7th International Thermal Spraying and Hardfacing Conference

PROGRESS, APPLICATIONS AND MODERN TECHNOLOGIES

BOOK OF ABSTRACTS

CONFERENCE ORGANIZER

Department of Metal Forming, Welding and Metrology,
Faculty of Mechanical Engineering of Wroclaw University of Science and Technology

CONFERENCE PARTNERS

European Thermal Spraying Association (ETSA)
Stowarzyszenie Inżynierów i Techników Mechaników Polskich (SIMP)

Wrocław University of Science and Technology

Table of Content

Wrocław 2025

7th INTERNATIONAL THERMAL SPRAYING AND HARDFACING CONFERENCE

PROGRESS, APPLICATIONS AND MODERN TECHNOLOGIES

Purpose of the conference

The aim of the conference is to present the latest researches and developments in the field of thermal spraying, as well as of hardfacing. We are looking for papers mainly dedicated to: new materials and technologies, properties of coatings and weld deposits, novel characterization methods as well as new industrial applications in different operating conditions. In addition, the problems concern training of specialists, quality and certification system at thermal spraying and hardfacing technologies will be discussed. The session dedicated to generative techniques (with particular emphasis on 3D printing) of metallic materials will be included since this year's edition.

Conference topics

- thermal spray processes: plasma spraying, High Velocity Oxigen/Air Fuel, cold spray,
- hardfacing processes: laser cladding, hardfacing,
- additive manufactiruing: 3D printing, Selective Laser Sintering, metal AM, Direct Metal Deposition and more…,
- allied processes: surface pretreatment, laser processing, heat treatment, …,
- new equipment for thermal spraying and hardfacing,
- development in materials for surface engineering,
- development in thermal spraying and hardfacing processes,
- quality and certification systems in thermal spraying.

Scientific committee

Chairman of Scientific Committee
Prof. Lech Pawłowski, University of Limoges, France

Darya Alontseva, East Kazakhstan Technical University, Kazakhstan
Lutz-Michael Berger, Fraunhofer IKTS, Germany
Giovanni Bolelli, Università degli Studi di Modena e Reggio Emilia, Italy
Ladislav Celko, Brno University of Technology, Czech Republic
Tomasz Chmielewski, Warsaw University of Technology, Poland
Susan Conze, Fraunhofer Institute for Ceramic Technologies and Systems, Germany
Artur Czupryński, Silesian University of Technology, Poland
Alain Denoirjean, University of Limoges, France
Sergi Dosta, Universitat de Barcelona, Spain
Dariusz Fydrych, Gdańsk University of Technology, Poland
Dariusz Golański, Warsaw University of Technology, Poland
Simon Goutier, University of Limoges, France
Anna Góral, Polish Academy of Science, Poland
Šárka Houdková, Research and Testing Institute Plzen, Czech Republic
Tanvir Hussain, University of Nottingham, United Kingdom
Damian Janicki, Silesian University of Technology, Poland
Ewa Jonda, Silesian University of Technology, Poland
Shrikant Joshi, University West, Sweden
Heli Koivuluoto, Tampere University, Finland
Ondřej Kovářík, Czech Technical University, Czech Republic
Tomasz Kurzynowski, Wrocław University of Science and Technology, Poland
Thomas Lampke, University of Chemnitz, Germany
Christoph Leyens, Fraunhofer IWS, Germany
Leszek Łatka, Wrocław University of Science and Technology, Poland
Aleksandra Małachowska, Wrocław University of Science and Technology, Poland
Monika Michalska, VSB – Technical University of Ostrava, Czech Republic
Grzegorz Moskal, Silesian University of Technology, Poland
Radek Mušálek, Institute of Plasma Physics, Czech Republic
Hanna Myalska-Głowacka, Silesian University of Technology, Poland
Amirhossein Pakseresht, FunGlass Centre, Slovakia
Paweł Sokołowski, Wrocław University of Science and Technology, Poland
Mirosław Szala, Lublin University of Technology, Poland
Aleksandra Świerczyńska, Gdańsk University of Technology, Poland
Rolando T. Candidato Jr., Mindanao State University, Philippines
Filofteia-Laura Toma, Fraunhofer IWS, Germany
Robert Vaßen, Forschungszentrum Jülich, Germany
Sergii Voinarovych, Paton Electric Welding Institute NASU, Ukraine
Mariusz Walczak, Lublin University of Technology, Poland
Marcin Winnicki, Wrocław University of Science and Technology, Poland

Day I | PLENARY LECTURES

HVOF coating of additive manufactured parts: exploring the effect of surface pre-treatments and surface topography

Giovanni Bolelli[a], Maria Francesca Bonilauri[a], Riccardo Franci[b], Giovanni Pulci[c], Francesco Marra[c], Laura Paglia[c], Gian Carlo Gazzadi[d], Stefano Frabboni[d,e], Luca Lusvarghi[a], Matteo Perini[f], Sasan Amirabdollahian[f], Edoardo M. Rossi[g], Gianluca Di Egidio[h], Carla Martini[h], Alessandro Morri[h], Davide Doni[i], Giacomo Trecordi[i]

[a] *Department of Engineering "Enzo Ferrari", Università degli Studi di Modena e Reggio Emilia, Via Pietro Vivarelli 10, 41125 Modena, Italy*
[b] *Il Sentiero International Campus S.r.l., Via Friuli 11, 36015 Schio, Italy*
[c] *Dipartimento di Ingegneria Chimica Materiali Ambiente, Università di Roma - 1 "La Sapienza", Via Eudossiana 18, 00184 Roma, Italy*
[d] *CNR-Istituto Nanoscienze-S3, Consiglio Nazionale delle Ricerche, Via Giuseppe Campi, 213/A, 41125 Modena, MO, Italy*
[e] *Dipartimento di Fisica, Informatica e Matematica, Università di Modena e Reggio Emilia, via G. Campi 213/A, 41125 Modena, MO, Italy*
[f] *ProM Facility - Trentino Sviluppo, Via Fortunato Zeni 8, 38068 (TN), Italy*
[g] *Università degli studi Roma Tre, Department of Civil, Computer and Aeronautical Engineering, Via Vito Volterra 62, Rome, 00146, Italy*
[h] *Department of Industrial Engineering (DIN), Alma Mater Studiorum University of Bologna, Via Zamboni 33, 40126 Bologna, Italy*
[i] *Flame Spay S.p.A, Via Leonardo da Vinci 30, 20877 Roncello (MB), Italy*

The deposition of thermal spray coatings onto additively manufactured parts has been attracting increasing scientific and industrial attention. The range of applications of additive manufacturing technologies has in fact been growing rapidly, and their unique surface features offer both novel challenges and unique opportunities for the deposition of coatings.
After a brief review of the existing literature, this contribution will cover the authors' recent experiences with various approaches to obtain strongly adherent coatings onto laser-powder bed fusion (LPBF) parts while minimizing or preventing the use of subtractive pre-treatments. We chose the HVOF spraying of WC-CoCr as a model system because it is widely employed for wear and corrosion protection in a range of applications. We studied the deposition of WC-CoCr coatings onto as-built AISI316 surfaces with different levels of oxide coverage; we examined the use of chemical pickling as a cleaner alternative to surface machining and grit-blasting; and we explored different laser surface remelting treatments to modify the topography of LPBF parts in-situ. We performed a range of microstructural, mechanical, tensile adhesion, cyclic impact, and electrochemical corrosion tests to verify both the quality of the deposited WC-CoCr layer and its adhesion and cohesion strength, and we coupled this with fine-scale analyses of the coating/substrate interface quality by TEM inspection of FIB-machined lamellae.
Finally, we verified the effect of the coating on the structural performance of coated parts under static and fatigue loading conditions, which is going to be described in greater detail in another, dedicated contribution to this Conference.

