stability, densification, hardness, and wear resistance will be presented. The post-processing possibilities will try to highlight the importance of integrating post-deposition modifications to widen the functionality and scope of application of cold-sprayed Ni-superalloy coatings.

KL-19: Process gas and its influence on cold spray process

Eklavya Calla
GE Vernova, Bengaluru, India

Cold spraying as a deposition technique with niche applications in repair and additive manufacturing has become very popular in recent times. Cold spray process uses a converging-diverging (CD) nozzle to accelerate process gas to supersonic velocities. The process gas accelerates feedstock particles due to its drag force and the subsequent impact of these particles on substrate creates the bonding between substrate and feedstock particles due to rapid deformation and adiabatic shear instability at the site of impact. Helium and nitrogen are the commonly used process gases in cold spray. Cold spray can deposit materials that are metallurgically bonded to the substrate, have negligible in-flight oxidation or phase change with ~99% density.

Cold spray process can be well understood using compressible fluid flow equations under the following assumptions:

The flow is one dimensional

The gas flow is isentropic (adiabatic and frictionless)
The gas is approximated as a perfect gas with constant specific heats
The gas flow is calculated without considering the influence of the powder flux
Above assumptions largely hold true as bulk of the flow occurs in the middle of the nozzle and its interactions with the nozzle wall can be ignored. Similarly, heat transfer through the nozzle walls and effect of feedstock powder flux can be ignored as gases are moving rapidly through the nozzle with little time for heat exchange and powder flux is maintained at a level where efficient deposition takes place. Compressibility effects are important when the gas velocity is >0.3 Mach. A counter intuitive phenomenon for compressible fluid flows would be increase in velocity with increase in area whereas, for sub-sonic non-compressible flows constriction of area increases pressure and increases flow velocity e.g. a water hose. For compressible fluid flow, a nozzle where the throat has velocity of Mach 1 is considered to be running in choked condition. Any further increase in gas mass flow in this nozzle will not increase the velocity at the throat but will result in higher density of gas. Supersonic flow is achieved in CD nozzle after the throat as cross-section area increase results in expansion of the compressed gases and their acceleration. Cross-section area of throat of a cold spray CD nozzle is important because this area determines the gas mass flow required for choked nozzle and subsequent expansion of nozzle to generate supersonic flow. The exit Mach number (M) in a CD nozzle that is running in choked condition (i.e. Mach 1 velocity at throat) can be calculated using the area ratio (area of nozzle exit/area of nozzle throat) and the γ (C_p/C_v) value of the gas being used. A choked nozzle achieves supersonic flow at exit where a normal shock occurs and turns the flow to sub-sonic. Thus, a CD nozzle can be very effective in accelerating feedstock particles and enabling their deposition on a substrate. This talk will focus its attention on understanding the compressible gas flow principles underlying the cold spray deposition and how it impacts deposition.

KL-20: Reminiscences on cold spray technology

Jeganathan Karthikeyan
Thermal Spray Consultant, Sea Ranch Lakes, United States

In the last three decades, Cold Spray Technology has matured and established as an integral part of thermal spray manufacturing technology. I was fortunate to be involved in this development right from the start on almost all aspects of the technology – design and development of cold spray nozzles, guns and systems, spray experiments with various raw materials, preparation and characterization of engineered coatings, application studies for advanced industries such as aerospace, biotechnology, defense, etc. A large number of experiments were carried out along this journey and a few of these novel experiments will be discussed in this presentation.

KL-21: Empowering Low-Pressure Cold Spray: Pathways for Industrial Adoption in India

Kesavan Ravi, Chaitanya Gullipalli
Indian Institute of Technology (Indian School of Mines) Dhanbad, Dhanbad, India

Low-pressure cold spray (LPCS) technology has emerged as a versatile coating and repair technique, offering unique advantages compared to its high-pressure counterpart. Its major strength lies in portability and the ability to access extreme remote locations, particularly relevant in the Indian context, where mining, energy, and infrastructure sectors often operate in challenging terrains. However, limitations such as reduced particle impact conditions and limited awareness of LPCS in Indian industries hinder its broader adoption. Despite these challenges, LPCS has already been established for polymers, soft metals, and certain composite coatings, enabling applications in corrosion protection, biomedical coatings, and lightweight structural components. To extend its industrial utility, the current disadvantages are currently addressed through various dedicated R&D. Strategies include effective toolpath planning (e.g., spiral vs. zig-zag deposition strategies under development at IIT (ISM) Dhanbad), novel nozzle designs, feedstock preheating, hybrid laser-assisted deposition, improved powder feeder designs, and computational simulations for process optimization. Empowering LPCS with these advancements will bridge the performance gap with high-pressure systems while retaining its inherent portability and cost-effectiveness. With sustained research, and industrial partnerships, LPCS can evolve into a robust fabrication and repair tool.

KL-22: Online monitoring of the cold spray process: coverage for full plume width and full process duration for optimal results

Jussi Larjo
Oseir Ltd., Tampere, Finland

Cold spray (CS) metal deposition process has been recently expanding its application area from simple coatings to other functions, in particular large scale additive manufacturing. Industrial applications of this technology are gaining steadily more acceptance, with more opportunities still available as the technology matures. In CS applications, maintaining deposit quality throughout the process duration is of great importance. Online particle monitoring is presented as a solution for optimizing the process quality. Available particle monitoring solutions differ in complexity and scope of the result, from simple acoustic and machine vision based solutions to full plume particle property mesurement. Different approaches with advantages of each solution are discussed. The operation principle and usage patterns of HiWatch particle sensors are presented, with examples and sample results from the extensive development work of the HiWatch sensor line.

KL-23: Bridging Research and Industry: Real-Time Diagnostics for Cold Spray

Jean-Félipe Henri
Tecnar, Canada

Cold spray has emerged as a transformative coating and additive manufacturing technology, offering unique advantages such as low oxidation, high deposition efficiency, and the ability to process oxygen-sensitive and temperature-sensitive materials. However, one of the long-standing challenges in cold spray is the lack of direct, real-time insights about the spray stream or plume. This complicates process optimization and quality assurance. To address this, Tecnar has developed the Accuraspray CS, an in-situ diagnostic tool specifically designed for cold spray applications. The Accuraspray CS employs the use of photo-optical detectors and advanced signal processing to provide real-time measurements of in-flight particle velocity and particle flux directly from the spray plume. The sensor is designed to be compact, robust, and easy to use to enable both researchers and industrial users to quantify plume behavior under varying gas pressures, temperatures, and nozzle conditions. By offering real-time feedback, the sensor facilitates rapid parameter optimization, early detection of process drift, and greater confidence in coating repeatability. To demonstrate the versatility of the Accuraspray CS and how it is employed by users, two case studies will be presented. The first case study will cover the use of the sensor for an academic research project. Here the experimental velocity values of a high pressure cold spray system as measured by the Accuraspray CS, unlocked novel findings about the method of determining flattening ratios of spherical Titanium particles. In contrast, the second case study will elaborate on the use of the Accuraspray CS in a large-scale, high pressure cold spray production facility. Here, the device is fully integrated into the production cold spray booth, serving as an early warning system, detecting wear or clogging of the nozzle and any drift in the process. The sensor is also used as a real-time decision maker on the process quality leading to reduced downtime and achieving higher coating repeatability. These two case

studies will paint a picture of how diagnostic technology is bridging the gap between academic exploration and heavy industrial use of cold spray technology, ultimately, making cold spray a more stable, repeatable and profitable manufacturing technology.

KL-24: An overview of Cold Spray coating activities at CSIR-NAL for Functional Applications and Component Repair

Meenu Srivastava
CSIR-National Aerospace Laboratories, Bengaluru, India

CSIR-NAL offers expertise and capabilities in low pressure cold spraying (LPCS) particularly for applications in aerospace, power plants, corrosion protection and other industries requiring high-performance materials like copper, aluminium, and high entropy alloy coatings. Some of the developments include anti-corrosion coatings for light weight Al and Mg alloys. Others include high-temperature oxidation-resistant Fe_3Al coating for power plants to extend the life of equipment exposed to high temperatures. Another development is on high-entropy alloy coatings for thermal barrier coating (TBC) applications. HEA coatings consist of multiple principal elements in high concentrations, providing exceptional properties such as enhanced oxidation and corrosion resistance. Research has also been undertaken on the repair of aircraft-grade aluminum alloys using LPCS, a process that avoids the heat-related damage associated with other thermal spray methods. This capability is particularly relevant for the aerospace industry. Yet another area of research is on metallization of carbon fibre reinforced composites for lightning strike protection in aircrafts.

One of the developments discussed elaborately is the development of a high temperature oxidation resistant Fe_3Al coating for enhancing the life of components of fossil fuel power plants, refineries and boilers. The high temperature coating prepared by LPCS essentially consists of iron along with 14wt% Al obtained by a low pressure (<5-6 bar) and low operating temperature (≤ 600 °C) process compared to the conventionally used any other thermal spraying process (>1200 °C). The thickness of the coating is in the range of 100 to 150 microns. The coating microstructure observed through field emission scanning electron microscope displayed a uniform dense microstructure compared to the lamellar structure displayed by a typical thermally sprayed, high velocity oxy fuel (HVOF) coating. The intermetallic Fe_3Al coating enhances the oxidation resistance especially at high temperatures and can be easily applied on any metallic material. The as-sprayed Fe_3Al coating exhibited a mean microhardness of 646±30 HV0.1 at 100 gmf load and the microhardness can be enhanced to as high as 955±30 HV0.1 upon heat treatment at 800 °C in air for a duration of 1 hr. No significant change in the composition of the coating is observed upon subjecting to isothermal heat treatment at 800 °C for different durations of 50, 100, 150 and 200 hrs. No delamination of the coating was observed even after 200 hrs heat treatment, suggesting good high temperature stability of the coating. The Fe_3Al coating also displays enhanced wear resistance upon heat treating at 800 °C for 1 h compared to uncoated mild steel. Thus, the process employed in the invention can be used for on-site repair of the components used in high temperature applications.

KL-25: Cold spray deposition of copper based alloys

Srinivasa Rao Bakshi
Indian Institute of Technology Madras, Chennai, India

One of the good applications of cold spray is for deposition of copper and copper based alloys. Copper based alloys can be easy as well as difficult to deposit based on their microstructure and hardness. The properties of the deposit in as-deposited and annealed condition varies significantly with gas used (He or N_2). It is observed that He sprayed coatings show better ductility than N2 sprayed coatings. Annealing of the coating results in recrystallization at low temperatures of 300 deg. C. However, the ductility is still not regained. The microstructural inhomogeneity is maintained even after recrystallization. The presentation will discuss the literature on cold spraying of copper based alloys with respect to effect of process parameters on the microstructure, annealing behaviour, and the properties of the coatings. Some potential applications will be discussed.

KL-26: Repairing AA2524 fuselage using cold spray coating

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Among Al-Cu 2000 series alloys, AA2524 finds wide usage in fuselage structure and airframes in aircrafts, owing to their lower density, excellent strength-to-weight ratio and reduced impurities in the alloy. However, the alloy is subjected to unavoidable fretting wear under service conditions and its replacement involves significant cost. Consequently, a suitable solid-state deposition repair technique avoiding oxidation and phase transformation is needed to retain its bulk properties in the repaired region. Cold spray coating is one of the advanced solid-state deposition methods that fulfils this requirement. Since the bonding in this process is highly localized, developing a reliable predictive model becomes necessary. Determining the correct Johnson-Cook (JC) model parameters under tension and compression is a prerequisite to model the bonding mechanism, arising from adiabatic shear instability. Considering this, the current work first explores the quasi-static response of AA2524-T3 alloy under hot tensile loading of strain rates in the range of 0.001 s^{-1} to 0.1 s^{-1} and temperatures between 25°C and 300°C. Following this, the study investigates the hot compressive deformation behaviour of AA2524-T3 alloy under different strain rates in the range of 0.01 s^{-1} to 100 s^{-1} and temperatures between 250 and 450°C. The microstructural evolutions are characterized through extensive microscopical analysis. Then, the parameters of JC constitutive model are determined to predict the flow stress behaviour of AA2524-T3 for selected testing conditions. Subsequently, the key parameters, such as strain rate sensitivity and thermal softening coefficient, are further optimized to improve accuracy. Thereafter, these parameters are provided as input for modeling the single and multi-particle deformation behaviour upon impact on both smooth and roughened substrates. The other input variables such as particle velocity and temperature are obtained using an axisymmetric model of a convergent-divergent nozzle, with nitrogen as the input gas carrying AA2524 particles ranging in size from 20 to 68 µm, and gas pressures at 3 MPa and 5 MPa, and temperatures at 300°C and 400°C. The numerical results are correlated with the experimentally measured particle velocity, splat deposition, interface shear strength, thickness and deposition efficiency of the coating to find the optimum process parameters. Consequently, the effect of post heat treatment on mechanical properties and fretting wear behaviour of cold sprayed AA2524 is studied under industrial conditions and evaluated through systematic microstructural investigation. Furthermore, the CEL model-predicted porosity and surface roughness are accounted to optimize the input parameters to minimize the efforts on the cold-sprayed AA2524 after post processing.