Keywords: laser-powder bed fusion, high velocity oxygen-fuel, , adhesion, surface pre-treatment

Day I | PLENARY LECTURES

Advanced methods for characterization of cold sprayed materials

Jan Cizek*, Jan Medricky, Filip Stefanik, Frantisek Lukac, Jan Kondas, Reeti Singh, Oksana Melikhova, Petr Hruska, Jakub Cizek, Michaela Janovska, Martin Koller, Martin Sevcik, Petr Sedlak, Hanus Seiner

**Institute of Plasma Physics, Czech Academy of Sciences, U Slovanky 2525/1a, 182 00 Prague 8, Libeň*

In this talk, three advanced non-destructive analytical methods for characterizing materials will be introduced with a focus on cold sprayed deposits. Positron annihilation spectroscopy (PAS) is a reliable technique for studying open volume lattice defects in materials at atomic-scale level. The method is sensitive not only to areal defects such as grain boundaries or line defects such as dislocations, but also to point defects, such as vacancies or vacancy clusters which are below the resolution limit of TEM. The information obtained from PAS provides critical insights into the deformation mechanisms in CS, complementary to the description by FEM modeling and SEM/TEM observations. Resonant ultrasound spectroscopy (RUS) is a technique for determination of elastic constants (Young's modulus, shear modulus and bulk modulus) and their anisotropy strength. The main advantage of RUS is that it enables determination of all independent elastic constants from measurements of one small sample. In addition, it also enables a direct assessment of the internal friction parameters of the examined material, offering additional diagnostic power for assessing material integrity, and defect density and activity. Scanning acoustic microscopy (SAM) is a subsurface imaging technique that may be used to reveal hidden structural features of materials. This includes imperfections and heterogeneities such as voids and pores, but also the quality of interface below a surface coating. In addition, SAM is capable of visualizing locations of deteriorated material that may have a significant influence on the overall properties yet cannot be directly seen by SEM observation.

Day I | PLASMA SPRAYING

Conductivity, Viscosity, Enthalpy: The Relevance of Nitrogen-Based Plasmas for Effective Feedstock Treatment in Thermal Spraying

Georg Mauer[a, b], Robert Vaßen[a, c]

[a] *Forschungszentrum Jülich GmbH, Institute of Energy Materials and Devices, IMD-2: Materials Synthesis and Processing, Jülich, Germany*
[b] *TU Dortmund University, Department of Mechanical Engineering, Chair of Materials Technology, Dortmund, Germany*
[c] *Ruhr University Bochum, Department of Mechanical Engineering, Institute for Materials, Bochum, Germany*

The objective of this work is to contribute to the understanding of the importance of nitrogen in improving the feedstock treatment in plasma spraying. Three different plasma gas compositions, a ternary argon-based plasma parameter, a ternary nitrogen-based parameter, and a binary nitrogen-based parameter without any argon, were used with the Axial III™ plasma torch for suspension plasma spraying. Thermodynamic and transport properties of the plasma gas mixtures were calculated and compared. Based on this, Ability of Acceleration Factors (AAF) and Ability of Heating Factors (AHF) were calculated and correlated with measured in-flight particle velocities and temperatures.
The computational and experimental results show that the transport properties, namely the thermal conductivity and the viscosity of the plasma gas, are key factors for the feedstock treatment. In this respect, a high nitrogen content is advantageous, especially for the heating of the particles. Therefore, nitrogen can be considered as a high heat transfer component of the plasma. However, the use of nitrogen requires a thermally robust plasma torch design.
Nitrogen also has a relatively high enthalpy. Enthalpy describes the amount of energy stored in the plasma gas that can be released. If the amount of this energy is not sufficient to heat the feedstock as required, e.g. at high feed rates of solid or liquid feedstocks, an insufficient enthalpy of the plasma gas is a limiting factor. Again, the computational and experimental results in this study show that a high nitrogen content can be advantageous.

Keywords: Plasma spraying, Plasma torch, Nitrogen, Enthalpy, Transport coefficient

Day I | PLASMA SPRAYING

Microstructure and Electrical Insulation Properties of Atmospheric Plasma-Sprayed Alumina (Al_2O_3) and Magnesium Aluminate Spinel ($MgAl_2O_4$) Coatings

Serhii Tkachenko[a], Michaela Remešová[a], Vendula Bednaříková[a], Martin Juliš[a], Ladislav Čelko[a]

[a] *High-Performance Materials and Coatings for Industry Research Group, Central European Institute of Technology, Brno University of Technology, Purkynova 565/123, 61200 Brno, Czech Republic*

Plasma-sprayed alumina (Al_2O_3) coatings are widely used in electrical insulation applications due to the high availability of alumina, low electrical conductivity, high mechanical properties, and excellent wear resistance. However, the insulation properties of alumina are significantly influenced by its phase composition, which results from thermal spraying processes, specifically the formation of metastable phases such as γ- or δ-Al_2O_3. In addition, exposure to atmospheric moisture, lubricants or other liquids further degrades the insulating properties of alumina. These limitations require the development of alternative coating systems that offer better environmental stability and maintain excellent insulation properties. One possible candidate is magnesium aluminate spinel ($MgAl_2O_4$), which has excellent electrical insulation performance, high mechanical strength and thermal shock resistance, lower sensitivity to moisture than alumina, and is thermodynamically stable during thermal spraying. Despite their insulating potential, spinel-based $MgAl_2O_4$ plasma-sprayed coatings are still poorly studied.

This study focuses on the microstructure and electrical insulation properties of atmospheric plasma-sprayed (APS) $MgAl_2O_4$ coatings compared to APS-sprayed alumina coatings. The coatings were impregnated with epoxy or silicone sealants to increase the electrical resistivity. Microstructural and electrical characterizations were performed using scanning electron microscopy (SEM), X-ray diffraction (XRD) and DC resistivity measurements.

Keywords: magnesium aluminate spinel, alumina, atmospheric plasma spraying, electric insulation

Day I | PLASMA SPRAYING

Influence of Mechanical Pretreatment on the Properties of APS-Deposited Hadfield Steel

Aleksandra Małachowska, Paweł Sokołowski, Adam Sajbura, Marcin Korzeniowski, Marcin Winnicki, Anna Kuś

Wroclaw University of Science and Technology, Faculty of Mechanical Engineering, Department of Metal Forming, Welding and Metrology, ul. Lukasiewicza 5, 50-371 Wroclaw, Poland

High-manganese steels (HMnS), also known as Hadfield steels, are characterized by exceptional work-hardening capabilities and a favorable toughness-to-ductility ratio, making them attractive candidates for protective coatings in dynamic wear environments. However, their wear resistance under static abrasive conditions remains limited due to a reduced hardening response in the absence of impact. This study investigates the enhancement of HMnS coatings deposited via atmospheric plasma spraying (APS) through surface pre-hardening treatments such as grinding, shot peening, and hammering, aimed at improving their performance under static wear conditions. The standard HMnS composition (X120Mn12) was compared to modified variants incorporating alloying elements such as chromium (Cr) or vanadium (V). The microstructure and mechanical properties of the coatings were examined via cross-sectional analysis and hardness testing. To evaluate and compare the effectiveness of the different hardening treatments, the Almen gauge test was performed. The study demonstrates the potential of combining advanced coating technologies with mechanical surface treatments to optimize HMnS coatings for applications requiring enhanced wear resistance under both static and dynamic conditions.
This study received co-funding provided by the National Center for Research and Development in Poland under the MEra-NET project: High-manganese steels to develop gradable coating systems by work hardening for sustainable wear protection applications, M-ERA.NET3/2022/86/IronWorkCoat/2023

Keywords: high-manganese steels, Hadfield steel, atmospheric plasma spraying (APS), protective coatings, wear resistance

Day I | ADDITIVE MANUFACTURING

Cavitation erosion resistance of DMLS additive manufactured 17-4PH steel after heat treatment and shot peening process

Aleksander Świetlicki, Mirosław Szala, Mariusz Walczak

Department of Materials Engineering, Faculty of Mechanical Engineering, Lublin University of Technology, Nadbystrzycka 36D, 20-618 Lublin, Poland

Components produced by additive manufacturing (AM) through direct metal laser sintering (DMLS) often show surface defects. Therefore, the surface properties of AM products should be modified to improve their strength, wear resistance, and ensure high erosion resistance. Shot peening is considered suitable for surface modification of both conventionally manufactured and additively manufactured engineering components made of 17-4PH (X5CrNiCuNb16-4) stainless steel. Mechanical properties of 17-4PH steel can be enhanced through appropriate heat treatment. However, limited information is available on combined treatments, such as shot peening of precipitation-hardened 17-4PH steel. This study aimed to evaluate the cavitation erosion resistance of DMLS-produced 17-4PH steel after heat treatment and shot peening. Three types of blasting media—CrNi steel shot, glass, and ceramic beads—were used for peening the DMLS 17-4PH stainless steel. Results showed that shot peening refined the steel's microstructure, promoting the formation of martensite (α) and reducing retained austenite (γ). Peened specimens exhibited increased surface hardening, as did heat-treated samples. Cavitation erosion tests followed the ASTM G32 standard procedure. The erosion resistance of both conventionally manufactured and additively manufactured 17-4PH steel was compared. Steel specimens modified by shot peening displayed various surface morphologies, hardness levels, and microstructures, all of which influence cavitation erosion resistance.

Keywords: additive manufacturing, microstructure, shot peening, stainless steel, cavitation erosion

Day I | ADDITIVE MANUFACTURING

Fatigue life of HVOF-coated additively manufactured parts

Maria Francesca Bonilauri[a]*, Gianluca Di Egidio[b], Carla Martini[b], Alessandro Morri[b], Riccardo Franci[c], Davide Doni[d], Giacomo Trecordi[d], Luca Lusvarghi[a, e, f], Giovanni Bolelli[a, e, f]

[a] *Department of Engineering "Enzo Ferrari", Università degli Studi di Modena e Reggio Emilia, Via Pietro Vivarelli 10, 41125 Modena, Italy*
[b] *Department of Industrial Engineering (DIN), Alma Mater Studiorum University of Bologna, Via Zamboni 33, 40126 Bologna, Italy*
[c] *Il Sentiero International Campus S.r.l., Via Friuli 11, 36015 Schio (VI), Italy*
[d] *Flame Spay S.p.A, Via Leonardo da Vinci 30, 20877 Roncello (MB), Italy*
[e] *InterMech – MO.RE., University of Modena and Reggio Emilia, Via P. Vivarelli 2, Modena, Italy*
[f] *INSTM, Research Unit: University of Modena and Reggio Emilia, Via P. Vivarelli 10, Modena, Italy*

The successful deposition of thermally sprayed coatings on metal parts produced by additive manufacturing has recently emerged as a promising advancement. Preliminary studies by the authors showed that High Velocity Oxygen-Fuel (HVOF) coatings can be deposited onto Laser Powder Bed Fused (L-PBF) parts without intermediate surface treatments. Optionally, adhesion can be enhanced by activating the substrate surface through pickling. However, the behaviour of these coated systems under fatigue loading remains unclear. This study evaluated whether applying a WC-10%Co-4%Cr HVOF coating affects the fatigue life of L-PBF AISI 316L steel components and how different substrate surface conditions influence this behaviour.
Rotating bending fatigue tests were performed on hourglass-shaped specimens coated in as-built, pickled, and machined and grit-blasted conditions. Additionally, uniaxial tensile and tensile adhesion tests were conducted on similar systems. Uncoated L-PBF samples in as-built conditions and subjected to machining and grit-blasting were tested as a reference to separate the effects of the coating.
The adhesion of the coatings was found to be independent of the surface treatment, with values around 70 MPa. This strong adhesion was evident after tensile tests, as individual splats remained bonded to the substrate even when ring-shaped coating fragments detached cohesively from the samples. The mechanical strength of coated systems remained comparable to uncoated references. However, elongation at break was significantly reduced in coated, sandblasted samples, due to embedded Al_2O_3 particles acting as stress concentrators. Interestingly, these samples exhibited the highest fatigue resistance among the coated ones. In all cases, the HVOF coating did not degrade fatigue performance compared to uncoated samples.

Keywords: laser-powder bed fusion, high velocity oxygen-fuel, fatigue, adhesion, surface finishing

Day I | HVOF SPRAYING

Effects of a Nitrogen Atmosphere on Cr_3C_2-containing Hardmetal Coatings at High Temperatures

Lutz-Michael Berger, Kerstin Gnauck, Susan Conze

Fraunhofer IKTS, Winterbergstr. 28, 01277 Dresden, Germany

The work presented in this contribution is part of a larger project, where the safety from failure of HVOF-sprayed hardmetal coatings at high-temperature service is investigated. Cr_3C_2-NiCr coatings are most common for high temperature applications. However, binary Cr_3C_2-WC-Ni-based compositions offer certain advantages for such service conditions.

For high-temperature service the hardmetal coatings are occasionally applied in a protective nitrogen or nitrogen-containing atmosphere. It is known that Cr_3C_2 can interact with nitrogen and form Cr_2N or CrN, but the mechanism and consequences of nitride formation are not studied so far. In this contribution the interaction of 73%WC-20%"Cr_3C_2"-7%Ni, 42%WC-42%Cr_3C_2-16%Ni, 70%Cr_3C_2-10%WC-20%Ni (experimental composition) and Cr_3C_2-NiCr coatings deposited on specimen of 25 mm diameter of 1.4828 (AISI 309) or 2.4856 (Alloy 625) with nitrogen was studied. Heat treatment was performed in a tube furnace with a small nitrogen flow (2 l/h) in the temperature range 700°C-900°C for 2-32 days. The as-sprayed and heat-treated coatings were investigated by XRD, after conventional metallographic preparation and by FESEM and EDS mappings. Besides, the changes in the coatings focus was made on the coating-substrate interface. Formation of nitrides was observed in the coating down to the interface. High nitrogen concentrations were inhomogeneously distributed. It is assumed that the nitride formation results in liberation of carbon from the carbide. The carbon is able to diffuse into the substrate, leading there to precipitations close to the interface.