KL-27: Advancing Cold Spray through Varying-Fidelity Physical Models, Integrated Sensors, and Engineered Data

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A predictable and a reliable cold spray (CS) process requires a thorough characterization of the powder-process-property relationships, monitoring the process with integrated sensors, correlating sensor data with physical attributes, and associating in-process

variations with the properties of the final product. However, this is nontrivial as CS is a multi-physics process with over two dozen variables and is prone to temporal changes associated with nozzle wear, thermal state of the workpiece, continuously changing surface geometry, and other factors. Additionally, the presence of particles with varying shapes and sizes in the 10^{-7} m to 10^{-5} m range, the high Reynolds number supersonic flow regimes, and the supersonic jet impingement and heat transfer introduce complexities which are difficult to capture and/or interpret in an in-situ fashion. In this talk, a case study of how high-fidelity computational fluid dynamics (CFD) models can be used for understanding the airborne acoustic signals which originate from the CS processes is presented. Aeroacoustic signatures associated with discrete and temporal variations in nozzle geometry, powder feed rate, and standoff distance are characterized experimentally and studied using CFD. Moreover, engineering features significant for process monitoring and machine learning supported anomaly identification are presented. A further discussion is provided on how higher efficiency, but reduced fidelity models can be integrated with artificial neural networks for CS process design involving a large number of variables.

KL-28: Deposition of Ceramic Coatings on Metallic Substrates by Low-Pressure Cold Spray: Experimental Validation and Numerical Modeling

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This study investigates the Low-Pressure Cold Spraying (LPCS) technique for ceramic coatings with the aim of improving deposition efficiency and clarifying the underlying bonding mechanisms. The deposition of ceramic coatings via LPCS is examined using hydroxyapatite (HA) sprayed onto 316L stainless steel (SS) as a representative case. Although LPCS offers several advantages, effective retention of HA particles remains challenging, leading to thin coatings (11.09 ± 2.56 µm) with low bonding strength (1.80 ± 0.19 MPa). To overcome this limitation, a composite coating approach was developed by blending 80 wt.% HA with 20 wt.% Cu–Zn powder. This strategy resulted in a substantial enhancement in coating performance, yielding higher bonding strength (33.70 ± 1.13 MPa), improved deposition efficiency (27%), and increased hardness (136.30 ± 2.45 HV) compared with pure Cu–Zn coatings. Numerical simulations were employed to support and interpret the experimental findings, revealing that the incorporation of metallic constituents with HA

significantly enhances deposition efficiency, bonding strength, and hardness. In pure HA coatings, particles undergo fragmentation into submicron grains and become embedded into the substrate via mechanical interlocking (MI), with shockwave-induced effects contributing to the strengthening of subsequent layers. In Cu–Zn coatings, bonding is governed by a combination of MI and adiabatic shear instability (ASI). For HA–Cu–Zn composite coatings, high-velocity HA and Zn particles further enhance bonding through an in situ tamping effect.

Keywords: LPCS, Hydroxyapatite, Adiabatic Shear Instability, HA-Cu-Zn

Contributory Lecture Abstracts

CL-01: Preliminary Deposition Behaviour of an In-House Developed Co-Axial Laser-Assisted Cold Spray System

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Laser-assisted cold spray (LACS) has demonstrated clear advantages, including improved coating adhesion, reduced porosity, and lower processing costs, while also enabling the deposition of hard materials that are otherwise difficult to deposit using conventional cold spray. However, most existing LACS configurations rely on an externally mounted laser that is focused directly on the substrate, leading to complex hardware integration and limited ability to heat in-flight particles. Consequently, such systems primarily rely on substrate preheating and still require additional gas heating, similar to conventional cold spray. The present work introduces a co-axial laser-assisted cold spray (COLA-CS) system in which the laser beam passes directly through a converging–diverging supersonic cold spray nozzle. This configuration enables simultaneous heating of both particles and substrate, thereby eliminating the need for carrier-gas heating. A coupled computational fluid dynamics (CFD) and discrete phase modelling (DPM) simulation is used to design the nozzle based on optimized flow characteristics and particle acceleration. Laser–particle interaction and particle temperature evolution are also modelled by incorporating a Gaussian heat source in the CFD–DPM simulation. Using this COLA-CS system, a 1 mm thick SS316L coating was successfully deposited on mild steel at a low nitrogen gas pressure of 10 bar without gas

heating. Deposition-zone temperatures measured by IR pyrometer ranged between 1260–1310 °C, below the melting points of both SS316L and mild steel. Besides, cross-sectional analysis showed splat boundaries with no evidence of dilution or full melting, confirming solid-state deposition. This initial development demonstrates the potential of the developed COLA-CS for economically depositing hard materials at low gas pressures and without gas heating.

CL-02: Evaluation of inter-splat bonding in cold spraying using scratch test

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Cold Spraying is a solid-state coating deposition technique where micron-sized particles are deposited onto a suitably prepared substrate. Due to its layer-by-layer buildup, it is utilized for both coating and repair applications. The properties of cold-sprayed deposits are often influenced by the inter-splat bonding state. In this study, the scratch test was employed as a key parameter to evaluate the inter-splat bonding state in Inconel coatings developed using a high-pressure cold spray system. To enhance inter-splat bonding, the coatings were subjected to various heat treatment conditions. The effectiveness of the heat treatment in improving bonding was assessed through scratch testing. Additionally, the corrosion performance of the coatings, which is strongly influenced by the inter-sdraft contestantplat bonding state was analyzed and correlated with the scratch test results.

Keywords: Cold Spray, Inter-splat Bonding, Inconel, Corrosion, Heat Treatment, Scratch Test

CL-03: Self-Peening Assisted Cold Spray Deposition for Enhanced Properties of 316L Stainless Steel Using Nitrogen Gas

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Cold-sprayed austenitic steel deposits often exhibit poor adhesion and cohesion due to limited deformation of powder particles and concomitant strain hardening, resulting in suboptimal performance for demanding service conditions. While post-processing treatments can enhance these properties, their application is typically impractical at industrial scales due to associated costs and component size constraints. An alternative approach involves in-situ shot peening or micro-forging using hard, heavy particles (e.g., WC, CrC, BN) to consolidate the cold spray deposits. However, disparities in thermal and mechanical properties between these peening agents and the feedstock powders can compromise coating integrity and corrosion resistance. This study explores the feasibility of employing large and hardened 316L stainless steel powder particles as a self-peening agent during the cold spray deposition of gas-atomized 316L powders. The self-peening particles were produced via mechanical milling and systematically evaluated by co-depositing them with gas-atomized powders at varying proportions. The resulting self-peened deposits demonstrated significantly reduced porosity and enhanced hardness compared to deposits solely derived from gas-atomized powders. These improvements translated into superior adhesive and cohesive properties, as confirmed through triple-lug shear and tensile testing. Overall, this investigation validates a novel self-peening approach that substantially enhances the mechanical performance of 316L cold spray deposits. This method presents a cost-effective and industrially viable alternative to expensive helium gas spraying or conventional post-treatments, overcoming key limitations in cold spray technology for high strength materials.

CL-04: Micromachinability Analysis of Cold-Sprayed Additively Manufactured Al-6061 Alloy.

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Additive manufacturing (AM) is an advanced fabrication technique that enables the production of complex components through a layer-by-layer material deposition approach. It offers efficient material utilization and is well-suited for both new part fabrication and repair applications. However, conventional high-temperature AM processes such as Selective Laser Melting (SLM), Selective Laser Sintering (SLS), and Electron Beam Melting (EBM) often lead to issues like residual stresses, oxidation, and microstructural distortions, which can degrade the mechanical properties of the final product. To address these

limitations, the cold spray additive manufacturing (CSAM) process has emerged as a promising solid-state alternative. In CSAM, fine metal powders bond through severe plastic deformation without melting, resulting in minimal oxidation and negligible thermal effects. Despite these advantages, CSAM components exhibit defects like surface roughness, porosity, strain hardening and weak bonding; necessitating effective post-processing. To achieve desired surface quality and dimensional accuracy, micromachining can play a crucial role as a post-processing technique for CSAM components, as it enables precise surface finishing and dimensional control at small scales. However, the machinability of CSAM materials significantly differs from that of their bulk counterparts due to variations in density, microstructure, and hardness. This study investigates the micromachining behaviour of cold-sprayed additively manufactured Al6061 in comparison with bulk Al6061. The work focuses on evaluating surface finish, surface morphology, cutting forces, chip formation, and tool wear under different machining parameters to understand the influence of CSAM-specific microstructural characteristics on machinability.

CL-05: Evaluation of Cold-Sprayed IN718 Coating Properties on IN718 Substrate for Repair Applications

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Inconel 718 (IN718), a nickel-based superalloy, is extensively used in aerospace components due to its high strength and ductility in the temperature range of 650–760 °C. However, these components are prone to degradation under extreme service conditions, necessitating timely repair. Cold Spray (CS), a solid-state deposition technique, offers significant advantages over conventional thermal spray methods by avoiding melting and oxidation, enabling the deposition of dense, low-porosity coatings with near-forged mechanical properties.

This study explores the feasibility of using CS for the repair and restoration of IN718 components by systematically investigating the effects of deposition parameters and post-spray heat treatments. A thick (~4 mm) CS IN718 coatings were deposited on ground and polished IN718 substrates using nitrogen gas heated to 1000 °C at pressures of 5 and 7 MPa. The coatings were subjected to standard double aging (DA) and solution treatment followed by double aging (STDA) heat treatments. Microstructure, hardness, porosity, adhesion, and tensile strength were evaluated for as-sprayed (AS) and heat-treated conditions. The AS coating microstructure exhibited a deformed powder microstructure having fine dendritic/cellular structure. Following the DA treatment, the dendritic features were preserved, accompanied by the precipitation of γ′, γ″, and δ phases. After STDA treatment, a homogeneous microstructure with the presence of γ′, γ″ and Nb and Ti carbides without any δ phase was observed. Higher gas pressure (7 MPa) resulted in enhanced particle velocity, reduced porosity (0.4 ± 0.1%), and improved mechanical properties, yielding a tensile strength of 1325 ± 10 MPa and 6.1 ± 0.6% failure strain (STDA). Additionally, the tensile properties of the coating–substrate combination (sandwich samples) were also evaluated and it showed improved strength (1049 ± 8.5 MPa) over standalone coatings. Further, the fretting wear behaviour of the coatings were assessed at room temperature (RT) and 500 °C with varying stroke lengths. DA-treated samples exhibited superior fretting resistance with lowest wear loss (47×10^{-5} mm^3 at RT and 21×10^{-5} mm^3 at 500 °C) for 7 MPa samples. Coefficient of friction decreased at elevated temperatures (~0.38) compared to RT (up to 0.68). At RT, adhesive wear predominates under low-stroke conditions, while a combination of adhesive and abrasive wear occurs under high-stroke conditions. At 500 °C, abrasive wear dominates throughout, regardless of stroke length. The study demonstrates that CS combined with appropriate heat treatments can significantly enhance the mechanical and tribological performance of IN718, making it a promising solution for the repair and life extension of critical aerospace components.