Other effects arrived from oxygen impurities in the nitrogen gas during the long duration of the experiments. These impurities have caused the formation of thin oxide scales at the coating surface. Also, coating delamination was observed in case of 1.4828 substrates. The reason for coating delamination was the formation of thin SiO_2 layers at the substrate surface.

Keywords: hardmetal coatings, high temperature service, nitrogen atmosphere, nitridation, CrN, coating delamination

Day I | HVOF SPRAYING

Effect of HVOF Spray Parameters on the Microstructure and Mechanical Characteristics of High-Entropy Alloy Coatings

F Acacio Rincón, María Parco, Georgiy Barykin, Mónica Salazar

Thermal Spray Group, Industry and Transport Division, TECNALIA, C/ Gabiria 82-84, 20305 Irun, Spain

High-entropy alloys (HEAs), including FeCrCoNiMn and 40Ni20Mn20Cr20Cu, exhibit promising mechanical properties. However, their performance is affected by microstructural features, such as chemical segregation in dendritic structures. High velocity oxy-fuel (HVOF) spraying, characterized by high kinetic energy and low temperature, offers advantages like excellent adhesion and reduced porosity over other thermal spray techniques. Despite these benefits, challenges such as oxidation during processing and residual stresses remain, potentially leading to defects like poor inter-splat adhesion and cracking. In this study, a proprietary HVOF system was employed to produce dense, high-bond-strength HEA coatings with low oxide content. The impact of various spraying parameters on the microstructure, phase formation, and mechanical properties of the coatings was analysed. The coatings exhibited a typical lamellar structure with a single solid solution phase and minimal oxide content.

Keywords: HEAs (High-Entropy Alloys), HVOF (High Velocity Oxy-Fuel), Coatings

Day I | HVOF SPRAYING

Potentials of Environmentally Friendly NbC-Fe-based Coatings for Wear and Corrosion Protection

Lukas Tegelkamp [a], Maximilian Grimm [a], Susan Conze [b], Lutz-Michael Berger [b], Thomas Lampke [a]

[a] *Materials and Surface Engineering Group, Institute of Materials Science and Engineering, Chemnitz University of Technology, Chemnitz, D-09107, Germany*
[b] *Fraunhofer IKTS, Fraunhofer Institute for Ceramic Technologies and Systems, Winterbergstr. 28, Dresden, D-01277, Germany*

WC-CoCr coatings are the standard in applications demanding high-wear and good corrosion resistance. However, recent developments in the field of hardmetal coatings are considering NbC-based cermets as a replacement. Because of the carcinogenic effect of cobalt and the critical role of cobalt and tungsten as raw materials, the replacement progress is driven by geopolitical concerns as well as increasingly high requirements of regulations regarding the impact of heavy metal emissions on the environment and human health. Compared to WC, NbC benefits from a significantly lower density and compatibility with environmentally friendly Fe-based alloys to be used as a binder replacing carcinogenic cobalt. To evaluate the potential of NbC-based cermets as a replacement for WC-CoCr various experimental powders made of NbC-reinforced Fe-based binders were developed by agglomeration and sintering and processed using high-velocity flame spraying. The coatings were analyzed regarding their microstructure, hardness and their properties in terms of wear and corrosion and compared to sintered samples of the powders as well as reference coatings made of WC-CoCr and Cr_3C_2-NiCr. While unidirectional dry sliding and abrasive tribological tests at room temperature showed high wear resistance competitive to the references, their high temperature performance suffered from instability and resulted in coating decomposition. The corrosion properties were investigated based on polarization curves with 3.5 % NaCl as well as immersion in 1 N H_2SO_4, 1 N NaCl and water. The results show, that the novel systems are comparable or partially outperforming the existing benchmarks, promising a future for environmentally friendly NbC-Fe-based coatings.

Keywords: NbC, thermal spraying, high-velocity flame spraying, wear, corrosion

Day I | HARDFACING PROCESSES

Microstructure and erosive wear behaviour of *in situ* NbC and (Nb, Ti)C-reinforced Inconel 625-based composite coatings produced by laser cladding

Damian Janicki

Welding Department, Faculty of Mechanical Engineering, Silesian University of Technology, Konarskiego 18A, 44-100 Gliwice, Poland

In situ NbC and (Nb, Ti)C-reinforced Inconel 625-based composite coatings were produced by a laser cladding process using powders containing different atomic ratios of C/Nb and C/(Nb+Ti), respectively. The microstructural characteristics of the coatings were investigated using scanning electron microscopy, transmission electron microscopy, and X-ray diffraction. Differences in the composition of the melt in the molten pool affected the fraction, growth morphology, and composition of the NbC-type reinforcing phase. Comparative erosion tests between the Inconel 625-based composite coatings and the metallic Inconel 625 coatings were performed following the ASTM G 76 standard test method. It was found that increasing the NbC fraction decreased erosion rates for both normal and oblique impact conditions. The erosive wear behaviour of composite coatings was discussed and related to the characteristics of reinforcing phase.

Keywords: in situ composite, Inconel 625, MMC, titanium carbide, niobium carbide, erosive wear, laser cladding

Day I | HARDFACING PROCESSES

Application of titanium diboride in plasma surfacing process of nickel matrix surface layers

Matesz Sowa

Welding Center, Łukasiewicz Research Network – Upper Silesian Institute of Technology, 44-100 Gliwice, Poland
Department of Welding Engineering, Silesian University of Technology, Street, 44-100 Gliwice, Poland

The subject of this research was to determine the influence of plasma deposition parameters, technological conditions, and the phase composition of experimental powders on the macrostructure and microstructure of the resulting coatings. The study explored the possibility of producing composite surface layers with the addition of carbide and boride phases. Due to the strong impact of the plasma arc on TiB_2 particles, it became necessary to implement an additional powder feeding system downstream of the plasma arc. To address this, a device was constructed using commercially available components, allowing full control over the amount of strengthening powder added to the deposition matrix.
The research demonstrated that, despite challenges such as segregation of the reinforcing and matrix phases in the powder feeder and the intense plasma arc impact on TiB_2 particles, promising technological solutions could be developed. These enabled the production of high-quality weld beads, free from defects, as confirmed by visual testing (VT) and macroscopic metallographic examination. However, achieving this required the development and construction of a dedicated fixture that allowed TiB_2 powder to be fed into the weld pool directly behind the plasma arc, using an independent controller and feeder. Modifying this fixture also enabled precise control over the ratio of strengthening powder to the deposition matrix in any desired proportion.
As part of this work, microstructural studies were conducted to identify precipitates in the TiB_2-containing coatings. Advanced techniques such as scanning electron microscopy (SEM) with energy-dispersive spectroscopy (EDS) were employed to analyze the microstructure.