CL-06: Deposition and characterization of cold sprayed compositionally graded multilayer SiC-Al based metal matrix composite (MMC) coatings on Al-6061 alloy

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This work focuses on enhancing the surface properties of aluminium alloys for advanced engineering applications. It investigates the use of cold spray deposition to apply compositionally graded multilayer SiC-Al based metal matrix composite (MMC) coatings on Al 6061 alloys. Since cold spraying is a solid-state process, it avoids melting the materials, which helps maintain their original structure and properties. This allows for precise layering of SiC and aluminium to create smooth compositional gradients across the coating. To understand the performance and quality of these coatings, detailed characterization was carried out using techniques such as Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), Optical Microscopy, and phase analysis through X-ray Diffraction (XRD). Mechanical tests including hardness and scratch resistance were also performed. The results highlight the potential of cold spray technology to produce strong,

multifunctional MMC coatings, making them suitable for aerospace, automotive, and defense applications where lightweight durability is essential.

Keywords: Cold spray, metal ceramic composites, functionally graded coatings, thermal spray coatings.

CL-07: Effect of TiO_2 Content on the Corrosion Behavior of Cold Sprayed Cu-Based Composite Coatings in Marine Applications

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Cold spray processing was used to fabricate Cu-based composite coatings reinforced with varying TiO_2 contents (10, 20, and 30 wt.%) to evaluate the influence of ceramic incorporation on microstructural and corrosion behavior in marine environments. The solid-state deposition preserved the intrinsic properties of the Cu matrix and TiO_2 particles while promoting work hardening and mechanical interlocking at the coating–substrate interface. Microstructural characterization revealed a progressive increase in ceramic dispersion and reduction in interconnected porosity with increasing TiO_2 content, with the 20 wt.% TiO_2 coating exhibiting the most uniform particle distribution and densest microstructure. Electrochemical corrosion testing in 3.5 wt.% NaCl solution demonstrated a significant improvement in corrosion resistance with increasing TiO_2 content and 20 wt.% TiO_2 coating achieving the lowest corrosion current density and highest polarization resistance. The enhanced performance is attributed to the formation of a compact Cu_2O/TiO_2 passive barrier layer and restricted electrolyte penetration pathways. These findings highlight the critical role of TiO_2 content in optimizing the corrosion protection efficiency of cold sprayed Cu-based composite coatings for marine applications and demonstrate that an intermediate reinforcement level provides the most effective balance between coating density and barrier performance.

CL-08: Corrosion Analysis of Cold-Sprayed Copper-Based Composite Coatings

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Copper (Cu) and its alloys are widely utilized in energy, power generation, rail transport, aerospace, defence, and electronics due to their outstanding electrical and thermal

conductivity combined with high ductility. However, their relatively lower corrosion resistance and susceptibility to environmental degradation limit their use in extreme service conditions. In this study, ZrC–Cu composite coatings containing varying ceramic fractions (0-85%) were deposited on Al-6061 substrates using high-pressure cold spray. Microstructural characterization was done using SEM/EDS and phase analysis via XRD. Additionally, all the coatings are tested for corrosion resistance in 3.5 wt% NaCl solution and compared with pure copper coatings. The results highlights, how the variation in ZrC-Cu composition effects the corrosion resistance in extreme marine environment and give insights to optimise the composition for better performance.

CL-09: Cold Spray Deposition of Sn with Ag Overlayers on CFRP as a Replacement for Stainless Steel Solar Mirrors

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The growing demand for lighter and more efficient materials for solar concentrator systems has accelerated interest in replacing traditional stainless steel (SS) mirrors with advanced composite-based alternatives. Stainless steel works well in terms of corrosion resistance and finishing quality, but its density (close to 7.99 g/cm^3) adds a lot of unnecessary weight to the overall structure. This becomes a problem when the system size increases or when installation needs to be simple. In contrast, CFRP, being much lighter and offer a superior alternative with a significantly lower density (around 1.5 g/cm^3) and still mechanically reliable, and corrosion resistance.
In this study, we have developed a reflective coating system on CFRP using tin (Sn) and an Ag–Sn bilayer. A Sn layer was cold-sprayed first and later polished quite extensively to reduce the surface roughness. After the Sn layer was polished down to remove most of the spray-induced roughness, we deposited a thin Ag overlayer, mainly with the aim of improve the reflectance as far as possible. The whole coating system was characterized using X-ray diffraction, Field emission scanning electron microscopy (FESEM), Energy-Dispersive X-ray Spectroscopy (EDS), Atomic Force Microscopy (AFM) and UV-VIS-NIR spectroscopy. From the optical studies, it is observed that the as-sprayed Sn was only giving around ~55% reflectance, which is consistent with the uneven surface we usually see from cold spray. The reflectance was increased by polishing to about 80 %, indicating that the majority of the scattering originated from surface irregularities. Further, an enhanced reflectance of about 91 to 99% was achieved in the UV-VIS-NIR region when the Ag layer was deposited.

The thermal characterization results were consistent with the optical behaviour of the coated system. The emissivity of the cold sprayed Sn coated CFRP substrate was found to be nearly 0.06, and it was reduced to the level of about 0.03 when the full Sn -Ag bilayer had been applied, showing that radiative heat losses were significantly minimized. The UV-VIS spectra also demonstrated the definite shift in the absorption edge where the calculated band-gap value shifted to the range of about 3.76 eV when Sn -Ag bilayer was applied. This change can be explained by the existence of SnO and SnO_2 phases produced during processing. The optical, thermal and microstructural findings substantiate the fact that Sn-Ag coated CFRP system is an efficient lightweight mirror material. The coating technique is found to be scalable to solar concentrators of next generation and other weight sensitive reflective technology.

CL-10: Low Pressure Cold Spray of Al-Al_2O_3 Coatings for Mining Pipeline Repair

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Low Pressure Cold Spray (LPCS) is a solid state deposition technique, which can deposit a wide range of materials, i.e., metals, composites, metal alloys, cermets. This ability made LPCS a suitable candidate for repair and refurbishment applications. Mining/slurry pipelines experience severe wear and tear due to the harsh working environments, which require frequent repair and refurbishment. In this regard, this work aims to investigate the feasibility of a new repair methodology for mining pipelines through LPCS. For that, Aluminum + Alumina composite coatings were deposited on mild steel substrates, and the deposition characteristics were studied. A total of 9 samples were prepared by varying process parameters, i.e., scan/toolpath strategy (zigzag, zigzag 45^0, and spiral tool path) and weight % of Alumina (20 %, 35%, and 50 %). The as-deposited samples were sectioned in the transverse direction for microstructure characterizations. The microstructure studies revealed excellent bonding at the interface and micro-level porosity in the coating region at particle-particle interfaces. Wear test and scratch tests were performed on the surface of the coatings. Further, 75 mm x 10 mm samples were cut from as-deposited samples, and these strips were subjected to 3 point bending test to assess the adhesion at the interface and cohesion in the coating. Finally, the results showed that both alumina content and toolpath strategy have had a significant effect on bond strength and wear resistance.

CL-11: Strength Restoration in Aircraft Grade AA2014-T6 Alloy Using Cold Spray- An Experimental Tensile Study

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Al–Al_2O_3 powder mixtures were deposited via the cold spray (CS) process onto AA 2014-T6 aluminium alloy substrates to repair artificially induced surface defects. The defects were classified into four geometries: V-Notch single-side (VS), V-Notch double-side (VD), V-Notch in the longitudinal direction (VL), and V-Notch in the transverse direction (VT). Microstructural and phase characterisations of the coatings were performed using X-ray diffraction (XRD) and field-emission scanning electron microscopy (FESEM). The XRD studies showed dominant peaks corresponding to face-centred cubic (FCC) aluminium, along with minor reflections attributed to α-Al_2O_3. Microhardness measurements showed average values of approximately 70 ± 10 $HV_{0\cdot05}$ for aluminium and 1120 ± 10 $HV_{0\cdot05}$ for Al_2O_3, indicating the clear mechanical contrast between the metallic and ceramic constituents.

The tensile tests were carried out following ASTM E8 standards. It is observed that cold spray repairs significantly enhance the mechanical properties. The modulus, yield strength, ultimate tensile strength (UTS) and percentage elongation of the damaged and repaired specimens were tested. Cold sprayed repaired samples have a significant increase in tensile strength compared to the damaged samples. In this experiment, the VS sample recorded an increase in UTS of 370 ± 5 PMa found in (defective state) to 386 ± 5 PMa (after repair). The repaired VD, VL, and VT specimens also exhibited higher UTS values (385 ± 5 MPa, 440 ± 5 MPa, and 432 ± 5 MPa) compared to their defective counterparts (365 ± 5 MPa, 421 ± 5 MPa, and 428 ± 5 MPa), respectively.

This increase in tensile strength is as a result of localized plastic deformation and strain hardening as the CS deposition takes place. High force of collision of the particles during cold spray coating of the material enhances densification in the area that has been repaired which enhances interfacial bond between the substrate and the repaired area. The findings of this study have clearly shown that Cold Spray deposition is a good repair method that can be used to repair defects particularly in the high strength aluminum alloys since it offers significant enhancement in both structural integrity and mechanical performance.

CL-12: Cold Spray Deposition for the next generation applications

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Cold Spray (CS) Deposition is an emerging solid-state deposition and additive manufacturing technique that enables the deposition of dense, pore-free and oxide-free coatings without melting the feedstock material. In this process, pure metal or alloy powders are accelerated to supersonic velocities through a high-pressure propelled gas jet and impact on the substrate surface, making a coating by severe plastic deformation and bonding. Since the process operates at below the melting temperature of materials, it preserves their original phase, purity, and mechanical integrity, making it ideal for temperature-sensitive applications. Cold spray technology has found significant use in various industrial sectors such as aerospace, automotive, marine, energy, and defense. It is employed for corrosion and wear protection, surface restoration, dimensional repair, and enhancement of electrical or thermal conductivity. For example, in aerospace and automotive industries, it is used to repair lightweight aluminium and titanium components, while in the energy sector, it enables the deposition of conductive and protective coatings on critical parts and in the marine sector, it enables corrosion-resistant coating. In next-generation applications, cold spray is gaining importance in advanced electronics, additive manufacturing, and sustainable smart manufacturing systems. It offers a promising route for producing high-purity conductive coatings, lightweight structures, and multifunctional surfaces without introducing thermal damage or oxidation of the feedstock and substrate. The ongoing developments in powder design, process control, and hybrid cold spray systems continue to expand their capabilities, establishing cold spray deposition as a key technology for future high-performance and environmentally responsible manufacturing.

CL-13: Microstructure and Tribological Behaviour of Cold Sprayed Tribaloy 400 Reinforced IN718 Coating

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The service life of worn gas turbine engine (GTE) components is frequently extended through refurbishment for economic reasons. Recently, the cold spray process has gained

prominence in the repair of GTE components because it can deposit a thick coating at a high deposition rate and at relatively low temperatures. The wear properties of cold sprayed as-deposited build-up coatings are inferior to those of the substrate or the wrought alloy, and therefore, they often demand a post-spray heat treatment. Heat treatment can be avoided if the wear properties of the as-sprayed coating can be improved. This work aims to improve the wear resistance of the as-sprayed alloy 718 (IN718) coating, a commonly used build-up coating in GTE, by reinforcing it with Tribaloy T400 particles. The T400 reinforced IN718 coatings were obtained by spraying mechanically mixed T400 powder with IN718 powder. The microstructural analysis of the IN718/T400 composite coating showed that the T400 particles were unevenly distributed within the IN718 matrix. Most of the T400 particles remained spherical, and a few others were fragmented. The fraction of the T400 particles retained in the coatings was significantly lower than the initial powder mixture. Due to the poor bonding probability, most of the T400 particles rebounded, resulting in a lowering of the deposition efficiency of the composite coatings. The tamping effect provided by the rebounding T400 particles helped to improve the coating characteristics, such as decreased porosity, reduced surface roughness, and increased adhesion strength, compared to IN718 coating. In addition, they induced additional microstrain in the IN718 matrix of the composite compared to IN718 coating. This additional strain and the presence of T400 improved the hardness of the composite coating compared to the IN718 coating. Sliding wear tests were carried out at room temperature (RT) and 600 °C using a ball-on-disc tribometer with alumina balls to assess the wear resistance of the coatings. The wear resistance of the composite coatings was significantly higher than the IN718 coating at RT and 600 °C due to the rise in hardness and load-bearing effect provided by the reinforcement. At RT, a combination of abrasive and tribo- oxidative wear mechanism was observed in the coating, whereas at high temperature, a combination of oxidative and abrasive wear mechanism was observed.