Keywords: hardfacing, titanium diboride, tungsten carbide, plasma cladding

Day I | HARDFACING PROCESSES

What Are the Differences Between Self-shielded Flux Cored Hardfacing Wires with Similar Weld Metal Chemical Composition?

Michał Szymura[a], Artur Czupryński[b]

[a] *FPM S.A., Wyzwolenia Street 12C, 43-190 Mikołów, Poland*
[b] *Department of Welding, Silesian University of Technology, Konarskiego Street 18A, 44-100 Gliwice, Poland*

Catalogue data of flux cored wires for hardfacing relate to their classification, chemical composition of the weld metal, hardness after surfacing of the third layer or hardness of the weld metal and examples of application. There is no information in the available literature that would allow for comparison of resistance to abrasive wear and technological indicators (e.g. deposition rate) of flux cored wires of similar chemical composition manufactured by different manufacturers. In connection with the above, an attempt was made to compare four self-shielded flux cored wires providing a weld metal of high-alloy chromium cast iron Fe15.
The scope of the research included tests of resistance to abrasive wear of the metal-mineral type, analysis of chemical and phase composition, macro- and microscopic metallographic tests, and measurement of hardness of the overlay welds. We also determined the deposition rate, electrode efficiency, dilution, as well as thickness and width of the weld beads.

Keywords: hardfacing, flux-cored wire, comparison

Day II

PLENARY LECTURES

Physical deposition methods for films and coatings

Lech Pawłowski
Professor emeritus

IRCER, University of Limoges, 87068 Limoges, France

Since the publication by Presse Polytechnique et Universitaire Romandes (PPUR) of the French edition of this book in 2003 under the title *Dépôts Physiques*, the techniques of physical methods of films and coatings deposition changed considerably. Many new countries started to develop and produce in this field, and the author hopes to reach these new readers. The economic growth of these methods has also resulted in new industrial applications of films and coatings. The new applications came from traditionally innovative fields such as microelectronics but also from the new domain grown rapidly in recent years such as biomaterials. Consequently, the content of the English edition covers these new fields and new applications.

Chapter 1 that describes the preparation of the substrates prior to films and coatings deposition. The chemical and physical properties of zones close to surfaces of substrates made of different types of materials were carefully described. The modern methods of cleaning and activation of surfaces using photons emitted by different types of industrial lasers were added to the methods using electric discharges. Also, methods describing the patterning of films and coating using different lithographic processes were described.

Some new atomistic films deposition techniques such as atomistic layer deposition (*ALD*) or plasma spray physical vapor deposition (*PS PVD*) were added to the second chapter. As the granular techniques using liquid feedstock, such as suspension plasma spraying (*SPS*) or solution precursor plasma spraying (*SPPS*), were intensively tested in recent years, they are also described in the present edition. An important activity, especially in research and development, concerning *additive manufacturing* being a part of bulk deposition methods was also considered in the chapter.

Chapter 3 includes the description of new knowledge concerning the simulation of atomistic layers' growth. Similarly, the phenomena of coating growth at the use of cold-gas spraying method (*CGSM*) and the splashing of micro- and nano-sized particles during liquid feedstock thermal spraying resulting in possible generation of columnar microstructure are part of the new knowledge added to this chapter. Finally, the description of bulk coatings' nucleation includes detailed description of the phenomena taking place at the deposition.

The methods of films and coating characterizations described in Chapter 4 include much more examples visualizing the usefulness of described methods. Some methods such as characterizing of the contact angle of a droplet on a solid surface or *in vitro* and in *vivo* testing of biomaterials were added.

Finally, Chapter 5 includes the description of properties of films and coatings obtained with new materials or new methods of deposition. Some new properties such as electron emission or results of biomaterials testing were also considered.

The author hopes that the readers from academia including students and professors as well as engineers and managers from industry will appreciate this edition of book in learning and keeping abreast with the development of films and coatings technologies.

Day II | THERMAL SPRAY PROCESSES

Microstructure, mechanical properties and wear resistance of Fe-based metallic glass coatings cold sprayed on different substrates

Anna Góral[a], Anna Trelka-Druzic[a], Wojciech Żórawski[b], Łukasz Maj[a], Martin Vicen[c], Otakar Bokuvka[c], Paweł Petrzak[a], Grzegorz Garzeł[a]

[a] *Institute of Metallurgy and Materials Science, Polish Academy of Sciences, 25 Reymonta St., 30-059 Krakow, Poland*
[b] *Faculty of Mechatronics and Mechanical Engineering, Kielce University of Technology, Tysiąclecia Państwa Polskiego 7, 25-314 Kielce, Poland*
[c] *Department of Materials Engineering, Faculty of Mechanical Engineering, University of Zilina, 010 26 Zilina, Slovakia*

Metallic glasses (MG) have unique properties resulting from their disordered atomic structure, lack of grain boundaries and crystal lattice defects. However, small critical size caused by poor glass formability and internal brittleness hinders their wide application as functional materials. These materials are used in the coating form to overcome the size limitation and expand their practical application. The work aims to determine the possibility of producing thick, compact amorphous coatings using the cold spray process and show the relationships between their structures, mechanical properties, and wear characteristics of coating-substrate systems. The Fe-based metallic glass coatings were cold sprayed on Al alloy and steel substrates using a high-pressure Impact Innovations 5/8 system with the robot Fanuc M-20iA. The effect of a substrate on the microstructure, phase composition, microhardness, flexural strength and wear behaviour of the coatings were investigated. The cold sprayed coatings revealed a fully amorphous compact structure and negligible porosity without signs of oxidation. The coating deposited on the steel substrate showed higher microhardness and better resistance to loose abrasive wear. The force required to destroy the durability of the coating-steel substrate system estimated during three-point bending tests was also much higher than in the case of the coating sprayed on the Al alloy. Both coatings were characterized by comparable friction coefficient and wear index tested in tribological association coating and Si_3N_4 ball. The identified microstructure features correlated with the examined properties are a valuable input in knowledge, which enables a prediction of the behaviour of coatings during practical applications.

Acknowledgements
This research was partially financially supported by the Institute of Metallurgy and Materials Science of the Polish Academy of Sciences within the statutory work "*Alloy coatings resistant to abrasive wear*" Z-1/2024-2027.