CL-14: Enhancing the Mechanical and Tribological Properties of Cold-Sprayed Nickel-Aluminum Bronze Coatings through Heat Treatment

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Nickel-aluminium bronzes (NAB) are crucial copper alloys for marine applications due to their exceptional strength and corrosion resistance. Damage from wear and cavitation necessitates effective repair. Conventional methods, such as welding and thermal spray, involve melting, which causes detrimental phase changes that necessitate post-process heat treatment. Cold spray is a solid-state alternative in which particles bond through plastic deformation, thereby avoiding phase transformations. However, the martensitic structure of typical NAB powder impedes deformation and bonding, limiting deposition efficiency and coating integrity.

This study addresses this challenge by employing heat treatment on the feedstock powder to transform the martensite into alpha phase, enhancing particle deformability for improved deposition. Furthermore, a post-deposition heat treatment is applied to the cold-sprayed coating to strengthen interparticle bonds through diffusion. The influence of this dual heat-treatment strategy on the mechanical and tribological properties of the coatings is systematically investigated.

Results demonstrate that the heat treatments significantly enhance both adhesive strength to the substrate and cohesive strength within the coating. This microstructural improvement directly translates to superior functional performance, with the heat-treated coatings exhibiting markedly increased resistance to sliding wear and cavitation erosion. The research confirms that pre- and post-deposition heat treatments are effective in optimizing cold-sprayed NAB coatings, providing a high-integrity, solid-state repair solution that preserves the alloy's inherent properties.

CL-15: Introduction to SPRAYCOLD ® : India's First Cold Spray Unit

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This work presents the development of India’s first economical low-pressure cold spray system for repair and additive restoration applications. The process enables solid-state particle deposition without melting, ensuring minimal thermal distortion and superior coating integrity. The technology establishes a cost-effective pathway for sustainable manufacturing and in-situ component repair across industrial sectors.

CL-16: Design and Experimental Validation of a Novel Cold Spray Nozzle for Enhanced Particle Acceleration and Thermal Management

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The performance of Cold Spray systems is fundamentally governed by nozzle design, which dictates gas dynamics, particle acceleration, and temperature uniformity within the supersonic jet. This study presents the development of a novel inline annular nozzle, engineered to deliver high deposition efficiency across a broad spectrum of materials from ductile aluminum to high-strength nickel based and stainless-steel alloys. The proposed design incorporates an adaptive internal geometry with variable throat and divergent sections, enabling flexible tuning of flow characteristics under different pressure and temperature regimes. Moreover, the configuration facilitates the spraying of temperature-sensitive materials at elevated gas temperatures, overcoming limitations commonly observed in upstream injection nozzles.

Computational fluid dynamics (CFD) simulations performed in ANSYS Fluent demonstrated significant improvements in flow uniformity, thermal homogeneity, and particle acceleration compared to conventional suction-based downstream injection nozzles. The optimized geometry was experimentally validated through in-situ particle velocimetry and coating trials on Al/Al and Cu/Al systems. Microstructural analyses of the resulting deposits revealed dense, well-bonded coatings with enhanced inter-particle cohesion, confirming improved bonding kinetics and overall coating integrity.

This work highlights a practical approach to achieving a balance between performance optimization and manufacturability, addressing one of the major barriers to scaling Cold Spray technology for industrial: on-site, and offshore applications.

CL-17: Cold Spray-Assisted Digital Manufacturing of Functional Polymer Architectures

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Digital manufacturing has become a central paradigm in advanced materials engineering, enabling data-driven control over geometry, material distribution, and performance. Within this framework, techniques such as fused deposition modelling (FDM), direct ink writing

(DIW), and stereolithography (SLA) are widely employed to fabricate components with tailored process–structure–property relationships. Building on this, our research focuses on advanced additive manufacturing strategies that integrate polymer processing, architected material design, and functional surface engineering to enable performance-driven digital manufacturing. The work encompasses FDM- and SLA-based fabrication of polymers, biopolymers, and composite systems, with emphasis on architected metamaterials and nature- inspired biomimetic geometries, such as nacre, to improve stiffness, damage tolerance, and energy absorption along with 3D-printed polymer architectures are explored for electrochemical applications. Additive manufacturing is further employed as a platform for surface and interfacial engineering, incorporating laser- and microwave-assisted treatments of fibers and polymeric constituents to enhance interfacial adhesion and functional performance in additively manufactured composites. In conjunction with this, solid-state deposition approaches such as cold spray additive manufacturing may be explored as routes for metallisation and functionalisation of polymeric components, wherein ductile metals are cold-sprayed under low-pressure or moderately heated conditions, enabling particles anchoring into locally softened polymer surfaces to form adherent, conductive coatings, enabling hybrid metal-polymer architectures for electrical conductivity, EMI shielding, surface wear resistance, and lightweight structural components for advanced engineering applications. Extending beyond static structures, the work advances into the domain of four-dimensional (4D) printing, focusing on stimuli-responsive polymeric and hydrogel-based architectures capable of programmable shape transformation for applications in biomedical systems, sensing, and environmental remediation. The complexity of these integrated manufacturing pathways necessitates leveraging systematic process optimisation using design of experiments tools like Taguchi and data-driven methodologies, like artificial intelligence and machine learning, to establish robust correlations between processing parameters and functional performance.

Keywords: Digital Manufacturing, Polymer Composites, Architected and Biomimetic Materials, Data-Driven Process Optimisation

CL-18: Significance of in-flight powder energy on cold-sprayed coatings

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Cold-spray deposition is a solid-state coating process in which powder particles are accelerated to supersonic velocities through a convergent-divergent nozzle. Although particle velocity has traditionally been considered the key parameter governing deposition and plastic deformation, particle temperature also plays a crucial role in determining bonding quality. The combined effect of particle velocity and temperature, often referred to as particle energy, significantly influences the degree of deformation. In this study, metals such as iron, copper, and nickel-based alloys, including pure nickel, NiCr, Inconel 625, and Inconel 718, were deposited at particle temperatures ranging from 600 °C to 800 °C under a stagnation pressure of 20 bar to investigate the influence of in-flight particle temperature on the deposition process. Higher particle temperatures were achieved by increasing the nozzle's convergent length. Finite element modelling (FEM) using ABAQUS and ANSYS was performed to simulate the deformation behaviour of metals with different melting points, from zinc (Zn) to tungsten (W). The results, validated experimentally and through simulation, indicate that higher in-flight particle temperatures enhance deformation, leading to improved inter-splat bonding and enhanced functional properties, including electrical conductivity, oxidation resistance, corrosion resistance, and elastic modulus. For example, increasing the stagnation temperature from 600 °C to 800 °C in NiCr coatings raised the inter-splat bonding fraction from 75% to nearly 100%. Also, Inconel coatings deposited under the same high-temperature conditions exhibited corrosion resistance comparable to that of bulk Inconel after heat treatment.

CL-19: Cold spray processing of AA2024/Al2O3 coating on magnesium AZ91D alloy: Process parameters optimization, microstructure and adhesive strength performance of coating

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The automotive and aerospace sectors are progressively employing the magnesium (Mg) alloy of the grade AZ91D because of its excellent castability, low density, and high ratio of strength to weight. Nevertheless, the limited ability of AZ91D alloy to withstand corrosion limits their use in several fields of technology. In order to solve this problem, the AZ91D alloy is coated utilizing an AA2024/Al2O3 metal matrix composite (MMC) coating that is applied by the cold spray coating (CS) method. The primary goal of this work is the parametric optimization of CS process for maximizing adhesive strength of MMC-coated Mg-alloy substrate. Response surface methodology (RSM) is implemented to find the optimum CS parameters, including feed rate of powder – FRP (g/min), standoff distance of gun – SDG (mm) and processing temperature – TEMP (°C). The regression-based parametric adhesion

strength prediction (ASP) model was formulated using the RSM and statistically validated using analysis of variance (ANOVA). Employing 3D surface of responses, the influence of CS parameters on the adhesion strength of an MMC-coating was assessed. The findings revealed that when the MMC-coating was cold sprayed on the Mg-alloy using FRP of 22 g/min, SDG of 12 mm, and TEMP of 520 °C, the maximum adhesion strength of MMC-coating was 70 MPa (actual). Given less than 2% error at 95% confidence, the parametric ASP model correctly predicted the adhesion strength of the MMC-coating. The ANOVA findings showed that FRP (g/min) had significant effect on adhesive strength of MMC-coating followed by SDG (mm) and TEMP (°C). The MMC-coating applied using the RSM optimized CS parameters showed 70.73% superior adhesive strength owing to the lower porosity formation of 2 vol% which offers greater interfacial area. The ASP equation was formulated using the "best fitting line" approach and validated using ANOVA for predicting the adhesive strength (MPa) from the porosity formation (vol%) in the MMC-coating.

CL-20: A Comparative Analysis for Al-TiO_2 Composite Coatings Fabricated using Cold Spray, Flame Spray, and HVOF

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Marine components and structures encounter aggressive chloride-rich conditions that accelerate corrosion and degradation of the material. In order to overcome this challenge, Al-TiO_2 composite coatings have been fabricated on steel substrate using Cold Spray (CS), Flame Spray (FS), and High-Velocity Oxygen-Fuel (HVOF) techniques to evaluate their suitability for marine corrosion protection. Various characterization techniques and mechanical testing such as SEM-EDS, XRD, microhardness testing, scratch testing, and electrochemical evaluation, have been performed to analyze the surface morphology, phase composition, chemical states, and surface hardness of the developed coatings. CS coatings exhibited a dense, oxide-free microstructure with minimal porosity, while FS and HVOF coatings resulted in increased oxidation and structural defects. The results reveal reduced surface roughness parameters, lowest porosity and high micro-hardness in cold-sprayed coatings as compared to FS and HVOF. The corrosion resistance assessments, including electrochemical impedance spectroscopy and 60-day immersion in NaCl solution, demonstrated that cold-sprayed coatings exhibited the highest polarization resistance, lowest corrosion current density, and the most favorable impedance response. This research attempt opens up a promising potential of cold-sprayed Al-TiO_2 coatings as high-performance barriers for marine, chemical, and structurally demanding environments.

CL-21: Influence of Substrate Surface Roughness on the Microstructure and Mechanical properties of Cold-Sprayed Ti-FeCoCuNbMo Coatings on SS316l

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High-entropy alloys (HEAs) offer a novel approach to alloy design by combining multiple principal elements in near-equiatomic ratios, forming stable multi-component solid solutions with outstanding mechanical and corrosion-resistant properties. In this study, titanium-based composite HEA coatings (Ti–FeCoCuNbMo) were developed on SS316L substrates using the high-pressure cold spray process for potential biomedical applications. Two coating compositions, Ti with 30 wt.% HEA and Ti with 50 wt.% HEA, were deposited onto substrates with different surface conditions: mirror-polished and laser-textured. The effect of substrate surface roughness on coating microstructure and mechanical behaviour was systematically investigated. Field Emission Scanning Electron Microscopy (FE-SEM) revealed dense coatings with refined nanostructured grains and uniform interfacial bonding. Scratch testing confirmed strong adhesion without evidence of delamination or cracking, while microhardness measurements indicated a significant improvement in hardness compared to the uncoated SS316L substrate. The findings demonstrate that optimising substrate surface roughness enhances particle anchoring and bonding, thereby improving the overall mechanical integrity and coating performance.

CL-22: Insights into the Fracture and Fatigue Behavior of Cold-Sprayed Al–Fe Bimetallic Structures

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The aluminum–iron (Al–Fe) bimetal is a promising candidate for lightweight, high-performance applications, combining the low density, high thermal conductivity, and good corrosion resistance of aluminum with the high strength and wear resistance of iron. Traditionally, these bimetals have been fabricated using thermal spray or powder metallurgy techniques; however, such high-temperature processes often promote the formation of brittle intermetallic phases, along with porosity, microcracks, and residual stresses. To overcome these limitations, cold spray (CS), a solid-state deposition method,

has emerged as a technique capable of producing dense deposits with minimal oxidation and interdiffusion.

In this work, bimetallic composites with varying Al/Fe ratios were produced by in-flight mixing of the feedstock powders from two independent feeders during CS deposition. The study focused on evaluating the fracture and fatigue behavior of these materials cut out from freestanding CS deposits. The stress–strain data were first obtained from four-point bending (4PB) experiments to provide baseline mechanical characterization, followed by fatigue crack growth rate (FCGR) analyses to study crack propagation. Fracture toughness was then determined using three-point bending (3PB) tests based on the J-integral method. Complementary SEM analyses were conducted to examine fracture surfaces and correlate microstructural features with the observed failure behavior.

The results highlight the critical role of composition and microstructural continuity in controlling crack propagation and overall fracture resistance and provide valuable insights into the mechanical integrity of cold-sprayed Al–Fe bimetals, supporting further optimization of processing parameters for enhanced structural performance.

CL-23: High-Temperature Tribological Behaviour of Cold Sprayed Coating on Die Steel

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The hot-forming dies are subjected to high contact pressures and high temperatures. The main cause of die failure is wear and friction between the die and the workpiece. It affects the efficiency of the process and the cost-effectiveness by shortening the lifespan of dies. To increase the life of dies in the hot-forming industry, it has become essential to combat wear. The surface coatings play a vital role in reducing the wear. Globally, researchers have investigated the behaviour of several coatings, but work is still required to explore the potential of cold spray techniques in developing coatings to reduce wear. An attempt has been made in the present study wherein the authors have developed the Cr_3C_2-35NiCr coating by cold spray on the AISI H13 hot-forming die steel. The detailed characterization of the as-sprayed specimens was done by field emission-scanning electron microscopy/energy-dispersive spectroscopy and x-ray diffraction techniques. The mechanical and physical properties such as hardness, bond strength, porosity, and density were measured. Subsequently, the tribological behaviour of the uncoated and coated specimens were studied on a high-temperature pin-on-disc tribometer in the laboratory under two different loads and temperatures ranging from room temperature to 600°C. Wear

mechanisms were mainly found as the combination of oxidative, abrasive, and adhesive wear at elevated temperatures.

CL-24: High-Temperature Degradation Behaviour of Cold-Sprayed Inconel 718 Coatings

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Cold spray (CS) technology has gained increasing attention as an effective solid-state deposition technique for the repair and refurbishment of high-value engineering components, particularly in aerospace and power generation applications. Owing to its low process temperature, CS enables the retention of the feedstock microstructure while minimizing thermal degradation, oxidation, and undesirable phase transformations in both the deposited material and the substrate. Inconel 718 (IN718), a precipitation-hardened nickel-based superalloy extensively used in turbine engine components, offers excellent high-temperature strength and corrosion resistance. However, prolonged exposure to elevated temperatures (≥650 °C) can lead to oxidation and microstructural instability, notably through the transformation of the strengthening γ″ (Ni_3Nb, body-centred tetragonal) phase into the thermodynamically stable but mechanically inferior δ (Ni_3Nb, orthorhombic) phase.

Although the mechanical properties of cold-sprayed IN718 coatings have been widely studied, their long-term oxidation and corrosion behaviour is not yet well understood. In this work, the isothermal oxidation and hot corrosion behaviour of cold-sprayed IN718 coatings were investigated at 650 °C for exposure durations up to 2000 hours. The coatings were deposited using gas-atomised IN718 powder at a chamber pressure of 5 MPa and a process temperature of 1000 °C. Post-deposition heat treatment involved solutionizing at 1200 °C for 2 hours followed by a standard double-aging treatment. Two coating conditions—as-sprayed and heat-treated—were evaluated, with wrought IN718 alloy used as a reference material.

Oxidation kinetics revealed a parabolic rate law for all conditions, indicating diffusion-controlled oxide growth. Heat-treated coatings exhibited significantly improved oxidation resistance, with weight gain and oxide scale thickness comparable to wrought IN718. In contrast, as-sprayed coatings showed higher mass gain and thicker, less adherent oxide scales, attributed to their higher porosity and limited grain boundary diffusion control. Oxide scale characterization using Raman spectroscopy, and Scanning electron spectroscopy revealed cyclic oxide growth and spallation in both coating conditions, with more severe scale instability in the as-sprayed state.

Hot corrosion studies conducted using a molten salt mixture of 60 wt.% Na_2SO_4, 10 wt.% NaCl, and 30 wt.% $NaVO_3$ at 650 °C demonstrated pronounced microstructural degradation, particularly in as-sprayed coatings. A chromium-depleted zone was consistently observed beneath the oxide–alloy interface, accompanied by extensive scale formation. Overall, this work underscores the critical role of post-deposition heat treatment in enhancing the oxidation and hot corrosion resistance of cold-sprayed IN718 coatings and provides valuable insights into their long-term viability for high-temperature service in aerospace and gas turbine applications.

CL-25: Cold-Sprayed ZrC–Cu Composite Coatings: Processing–Structure–Property–Tribology Relationships and Laser Damage Resistance

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Zirconium carbide–copper (ZrC–Cu) composite coatings were deposited on Al-6061 substrates using high-pressure cold spray to develop mechanically robust and laser-resistant protective surfaces. Coatings containing 30–85 vol.% ZrC were investigated to establish processing–structure–property–tribology–laser interaction relationships. All compositions exhibited stable build-up, although deposition efficiency decreased with increasing ceramic content due to enhanced particle rebound. Dense coatings with minimal porosity and improved ceramic retention were obtained, and XRD confirmed the formation of Cu–ZrC composite coatings without ZrC decarburization or Cu oxidation. Mechanical and tribological testing revealed increasing hardness, scratch resistance, and wear resistance with higher ZrC content, while maximum adhesion strength was achieved at intermediate compositions (50–70 vol.% ZrC). Scratch and sliding wear tests showed distinct deformation mechanisms, transitioning from ductile adhesive wear to brittle fragmentation at high ceramic loading. Optical reflectivity measurements showed high near-infrared reflectance, with Cu–30 vol.% ZrC achieving ~75% reflectivity at 1080 nm. Laser ablation tests demonstrated that coatings containing 30–70 vol.% ZrC remained undamaged under irradiation, whereas Cu–85 vol.% ZrC exhibited localized ablation. Overall, intermediate ZrC contents offer the best balance between reflectivity, mechanical integrity, wear resistance, and laser damage tolerance.

CL-26: Thermal Stability and Oxidation Resistance of NiCrAl Substrate – AlCoCrFeNi HEA Interface

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The thermal stability of the substrate-bond coat interface is crucial for the long-term stability and maintenance of structural integrity of the components in high-temperature applications (for example, turbine blades in aerospace applications). If the interface is not stable at high temperatures, it can lead to diffusion of atoms across the interface, which may result in the formation of new or intermetallic phases, which can alter mechanical stability, development of cracks, and delamination due to thermal stresses, oxidation, and corrosion. Because of their exceptionally high tensile strength, creep and corrosion resistance, and hardness, Ni-based superalloys such as Inconel 718 have been the material of choice for high temperature applications such as turbine blades in aerospace applications. AlCoCrFeNi HEA coatings have been reported on substrates such as AISI 304, SS316L, 45# stainless steel, etc. Nevertheless, experiments makes it challenging to fully comprehend what is occurring at the interface. Computational tools enables to rapidly investigate microstructural alterations, thermodynamic behavior, and interface characteristics, many of which are challenging or expensive to replicate in actual experiments. Simulations minimize trial-and-error and facilitate the optimization of HEA - substrates coating by providing a clear view from the atomic scale up to the mesoscale. The literature discussing HEA coatings on Inconel 718 substrates is scarce. To the best of our knowledge, no study has been done using computational simulation for AlCoCrFeNi HEA coatings on Inconel 718 substrate.

Therefore, the present research focuses on studying the microstructure evolution during coating, interface stability, and oxidation behavior of AlCoCrFeNi HEA–NiCrAl substrate system using atomistic simulations. The evolution and stability of the interface were examined through various investigations, such as microstructure evolution of HEA on a fixed substrate during the coating process, response of substrate-HEA interface to thermal treatment, and surface oxidation energetics. The results showed the the effect on annealing on microstructure transformation (BCC→FCC). It was observed that (110) plane of HEA and (111) plane in substrate is the most stable surface. The binding energy between HEA-substrate surfaces suggested a strong interaction. The coating process simulations suggest that Al atoms preferably diffuse to the surface of HEA during cooling stage on substrate, and surface atoms rich in Al form a mixed phase having a dominant BCC phase. This is, in a way, advantageous as the Al atoms get easily oxidized to form stable Al_2O_3, which in turn protects the substrate from oxidation and cracking, along with providing strength and stability. When the substrate-HEA interface was subjected to thermal treatment, the interface was intact till a temperature of 1720 K with no intermixing of atoms of substrate and HEA. This confirms the thermal stability of the interface. Surface oxidation studies reveal that the NiCrAl surface forms more stable oxides compared to the HEA surface. Also, the oxidation adsorption energies were observed to be stronger on Al, Cr, and Fe sites, while being weaker on Co and Ni sites. Overall, this research provides a comprehensive insight into the thermal stability and oxidation resistance of NiCrAl substrate and AlCoCrFeNi HEA bond coat.

CL-27: Computational Analysis of Flow and Acoustic Proxy Characteristics in Cold Spray Nozzle Configurations

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The technological advancements in the field of additive manufacturing have been growing at an exponential rate. Among these developments, cold spraying has been recognized as a promising technology owing to its inherent characteristics of solid-state and enhanced deposition rate. The work outlines a computational study aimed at analysing the flow and acoustic behaviour of different cold spray nozzle configurations. It focuses on a standard De Laval nozzle and two modified variants — a chevron-type nozzle and a toroidal (aerospike-style) nozzle — to understand exit geometry influence on flow field and sound generation in cold spray systems. An attempt has been made to design a simple numerical framework that can be used to compare gas dynamics and qualitative acoustic output of these designs. It includes geometry creation with modelling of three nozzle geometries i.e. baseline De Laval nozzle with a conventional converging–diverging profile, chevron-type nozzle with serrated exit edges and toroidal or aerospike-style nozzle with a central protrusion to modify expansion; flow simulation; and acoustic proxy analysis.
Software used for flow simulation is ANSYS Fluent with air as working fluid and the steady-state flow fields have been used for estimating regions of potential noise generation through visualization of local velocity gradients, vorticity, and turbulence intensity near the nozzle exit and in the jet core. Further, a comparative analysis has been conducted for all the three nozzle geometries based on flow uniformity, exit Mach number distribution, and predicted acoustic activity zones focusing smoother flow expansion and reduced predicted noise without requiring complex or high-cost analysis. This simulation-based study provides a low-cost alternative to explore the influence of minor geometric changes on both aerodynamic and acoustic aspects of cold spray nozzles. It also establishes a framework for experimental validation through Schlieren visualization and basic sound measurements.