Keywords: metallic glasses, cold spraying, microstructure, microhardness, flexural strength, wear resistance

Day II | THERMAL SPRAY PROCESSES

Advanced Thermal Spraying in Monosilane Atmospheres: Towards Oxide-Free and Cohesively Bonded Coatings

Manuel Rodriguez Diaz[a], Kai Möhwald[a], Maik Szafarska[b], René Gustus[b], Hans Jürgen Maier[a]

[a] *Institut für Werkstoffkunde (Materials Science), Leibniz Universität Hannover, 30823 Garbsen, Germany*
[b] *Clausthaler Zentrum für Materialtechnik, Technische Universität Clausthal, 38678 Clausthal-Zellerfeld, Germany*

Conventional thermal spray processes are usually performed in air using oxygen-containing process gases, which leads to oxidation of spray particles and interlamellar interfaces within the coatings. Additionally, substrate surface preparation and handling in ambient atmosphere result in native oxide layers on surfaces that hinder wetting. Consequently, thermally sprayed metallic and metal-ceramic coatings often exhibit heterogeneous microstructures with interlamellar oxide seams and low bonding strength, as adhesion relies primarily on mechanical interlocking rather than cohesive bonding.
This study explores the potential of thermal spraying in an atmospheric-pressure environment using a mixture of monosilane and inert gas as an alternative to vacuum spraying. Using arc-sprayed coatings as a model system, it is demonstrated that the extremely low oxygen partial pressure in this environment results in oxide-free coatings with significantly denser and more homogeneous microstructures. For the first time, large-area cohesive bonding between the coating and substrate is achieved, leading to a substantial increase in adhesive tensile strength.
Furthermore, the coating of titanium under these conditions illustrates how the application range of conventional spraying systems can be extended beyond current material limitations. The findings highlight the potential for improved coating performance and adhesion by modifying the process atmosphere, opening new possibilities for advanced surface engineering using thermal spray technology.

Keywords: Thermal spraying, oxygen-free process

Day II | THERMAL SPRAY PROCESSES

Low pressure cold spraying of H_2O_2-modified TiO_2

Anna Gibas[a], Agnieszka Baszczuk[a], Marcin Winnicki[b]

[a] *Department of Mechanics, Materials and Biomedical Engineering, Wroclaw University of Science and Technology, Smoluchowskiego Street 25, 50-370 Wroclaw, Poland*
[b] *Department of Metal Forming, Welding and Metrology, Wroclaw University of Science and Technology, Łukasiewicza Street 7, 50-371 Wrocław, Poland*

Developing suitable feedstock materials for low-pressure cold spraying (LPCS) requires a comprehensive evaluation of their initial properties, as these strongly influence both the deposition process and the final coating characteristics. It is crucial to assess not only whether a material can be effectively deposited, but also how the LPCS process itself may enhance or modify the feedstock, potentially improving its functionality and reducing overall production time. Additionally, by optimizing deposition parameters and adapting the LPCS setup, it is possible to overcome material limitations and gain greater control over the microstructure and performance of the produced coatings.

This work presents formation and deposition of oxygen-rich titanium dioxide (TiO_2) coatings using low-pressure cold spraying (LPCS). Oxygen-rich structure was a result of hydrogen peroxide treatment of TiO_2 during a single-pot sol-gel synthesis. A key focus is the development of LPCS techniques using different forms of sol-gel feedstock: powder, suspension, and aerosolised suspension. The research demonstrates that sol-gel materials can be effectively deposited while maintaining oxygen-rich functional groups, if process parameters are carefully optimized. The use of sol-gel suspensions reduces thermal energy through liquid evaporation, which aids in preserving desired chemical functionalities. Aerosolised suspensions further enhance evaporation, reducing H_2O_2 retention and improving coating uniformity. These findings contribute to the advancement of environmentally friendly and energy-efficient methods for fabricating functional oxide coatings with controlled chemical and structural properties.

Keywords: TiO_2, H_2O_2, low-pressure cold spray, suspension spraying, aerosolization

Day II | THERMAL SPRAY PROCESSES

Structure and properties of hybrid plasma sprayed TiO_2-ZnO coatings

Karolina Płatek[a], Jonas Dudik[b], Radosław Szymon[c], Pavel Ctibor[b], Leszek Łatka[a]

[a] *Department of Metal Forming, Welding and Metrology, Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, 5 Łukasiewicza St., 50-371 Wroclaw, Poland*
[b] *Institute of Plasma Physics, The Czech Academy of Sciences, Za Slovankou 3, 182 00 Prague, Czech Republic*
[c] *Department of Experimental Physics, Wroclaw University of Science and Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wroclaw, Poland*

TiO_2-ZnO heterostructures exhibit enhanced photoelectronic properties compared to pristine TiO_2, making them attractive for photocatalytic and optoelectronic applications. However, their deposition often requires multi-step and technically demanding procedures that limit industrial scalability. In this study, TiO_2-ZnO coatings were produced using the Water Stabilized Plasma Hybrid torch by Hybrid Plasma Spraying (HPS) process, which enables the simultaneous deposition of materials differing in form or chemical composition. As feedstock, TiO_2 powder containing 97% anatase phase and water-based ZnO suspensions with submicron particle size were used. Two heterostructures with distinct architectures were obtained: one synthesized using a double-injector configuration, and another produced sequentially, layer-by-layer. As reference, a conventional atmospheric plasma-sprayed (APS) TiO_2 coating was also deposited.
The coatings were examined for their morphology (SEM) and phase composition (XRD, Raman spectroscopy). Mechanical properties were determined by nanoindentation, while photoelectronic performance was assessed by photoluminescence (PL) spectroscopy. The results revealed that ZnO emission intensity strongly exceeded that of TiO_2. The most pronounced PL response, with a peak around 2.4 eV, was obtained for the coating in which the top layer was entirely composed of ZnO. This emission is most likely attributed to oxygen vacancy states within the ZnO lattice, highlighting the role of defects in tailoring the optical activity of TiO_2-ZnO heterostructures.

Keywords: TiO_2, ZnO, heterostructures, hybrid plasma spraying, photoelectronic properties

Day II | THERMAL SPRAY PROCESSES

Towards sustainable coatings: Process Optimization and Performance Evaluation of HVAF Sprayed Fe-Based BMG Coatings

Rahul Jude Alroy [a], David Linder [b], Edouard Mignot [a], Vasanth Gopal [a], Stefan Björklund [a], Shrikant Joshi [a]

[a] *Department of Engineering Science, University West, 46132, Trollhättan, Sweden*
[b] *QuesTek Europe AB, Sweden, 16967, Stockholm, Sweden*

Bulk metallic glasses (BMGs) have emerged as promising materials for surface engineering due to their unique combination of high hardness, corrosion resistance, and wear resistance, key attributes for components operating in harsh environments. These properties make Fe-based BMGs strong candidates to replace conventional coatings that rely on toxic or critical raw materials, contributing to global sustainability and regulatory goals.

This study explored a newly developed Fe-based BMG alloy with improved glass formability and processability for thermal spray coating applications. Despite their excellent properties, BMGs present significant processing challenges, particularly a tendency to crack due to limited ductility. To address this, we investigated the feasibility of depositing Fe-based BMG coatings using High Velocity Air Fuel (HVAF) spraying, aiming to produce dense coatings with superior wear and corrosion resistance.