CL-28: Numerical Investigation of Low-pressure Cold Spray Operations with Back-pressure Control

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Low Pressure Cold Spray Systems are attractive for their portability, and various applications in coating , repair and restoration, but struggle with lower efficiencies. Their operations at moderate conditions (P_o = 6 - 10 bar, T_o <= 500°C) lead to 10-20% powder particles reaching up to required critical velocity for effective bonding. The current study is motivated to develop strategies based on back-pressure control to enhance powder particle acceleration, which can lead to improved deposition efficiency of low-pressure cold spray system. The low-pressure cold spray system with enclosed working chamber with back-pressure control can also facilitate gas and powder recovery. Numerical investigations are carried out for low-pressure cold spray system operating with nitrogen at P_o = 10 bar, T_o = 300 - 500°C with Aluminium powder particle (20 - 60 microns) in a controlled chamber back pressure (P_{ch} < 100 kP_a). Computational Fluid Dynamics (CFD) is employed to estimate the effects of optimised operating conditions on the low-pressure cold spray system. Gas and Particle Velocity profiles are determined through rigorous steady, two-dimensional, and axisymmetric simulations. The particles trajectory and speeds are computed by using a Discrete Phase Model (DPM). The results of the study aim to establish operating maps and design guidelines by identifying the P_{ch} bands and nozzle sizing, to improve efficiency of portable Low-Pressure Cold Spray Systems. By improving the deposition efficiency under controlled ambient conditions, low-pressure systems can better meet the industrial needs for potability, flexibility and cos-effectiveness in coating, repair, and on-site fabrication and additive manufacturing.

CL-29: Inner-Diameter Cold Spraying: Optimization and Toolpath planning

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This research work presents a framework for a novel inner diameter (ID) cold spray (CS) process combined with modeling and CAD-based toolpath generation for repairs in

confined geometries like hollow cylinders, hydraulic actuators, corrosion-resistant pipeline linings, and conductive coatings with optimal coating characteristics. The confined nature of ID-CS alters gas expansion and leads to particle flow compared to external surface applications. Also, particles in-flight properties are measured to satisfy critical velocity requirements and to predict the deposit quality. The integration of artificial intelligence, offline parameter optimization, and predictive modeling addresses the fundamental challenge of achieving consistent coating quality. Moreover, it allows deposit profile evolution, multi-pass accumulation effects, and dimensional changes during coating build-up for precise deposit to minimize the post-processing needs. Furthermore, the path planning algorithms optimize traverse speed, spray angle, and standoff distance based on internal geometry characteristics, substrate materials, desired coating thickness, hardness, porosity, deposition efficiency, and quality parameters. Finally, robotic control systems enable precise execution of complex trajectories while maintaining consistent process parameters throughout the coating operation. This research is funded by the project of Refurbishment and additive manufacturing accomplished by kinetic deposition (Re-Make), EU/Horizon Europe/MSC Grant Agreement No 101119988.

CL-30: Investigation on the effects of bilayer sequential cold spray deposition on coating properties in cold-sprayed Ni-base superalloys

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Cold spray is a solid-state coating deposition technique that facilitates the application of high-performance metallic powder coatings without substantial thermal degradation or oxidation. Inconel alloys, including Inconel 625 and Inconel 718, are extensively utilised in the aerospace, maritime, and power generation sectors owing to their remarkable mechanical strength, oxidation resistance, and corrosion resistance in harsh conditions. This study involves the production of bilayer coatings using the cold spray deposition of successive Inconel alloys onto metallic substrates. The aim was to utilise the synergistic characteristics of two different Inconel compositions to develop a coating system with improved functionality, specifically in terms of mechanical and tribological performance. The bilayer arrangement was engineered to enhance adhesion strength, thermal stability, and surface hardness. A comprehensive microstructural examination, conducted using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX), revealed dense microstructures with minimal porosity and a robust interface between the two Inconel layers. Hardness testing revealed a significant enhancement compared to monolayer coatings, while tribological assessment showed less wear under dry sliding conditions. This study emphasises the efficacy of the cold spray technique in generating functionally tailored bilayer coatings with high-performance nickel-based superalloys. The research establishes a basis for creating advanced multilayer coatings suitable for harsh conditions, thereby opening up new possibilities for design improvement in surface engineering applications.

CL-31: Identifying the reliable Johnson-Cook model parameters and developing the modeling procedure to cold spray AA2524 alloy for repairing fretting wear in Aircraft application

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The emergence of cold spray technology for repairing the aluminum alloys has revolutionized the field of materials science and aeronautical sectors. However, due to nozzle clogging issues, changes in the microstructure, and the unavailability of thermo-mechanical data for numerical prediction, the research community faces challenges in addressing the optimum process parameters for cold spraying of developed aluminum 2000 series alloys. Consequently, exploring the research on these alloys often gets delayed and is found to be limited. Considering this, the current work focuses on developing a systematic approach for cold spraying the AA2524 alloy to repair fretting wear, along with the support of modeling and characterization. Subsequently, at first, the flow stress behaviour of AA2524 under tensile and compressive deformation at different strain rates and temperatures is explored. Then, the Johnson-cook model parameters are predicted and further optimized to achieve reliable constitutive model parameters. Thereafter, the selection of nozzle material, numerical modeling and characterization for cold spraying AA2524 alloy were studied. Finally, the effect of post-heat treatments on cold-sprayed AA2524 and their fretting wear responses was investigated. It is found that solutioning and aging on as-sprayed AA2524 improved the fretting wear resistance. To save post-processing effort for as-sprayed AA2524, a reliable forecast CEL-based modeling procedure was developed to predict the porosity and surface roughness.

CL-32: A Comprehensive Literature Review on the Mechanical and Tribological Properties of Cold-Sprayed High-Entropy Alloy Coatings.

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High-Entropy Alloys (HEAs) are a new class of materials made by mixing five or more principal elements in roughly equal proportions, which is different from traditional alloys that have one or two main elements. These advanced materials offer exceptional performance attributes that make them highly desirable for surface engineering applications. The application of the Cold Spray (CS) deposition technique is particularly critical, as it operates in a solid-state regime, effectively mitigating the issues of phase segregation, and detrimental oxidation common in conventional thermal spray methods.This comprehensive literature review systematically analyzes recent scientific investigations concerning the influence of CS processing parameters on the microstructural evolution and functional performance of HEA coatings. The primary focus is on mechanical and tribological properties.

This review shows that the high kinetic energy of the CS process yields dense coatings with preserved HEA phase integrity, directly correlating with superior mechanical properties compared to bulk counterparts. Tribological studies reveal unique wear mechanisms, often characterized by exceptional work-hardening capabilities and resistance to abrasion. However, the existing literature shows a persistent challenge process variables are often inconsistently optimized, which can lead to porosity and variations in coating quality.

In conclusion, this literature survey shows Cold Spray as a effective fabrication route for achieving HEA coatings with advanced mechanical and tribological profiles. This review summarizes current findings, explains the key relation between the manufacturing process, the coating's microstructure, and its performance.

Poster Abstracts

P01: A Critical Review of High Velocity Oxy Fuel (HVOF) Coating Techniques: Materials, Processes, and Applications.

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Thermal spraying is a very versatile surface engineering process applied to deposit coatings of thickness from as little as 10 μm to a few millimetres. This process imparts functional surface properties like increased wear, corrosion, and erosion resistance, better thermal and electrical insulation, and specially designed frictional behaviour—so it is adaptable to a wide range of industrial applications. Among several thermal spray processes, High-Velocity Oxy-Fuel (HVOF) spraying is of increasing prominence owing to the capacity of providing dense, low-porosity coatings (average <1%), with better adhesion and hardness. Such qualities immensely enhance coated components' mechanical integrity and life of service in severe environments. The success of the HVOF process lies in the high-kinetic-energy particle streams it generates, which yield coatings of high cohesion and low residual stresses. Moreover, the controlled deposition atmosphere and gradual cooling allow relative thick coatings (up to ~1.5 mm) to grow without structural instability. The advantages render HVOF to be a state-of-the-art coating technology that is capable of responding to the growing demands in today's industries.

P02: Influence of Twin Wire Arc Spraying Parameters on Coating Thickness of Copper Coating on Ferrous Metals

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The application of copper coatings on ferrous substrates using Twin Wire Arc Spraying (TWAS) has garnered significant attention for enhancing surface functionalities such as corrosion resistance, electrical conductivity, and antimicrobial efficacy. This study systematically investigates the influence of key TWAS process parameters arc voltage, wire feed rate, spray distance, traverse speed, and atomizing gas pressure on the coating thickness of copper deposited on low carbon steel and stainless-steel substrates. A statistically designed experimental approach utilizing Response Surface Methodology (RSM)

and Central Composite Design was employed to evaluate individual and interactive effects of process variables on the resultant coating thickness. Results indicate that wire feed rate and spray distance exert the most significant influence, where increased wire feed rates enhance the deposition rate, and larger spray distances reduce coating thickness due to increased dispersion and oxidation of molten particles. Additionally, arc voltage and gas pressure were found to affect particle velocity and temperature, thereby influencing the bonding mechanism and deposition efficiency. The development of an empirical regression model enables accurate prediction of coating thickness as a function of input parameters, with high statistical reliability. Microstructural analysis using optical microscopy and scanning electron microscopy reveals a correlation between processing parameters and coating morphology, particularly splat formation and porosity levels. This research contributes a robust understanding of TWAS parameter optimization for producing uniform and defect-minimized copper coatings, thereby facilitating improved control in industrial applications involving thermal spraying on ferrous metals.
Keywords: Twin Wire Arc Spraying, Copper Coatings, Ferrous Substrates, Coating Thickness, Process Optimization, Wire Feed Rate, Spray Distance, Arc Voltage, Atomizing Gas Pressure, Deposition Efficiency, Response Surface Methodology, Central Composite Design, Thermal Spray Coating, Surface Engineering, Coating Morphology.

P03: Development of empirical relationship to predict the porosity level of Twin Wire Arc Sprayed Coatings on stainless steel

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The porosity of Twin Wire Arc Sprayed (TWAS) coatings plays a pivotal role in determining the functional performance of coated components, especially when applied to stainless steel substrates in critical environments such as biomedical, marine, or antimicrobial applications. This study presents the development of an empirical predictive model to estimate the porosity of TWAS coatings as a function of key process parameters including arc voltage, arc current, atomizing gas pressure, spray distance, and traverse speed. A systematic experimental campaign was designed using Response Surface Methodology (RSM) to evaluate the combined and interactive effects of these variables on porosity levels. Coatings were characterized using Scanning Electron Microscopy (SEM) and quantified via digital image analysis. Multiple regression analysis was employed to construct a second-order polynomial model, which demonstrated high statistical significance ($R^2 > 0.95$) and strong predictive accuracy upon validation. Analysis of variance (ANOVA) revealed that

spray distance and gas pressure were the most influential factors governing porosity formation. The developed model offers a practical and reliable tool for optimizing TWAS process parameters, thereby enabling improved control over coating microstructure and performance. The findings contribute toward process-tailored thermal spraying, enhancing both coating quality and application-specific functionality.

P04: Evolutionary Optimization of Cold Spray Deposition: Genetic Algorithm Approach for AA2024–YSZ Composite Coatings

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Optimization of cold spray (CS) process parameters is essential for minimizing wear loss and enhancing the tribological performance of metal matrix coatings (MMCs). In this study, yttria-stabilized zirconia (YSZ) particles were reinforced into an AA2024 aluminum matrix and deposited onto an AZ31B magnesium alloy substrate using the CS technique. A three-factor, five-level design was employed to establish a quadratic regression model linking wear loss with carrier gas temperature (CGT), nozzle jet distance (NJD), and powder injection rate (PIR). Analysis of variance (ANOVA) confirmed the statistical significance of the model ($F = 22.43$, $p < 0.0001$), with a high coefficient of determination ($R^2 = 0.9528$), adjusted R^2 (0.9103), and predicted R^2 (0.8281). Regression diagnostics and residual analysis verified conformity with statistical assumptions, as all residuals fell within ±4.15 and errors remained randomly scattered, confirming excellent predictive accuracy. The desirability function identified parameter-level desirability values of 1.0 and an overall composite desirability of 0.871, indicating robust optimization. Sensitivity analysis revealed the parameter influence order as CGT > NJD > PIR. Using a genetic algorithm (GA), the optimal operating conditions were determined as CGT = 530.021°C, NJD = 10.561 mm, and PIR = 16.243 g/min, corresponding to a global optimum wear loss of 2.2877 mg. Microstructural analysis of the optimized coatings validated uniform particle attachment, which contributed to improved wear resistance.