Initial trials yielded coatings with significant cracking, delamination, and poor adhesion. However, through systematic optimization of spray parameters, we successfully achieved coatings with reduced cracking, improved adhesion, and enhanced microstructural integrity. The coatings were characterized for microstructure, degree of amorphicity, and hardness. Their wear and corrosion performance were evaluated and corroborated with microstructural findings. This work presents an important step toward realizing Fe-based BMGs as viable, environmentally friendly coating solutions through HVAF thermal spraying

Keywords: Bulk metallic glass, thermal spraying, HVAF, wear, corrosion, sustainable coatings

Day II | THERMAL SPRAY PROCESSES

Functionalized Thermally Sprayed Coatings for Biomedical Applications

M. Nicolaus[a], S. Singh[b], S. Pinches[b], A. Meghwal[b], A. Ang[b], K. Möhwald[a], C. C. Berndt[b], H. J. Maier[a]

[a] *Leibniz Universität Hannover, Institut für Werkstoffkunde (Materials Science), 30823 Garbsen, Germany*
[b] *Australian Research Council (ARC) Industrial Transformation Training Centre in Surface Engineering for Advanced Materials (SEAM), Swinburne University of Technology, Hawthorn, VIC 3122, Australia*

Osteoarthritis of the hip or knee joint are some of the most common diseases in industrialized nations, with the most effective treatment option at present being implantation of an endoprosthesis. Effective fixation of the prosthesis can be achieved via cementless ingrowth into porous implant surfaces. In this case, porous coatings of biocompatible materials such as titanium/hydroxyapatite act as a bond coat between the implant material and the bone. These porous coatings can be generated by thermal spraying. For example, applying high porosity titanium via vacuum plasma spraying is state of the art. However, in some cases the durability of the prosthesis may be reduced because of aseptic inflammation or osteolysis due to wear in the acetabulum. Antibiotics can be used to prevent inflammation, while an artificial synovial fluid can be used to prevent wear. The aim of this research project is to avoid these complications, and therefore a special coating system is developed. Specifically, porous coatings using biocompatible materials were produced by thermal spraying in a way that medical drugs, e. g. antibiotics against inflammation and synovial liquid against wear, can be transported to the desired location and take effect there.

Keywords: endoprosthesis, biocompatible materials, porous coatings

Day II | THERMAL SPRAY PROCESSES

Influence of manufacturing methods on selected Fe-based amorphous/nanocrystalline coatings

Inez Kredowska[a], Wirginia Pilarczyk[b], Aleksandra Małachowska[b], Paweł Sokołowski[b]

[a] *Silesian University of Technology, Akademicka 2A, 44 100, Gliwice, Poland*
[b] *Wrocław University of Science and Technology, Wyb. Wyspańskiego 27, 50 370 Wrocław, Poland*

Amorphous and nanocrystalline Fe-based coatings are gaining increasing attention due to their unique combination of high hardness, excellent wear resistance, corrosion resistance, and thermal stability. These properties make them suitable for a wide range of advanced engineering applications, including in the automotive, aerospace, and energy sectors. The exceptional performance of these coatings is closely tied to their metastable structure, which lacks long-range atomic order or contains ultra-fine nanocrystals embedded in an amorphous matrix. Achieving and maintaining this structure during the coating process presents a technological challenge, as it is highly sensitive to processing conditions, including temperature, cooling rate, and in-flight particle dynamics. Among the most commonly used deposition techniques for Fe-based coatings are atmospheric plasma spraying (APS) and high-velocity oxygen fuel (HVOF), both of which differ significantly in terms of thermal energy input, particle acceleration, and interaction with the substrate.

This study focuses on evaluating the effect of different spraying methods on the microstructure and properties of Fe-based amorphous alloy coatings produced by atmospheric plasma spraying (APS) and high-velocity oxygen fuel (HVOF). A series of coatings were analyzed using X-ray diffraction (XRD) and scanning electron microscopy (SEM). Additionally, microhardness and wear resistance were examined to assess the influence of manufacturing methods on mechanical performance.

The results confirmed that the choice of spraying method significantly influences the structure and performance of the resulting coatings. Those differences are attributed to variations in particle velocity, temperature, and in-flight oxidation during the spraying process. The findings highlight the significance of selecting an appropriate manufacturing method to achieve the desired combination of structural integrity and functional performance in Fe-based amorphous/nanocrystalline coatings.

Keywords: thermal spraying, plasma spraying, HVOF, Fe-based amorphous alloys

Day II | THERMAL SPRAY PROCESSES

The influence of the spray distance on the mircrostructure features and selected mechanical properties of double carbides coatings deposited on AZ31 by HVOF

Leszek Łatka[a,b], Ewa Jonda[c], Marcin Godzierz[d]

[a] *Department of Metal Forming, Welding and Metrology, Wroclaw University of Science and Technology, 5 Łukasiewicza St., 50-371 Wroclaw, Poland;*
[b] *Centre of Materials Science and Metal Forming, Wrocław University of Science and Technology, Łukasiewicza 5, 50-351 Wrocław, Poland;*
[c] *Department of Engineering Materials and Biomaterials, Silesian University of Technology, 18a Konarskiego St., 44-100 Gliwice, Poland;*
[d] *Centre of Polymer and Carbon Materials Polish Academy of Sciences, 34 M. Curie-Skłodowskiej Str., 41819 Zabrze, Poland;*
Chemnitz University of Technology, Institute of Materials Science and Engineering, Materials and Surface Engineering Group, D-09107 Chemnitz, Germany

In current studies the microstructure, residual stress as well as mechanical properties of double carbides cermet coatings were investigated. The samples were deposited by high velocity oxy-fuel (HVOF) method on the AZ31 magnesium alloy substrates. The feedstock material was WC-20Cr_3C_2-7Ni powder. After preliminary studies, the stand-off distance was selected as variable parameter with 3 values: 320, 360 and 400 mm.
SEM observation revealed robust mechanical binding to the substrate as well as low porosity (below 1.5 vol. %). TEM observation provided information about types of precipitation: (i) WC hexagonal phase in the space group P-6m2 and (ii) Cr_7C_3 orthorhombic phase in the space group P nma. The phase analysis confirmed presence of these phases as well as additional Cr_3C_2 and W_2C. Crystallite sizes for all phases in each sample were below 100 nm.
Analysing the residual stress values, it was observed that with the increasing spray distance the values of linear and shear stress were increasing also, from -72.7 MPa to – 131.5 MPa and from 14.2 MPa to 32.2 MPa, respectively.
On the other hand, the increasing spray distance caused a decrease of the mechanical properties. In case of instrumental hardness (H_{IT}) it was from 13.07 to 11.93 GPa, and for instrumental elastic modulus (E_{IT}) it was from 316 to 305 GPa. In case of the fracture toughness (K_{IC}) all values were around 3.6 – 3.8 MPa·$m^{1/2}$.