P05: Process Development and Qualification of Ceramic Coatings on Copper Coils by Plasma Spray Technique

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In negative ion sources such as the TWIN Source and ITER NBI, high-power RF (1–2 MHz, several hundred kW) is coupled to plasma using inductively coupled copper coils. These coils operate under high-vacuum and high-voltage conditions, requiring robust electrical insulation. Conventional polymer-based insulators are limited by poor thermal stability, vacuum compatibility, and radiation resistance. Ceramic coatings, particularly alumina (Al_2O_3), provide a promising alternative owing to their high dielectric strength, thermal stability, and erosion resistance. In this work, a pre-stage process development was carried out for alumina coatings on copper coils using the plasma spray technique with 99.5% pure Al_2O_3. Plasma spraying enables the deposition of thick ceramic layers (hundreds of microns) by projecting molten alumina particles onto the substrate. The influence of parameters such as current, voltage, and spray distance on coating thickness and adhesion was systematically studied. Eight samples were fabricated for pre-qualification, all sandblasted prior to coating, with four receiving a Ni-625 bond coat. Bond-coated samples showed lower coating thickness compared to unbonded ones. A maximum thickness of 260 μm was achieved at 70 V and 530 A, although adhesion strength was limited to ~1.5 MPa. By reducing the ceramic powder size to below 40 μm, adhesion was improved significantly to ~6 MPa.The optimized parameters were applied to RF coil fabrication, yielding desirable coating thickness but highlighting challenges of adhesion and delamination due to residual and interfacial stresses from thermal mismatch. Microstructural and phase analysis of the coatings are presented, providing insights for further process optimization toward achieving >500 μm thick coatings with low porosity for NBI applications.

P06: Cold Spray Additive Manufacturing: A Material-Specific Review

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Cold Spray Additive Manufacturing (CSAM) has gained significant attention as a solid-state deposition technique for creating dense and durable structures without exposing materials to high temperatures. This review comprehensively explores the microstructural characteristics of materials processed via CSAM, including aluminum, copper, titanium, magnesium, ceramics, and metal matrix composites (MMCs). The analysis focuses on how process parameters, such as particle velocity, nozzle design, and substrate conditions, influence critical microstructural features like grain refinement, porosity, phase composition, and interfacial bonding. Particular attention is given to the role of CSAM in mitigating thermal effects, preserving material properties, and enabling the fabrication of complex geometries with tailored microstructures. The study highlights the challenges associated with adhesion, oxide formation, and heterogeneity in multi-material systems, while discussing advancements in process optimization and post-processing techniques. By presenting a detailed comparison of microstructural evolution across various material systems, this review underscores the versatility and potential of CSAM for applications in aerospace, automotive, and biomedical fields. Future research directions include enhancing microstructural control through real-time diagnostics and integrating computational models to optimize the additive manufacturing process.

P07: Identifying the optimal HVOF spray parameters to attain minimum porosity and maximum hardness in Tungsten Carbide 12 % Cobalt + Self-Fusing Nickel Alloy (WC12Co +Ni Ally + NiAl Blend) coatings on naval materials

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Flow-induced erosion and corrosion are common challenges in fluid-handling components such as propellers, impellers, and pumps used in naval applications, including warships and submarines. Although several coating materials have been developed to mitigate such degradation, ceramic and metal-based cermet coatings have demonstrated superior performance in enhancing resistance to erosion and corrosion. Among the available coating technologies, the High Velocity Oxy-Fuel (HVOF) spray process is recognized as one of the most effective methods for depositing cermet coatings. In the present study, a Tungsten Carbide–12% Cobalt with Self-Fusing Nickel Alloy and Nickel–Aluminium blend (WC–12Co + Ni Alloy + NiAl) coating was applied on a duplex stainless steel (DSS 2205) substrate using the HVOF spraying technique. Empirical models were developed to predict the porosity and microhardness of the coating based on critical HVOF process parameters such as oxygen flow rate, fuel flow rate, powder feed rate, and spray distance. Response Surface Methodology (RSM) and Machine Learning (ML) was employed to identify the optimal set of parameters to produce coatings with minimal porosity and maximum hardness.

Keywords: Erosion–corrosion; Naval applications, Cermet coatings, HVOF spray

P08: Machine Learning in Surface Coating Engineering: Current Trends, Challenges, and Future Directions: A Comprehensive Review

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Machine Learning (ML) has emerged as a powerful approach for designing and optimizing advanced surface coatings, enabling faster and more accurate prediction of coating performance. In thermal spray processes such as High Velocity Oxy-Fuel (HVOF), ML facilitates the identification of optimal process parameters to achieve desired properties like hardness, porosity, and corrosion resistance. Data-driven algorithms including Artificial Neural Networks (ANNs), Random Forests, and Genetic Algorithms (GAs) are increasingly used to model complex interactions among spray parameters and coating characteristics. These models reduce experimental effort, improve reproducibility, and accelerate material development. Recent studies demonstrate ML's potential in correlating microstructural features with mechanical and electrochemical performance. This review highlights current advances, key challenges, and future directions in integrating ML with numerical simulation and experimental validation for smart coating design. The approach provides a foundation for developing intelligent, corrosion-resistant coatings for sustainable naval and industrial applications.

Key words: ML, Thermal Spray Coatings, Optimization, HVOF Coating, Naval applications

P09: Effect of Traverse Scanning Speed on the Microstructure and Mechanical Properties of Cold-Sprayed Cu/Graphene Composite Coatings

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Cold spray is a solid-state coating process capable of producing dense and oxide-free metallic and composite layers. Copper reinforced with graphene (Cu–Gr) exhibits higher

hardness, higher thermal conductivity and strength compared to pure copper, making it a promising material for structural applications. This study focuses on the effect of traverse scanning speed (50, 100, and 200 mm/s) of the spray nozzle on the microstructure and mechanical properties of cold-sprayed Cu–Gr coatings. Traverse speed plays a major role in controlling particle deformation, coating porosity, and interface bonding and temperature accumulation during deposition. Microstructural observations and hardness measurements are carried out to evaluate coating quality. The study aims to understand how variations in traverse speed influence the overall coating integrity, density, and mechanical performance, providing useful insights for optimizing process parameters in cold spray fabrication of Cu–Gr composite coatings.

P10: Cold Spray as a Viable Repair Route for AA2014-T6 Airframe Materials- Evidence from NDT Studies

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Cold spray repair has become a promising solid-state method for restoring damaged aluminium aerospace components without causing thermal distortion or metallurgical deterioration. In this study, controlled defects, including pits, longitudinal, and transverse ones, were introduced on AA2014-T6 specimens to simulate in-service damage typically seen in AA2024-T3 airframe materials. These defects were repaired using an optimised Al–Al_2O_3 cold spray process, designed to produce dense, well-bonded deposits on the affected areas.

Microstructural analysis using X-ray diffraction, EDS, and FESEM confirmed the presence of a fully consolidated repair zone, with the coating exhibiting a face-centred cubic Al structure accompanied by minor α-Al_2O_3 peaks. The repaired specimens were thoroughly tested using non-destructive testing methods. Visual inspection was conducted in accordance with ASME Section V, Article 9. Additionally, fluorescent dye penetrant testing was conducted in accordance with ASTM E1417, and ultrasonic testing was performed (ASTM E2375). It is observed that no subsurface flaws, such as cracks, porosity, or unfilled regions, were detected. The results suggest that the complete restoration of artificially introduced flaws can be achieved through cold spray repair. Furthermore, Al–Al_2O_3 coatings enable defect-free repairs with strong interfacial bonding, facilitating the structural restoration of high-strength aluminium alloys. The study emphasises cold spray repair as a practical, sustainable alternative to traditional fusion-based repair methods for aerospace materials.

P11: Tribological and Corrosion Behaviour of Al_2O_3-Based Coatings

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Wear and corrosion are critical degradation mechanisms responsible for premature failure of industrial components operating under severe mechanical and chemical environments. In the present study, Al_2O_3-based coatings were developed with the addition of lanthanum oxide (La_2O_3) at 1.2, 1.6, and 1.8 wt.% to enhance phase stability and coating integrity. To further reduce friction and wear, hybrid self-lubricating coatings were fabricated by incorporating 3 wt.% hexagonal boron nitride (h-BN) along with La_2O_3. All coatings were deposited using the High Velocity Oxy-Fuel (HVOF) spraying technique. Prior to deposition, feedstock powders were ball milled, and SEM/EDS analysis confirmed uniform dispersion of reinforcements within the Al_2O_3 matrix. XRD analysis revealed α-Al_2O_3 as the dominant phase in all compositions, with La_2O_3 retained in doped powders. In hybrid powders, α-Al_2O_3, La_2O_3, and h-BN were preserved, along with minor phases such as C_3N_4 and $AlLaO_3$ at higher La_2O_3 contents, indicating milling-induced chemical reactions.

Following HVOF spraying, partial transformation of stable α-Al_2O_3 to metastable γ-Al_2O_3 was observed due to high processing temperatures. The 100% Al_2O_3 coating exhibited the highest γ-Al_2O_3 content. However, La_2O_3 addition up to 1.6 wt.% effectively stabilized α-Al_2O_3 and limited this transformation, leading to the formation of aluminum–lanthanum complex oxides such as $Al_{11}La_2O_{24}$. Hybrid coatings showed partial oxidation of h-BN, forming tribo-active phases including B_2O_3 and $Al_8B_2O_{15}$, while still retaining α-A_2O_3 and h-BN, particularly at 1.6 wt.% La_2O_3.

Mechanical characterization showed that 100% Al_2O_3 had the lowest hardness and highest porosity. The 1.6 wt.% La_2O_3 coating exhibited ~10% higher hardness and ~40% lower porosity due to grain refinement and complex phase formation. The hybrid 95.4%Al_2O_3–3%h-BN–1.6%La_2O_3 coating demonstrated the best performance, with ~15% higher hardness and ~58% lower porosity compared to pure Al_2O_3. This coating also showed the highest hydrophobicity, with a contact angle of ~131°.

Tribological tests conducted under 5 N and 15 N loads revealed decreasing coefficient of friction with increasing load for all coatings. The presence of h-BN significantly reduced friction due to the formation of a lubricious B_2O_3 tribo-layer. The hybrid 95.4%Al_2O_3–3%h-BN–1.6%La_2O_3 coating exhibited the lowest wear loss, achieving ~77% and ~76% reduction at 5 N and 15 N, respectively, compared to pure Al_2O_3.

Corrosion studies in 3.5 wt.% NaCl solution using Tafel, Nyquist, and EIS analyses showed that pure Al_2O_3 had the highest corrosion rate and lowest polarization resistance. La_2O_3-doped and hybrid coatings, particularly at 1.6 wt.% La_2O_3, exhibited significantly improved charge transfer resistance and Bode modulus. The 95.4%Al_2O_3–3%h-BN–1.6%La_2O_3 coating demonstrated the best corrosion resistance. SEM/EDS and XRD analyses confirmed pitting corrosion and the formation of complex corrosion products, highlighting strong coating–electrolyte interactions.

P12: Repair of H13 Die Steel using Cold Spray Coating

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H13 die steel is the dominant material in the aluminum forging and high pressure die casting industry. It is prone to wear due to erosion, abrasion, and thermal cycling. Conventional repair methods, primarily fusion welding, are often detrimental as they introduce residual stresses, and geometric distortions, and cracking due to martensitic transformation. Cold spray serves as a promising solid-state alternative to repair H13 components. However, there is currently only few literatures available demonstrating the successful deposition of H13 feedstock for repair applications. This study presents an exploratory method to overcome the inherent low sprayability of H13 powder caused by its hard martensitic phase. Gas-atomized H13 powder was subjected to heat treatment at 700 and 800 °C and the hardness post treatment was studied. Experimental results indicated that while the as-received powder yielded no deposition, this novel processing strategy successfully enhanced the Deposition Efficiency (DE) to nearly 50% for the segregated powders. These findings validate this exploratory approach as a potential pathway for the effective, solid-state restoration of die components.

Keywords: Cold Spray; H13 Tool Steel; Powder Heat Treatment; Die Repair; Tribology

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SPRAYCOLD

(COLD SPRAY SYSTEM)

Introducing a metal deposition process that requires no blast cleaning and no oxy-fuel gases. It works solely with air, providing a coating with high bond strength and density. You can apply almost any metal powder, including brass, copper, nickel, aluminum, zinc, tin, bronze, lead, stainless steel, aluminum - silicon carbide, aluminum-copper- zinc, nickel-zinc, copper-tin-lead and many more.

MCS - 23

Cold spray gun with heater installed.

MSC - 500

(MEC cold spray system with trolley, massflow controlled & pressurized powder feeder and PLC controlled panel.)

Advantages

- Green, solid-state process: No combustion flame, fumes, phase change during deposition.
- Ideal for in-situ repair, restoration & AM part correction.
- Delivers high deposition efficiency with minimal thermal impact.
- Enables coating of Al, Mg, Ti, and other reactive

Application of Cold Spray

- Repair, restore & AM part correction.
- Repair bearing seats.
- Cavitiation corrosion protection
- Hermetically seal rediators and air conditioner.
- Add electrical conductive layers to materials.
- Additive manufacturing and many more.

Special Features:

- The detachable type control screen can be removed and positioned on another stand or exterior wall of the spray chamber if user wants to spray using robot/manipulator.
- Working Gas: Air or Nitrogen
- Single Phase Electrical Supply Requirement.
- Operating pressure Temperature: 10 bar at 50 °C

Maximum power consumption:- 3.3kW

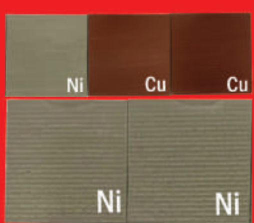
Power supply:- Single Phase 220v, 50/60Hz

Powder consumption:- 10-20 gm/min
(compatible powder will be supplied by MEC)

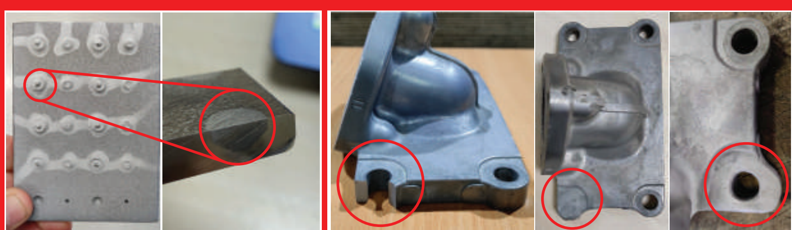
Capacity of Powder Feeder:- 3350 CC (3.3 Liter)

Dimensions and Weight of the System:-
Approx. 600(W) x 500(L) x 1400(H)
Approx. 110 kg
Compressed air consumption:- 0.3 - 0.4 m^3/min

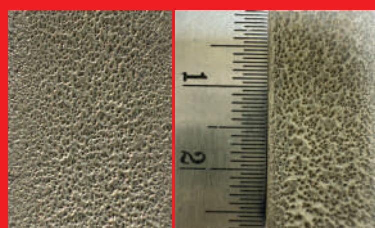
Ni and Cu coatings on CFRP sheet



Repair and Restore Part



Texture Driven Cold Sprayed Ni Coatings



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Unique robot mountable sensor offering continuous online particle data measurement

SprayWatch 4S

Workhorse for daily quality control for all hot thermal spray processes

HiWatch CS2

Easy and fast cold particle diagnostic

Benefits of spray diagnostics

Maximize your:

- Deposition efficiency
- Coating thickness control
- Yield, Profitability

Minimize your:

- Waste, environmental load
- Production cost
- Time to market

Surface Modification and Additive Research Technologies

SMART LAB

Cold spray & HVOF

Collaborations

Gun

HVOF torch

Hi-watch CS2

Pure metals: Al, Cu, Ni, Cr, Ti, etc

Alloys: IN718, SS, Cu, Al alloys etc

Composites: Tribaloy reinforced Ni coatings etc

Powder feeder

Spray booth

Coating on flat surface

Coating on cylindrical surface

Cold sprayed components

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kamaraj@iitm.ac.in
sbakshi@iitm.ac.in

We Provide

High-performance, thick, dense, and oxide-free coatings designed to repair, protect, and enhance materials durability and corrosion resistance for aerospace and other advanced engineering applications.

SMART LAB

Combined Plasma Nitriding & Diamond like carbon coating

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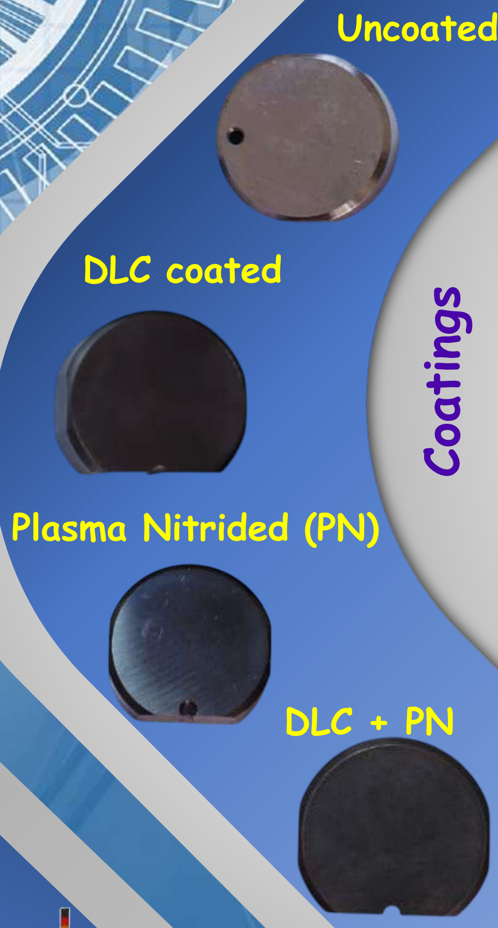
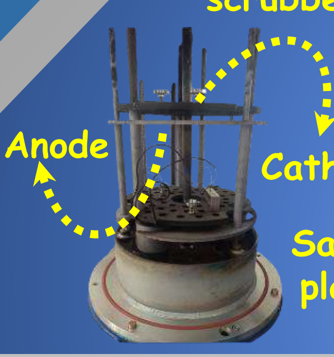
Surface Modification and Additive Research Technologies

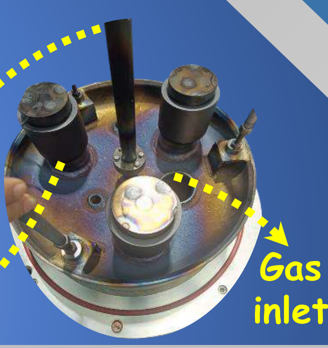
What we provide

Carbon-based hard material layer with excellent sliding properties. It enhances the wear resistance and corrosion resistance. The coating is water and oil repellent, chemical resistant, electrically insulating and has very low friction coefficient.



Collaborators & Sponsors





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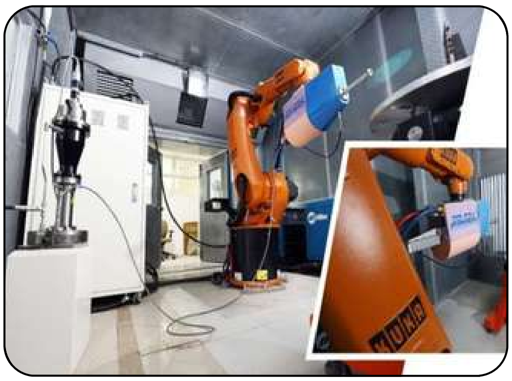
Facilities at CoE & YourLab



Cold SprayCoating Facility

Thermal Cycling Oxidation/ Hot Corrosion

IR Camera

Nitrogen Gas Plant

Cavitation Test Setup

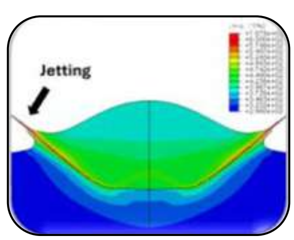
Fibre Cutting Mill

Scratch Tester

Thermal Conductivity Measurement setup

Ball Mill

Laser Setup



Simulation Capabilities

Accuraspray (inflight-particle velocity measurment)

Partner Organizations

Contact Us!

The Indian Thermal Spray Association
ITSA ASSOCIATION FOR THERMAL SPRAY TECHNOLOGY AND RESEARCH

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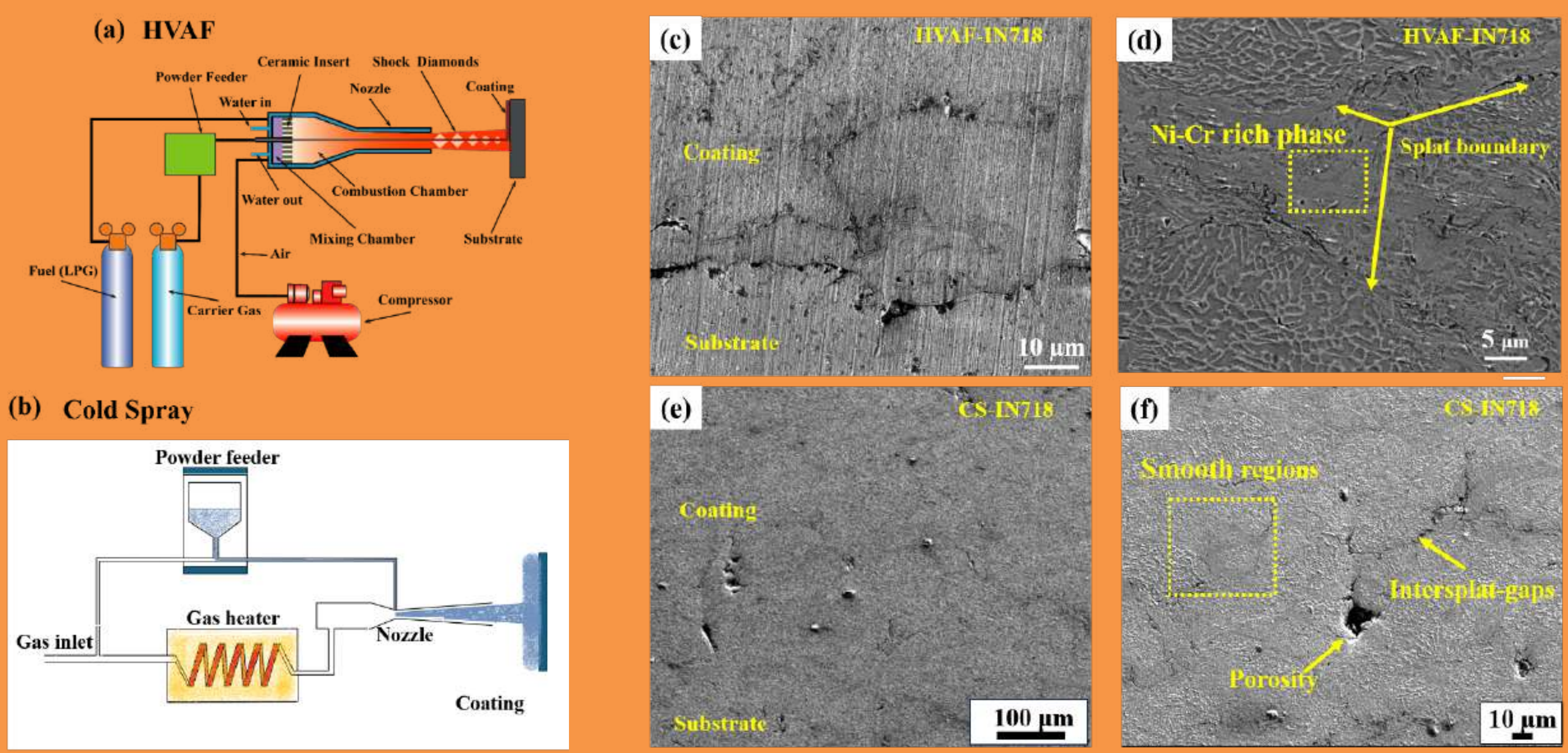

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