Keywords: carbides-based feedstock, AZ31, HVOF coating, microstructure, residual stress, mechanical properties

Day II | THERMAL SPRAY PROCESSES

Photocatalytic properties of suspension plasma sprayed sub-stoichiometric TiO_2 coatings

Afrodyta Daskalakis[a], Karolina Płatek[b], Adrian Zakrzewski[a], Patrycja Suchorska-Woźniak[a], Ryszard Korbutowicz[a], Leszek Łatka[b]

[a] *Faculty of Electronics, Photonics and Microsystems, Wrocław University of Science and Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wroclaw, Poland*
[b] *Department of Metal Forming, Welding and Metrology, Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, 5 Łukasiewicza St., 50-371 Wroclaw, Poland*

Titanium dioxide (TiO_2) is considered an exceptionally effective photocatalyst, particularly for the degradation of organic dyes in wastewater treatment. The material also presents high physical and chemical stability, as well as non-toxicity. In this study, TiO_2-based coatings were deposited using the suspension plasma spraying (SPS) process with an argon–hydrogen plasma mixture using Praxair SG-100 plasma torch. For suspension preparation, 100% anatase submicron powder (Sigma-Aldrich) was used. The suspensions were water-based, prepared without dispersants or surface-active agents, and had a solid phase content of 10 wt%. The influence of selected spraying parameters, namely hydrogen flow rate and spray distance on the electro-mechanical and photocatalytic properties of the obtained coatings was examined. The spray distance ranged from 50 to 75 mm, while the hydrogen flow rate was 5 or 10 slpm. The photocatalytic performance was evaluated through the degradation of organic dyes during a 120-minute process under UV-A illumination. The self-cleaning ability of the materials was also assessed by SEM/EDX.
This work provides insight into the effect of SPS process conditions on the functional performance of TiO_2 coatings. The use of water-based suspensions without additives highlights the potential of this environmentally friendly approach, while the variation in solid phase content allows for controlled adjustment of coating properties. The results of this study may support further optimization of plasma-sprayed TiO_2 coatings for applications in wastewater treatment and other environmental technologies.

Keywords: TiO_2, plasma spraying, photocatalysis, dye degradation

Day II | THERMAL SPRAY PROCESSES

Application of laser texturing as a method for substrate preparation in thermal spraying

Tomasz Kielczawa [a,b], Tadeusz Kubaszek [c], Pawel Pedrak [c],
Radek Musalek [d], Pawel Sokolowski [a,b]

[a] *Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, Wroclaw, Poland*
[b] *Centre of Materials Science and Metal Forming, Wrocław University of Science and Technology, Wrocław, Poland*
[c] *Faculty of Mechanical Engineering and Aeronautic, Rzeszów University of Technology, Rzeszów, Poland*
[d] *Institute of Plasma Physics, Czech Academy of Sciences, Prague, Czech Republic*

Substrate preparation plays a decisive role in determining the performance and durability of thermally sprayed coatings. Conventional mechanical roughening by grit blasting is widely used to enhance mechanical interlocking, yet recent advances in laser texturing have opened new pathways for controlled surface modification. Laser-based approaches enable precise tailoring of surface topography, chemical state, and wettability, offering advantages such as reproducibility, environmental friendliness, and compatibility with automated processes. However, potential drawbacks include high equipment costs, limited scalability, and the risk of inducing surface damage or microcracking under unsuitable processing conditions.
In this work a case study on a thermal barrier coating (TBC) system illustrates how laser texturing can influence the bond coat and top coat interface and enhance thermal cycling resistance compared to conventional treatments. The work concludes that optimized substrate engineering, particularly through laser texturing, provides a critical foundation for improving the performance and reliability of thermal spray technologies across diverse industries.

Keywords: substrate preparation, surface topography, laser texturing, sustainability

Day II | THERMAL SPRAY DIAGNOSTIC

Spatial resolved insights into surfaces - New evaluation strategies for large-volume measurements with non-destructive and automated surface acoustic wave spectroscopy

Stefan Makowski, Martin Zawischa , Yazan Atassi, Robert Knieß, Fabian Härtwig

Fraunhofer Institute for Material and Beam Technology IWS, Winterbergstraße 28, 01277 Dresden, Germany

In recent years non-destructive surface acoustic wave spectroscopy was shown to be a power-ful method to study mechanical properties of surfaces and coatings, including influence from defects such as pores, cracks and delamination.
The method was already applied in several scenarios like HVOF-sprayed cemented car-bide coatings, laser-cladded brake disks as well as nitride and case hardened surface among many other. The ability to complete a measurement in less than a minute allows the possibility to collect data from many measurement points with little effort. Automation of the measure-ment process then enables mapping of samples, to study the influence of aspects such as coating gun trajectories and heat distribution on the mechanical properties without destroying the part or sample.
So far, evaluation of surface acoustic waves was a manual process, typically fitting a sub-strate-coating material model to the dispersion curve of the measured data. While this step can be automated for some applications as well, this strategy is limited when deviations from the ideal material cannot be modelled as a homogeneous coating.
In this work, a new strategy is employed where a modified LAwave measurement system is used for automated measurement to obtain large-volume data for training of a neural network. It is shown that different types of coating characteristics such as defects can be distinguished fully automated and with high precision. Investigated surfaces are thermal sprayed cemented carbide coatings, laser cladded brake disks as well as laser shot-peened metal surfaces.

Keywords: non-destructive testing, mapping, coating defects, surface acoustic wave spectroscopy, thermal spraying, laser cladding, laser shot peening

Day II | THERMAL SPRAY DIAGNOSTIC

Increasing Durability of the Outer Air Seal Coating in the High Pressure Turbine by using a NiCoCrAlY/NiAl Bond Coat

M. Nicolaus, K. Möhwald, H. J. Maier

Leibniz Universität Hannover, Institut für Werkstoffkunde (Materials Science), 30823 Garbsen, Germany

The aim of this project is to increase the durability of the outer air seal coating of the high-pressure turbine. The outer air seal coating or abradable coating is used to control the gap between the housing and the turbine blades in order to maintain turbine efficiency. The abradable coating of the high pressure turbine consists of a ceramic thermal barrier coating (usually yttria stabilized zirconia), which is applied to the outer air seal by atmospheric plasma spraying. Due to the significantly different expansion coefficients of the ceramic and the air seal, a thermally sprayed metallic bond coat is used, which typically is an MCrAlY (M = Ni and/or Co) layer. During operation, a thin layer of aluminium oxide (TGO, thermally grown oxide) forms at the interface between the bond coat and the ceramic, which affects the bonding of the ceramic, potentially resulting in delamination. In this study, the bond coat is modified in such a way that the MCrAlY layer is enhanced by a NiAl layer (β-phase). Because of the β-phase, the formation of the TGO is delayed, which leads to decreased tendency for delamination of the abradable coating. Furnace cycle testing as well as SEM and element distribution investigations were carried out and a possible mechanism for the formation of the TGO is discussed.

Keywords: outer air seal, thermal barrier coating, thermally grown oxide

Day II | THERMAL SPRAY DIAGNOSTIC

Investigation of Plasma-Sprayed Tungsten Coatings Under Plasma Exposure

G. Schmidtmann[a,b] , A. Litnovsky[a], A. Kreter[a], S. Möller[a], A. Houben[a], J. W. Coenen[a,c,d], R. Vaßen[b], S. Brezinsek[a], Ch. Linsmeier[a], O. Guillon[b], G. Mauer[b]

[a]*Institute of Fusion Energy and Nuclear Waste Management – Plasma Physics (IFN-1), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany*
[b]*Institute of Energy Materials and Devices – Materials Synthesis and Processing (IMD-2), Forschungszentrum Jülich GmbH, 52425 Jülich, Germany*
[c]*Department of Nuclear Engineering & Engineering Physics, University of Wisconsin -Madison, 53706, Madison, United States of America*
[d]*Southwestern Institute of Physics, Chengdu 610064, China*

Due to its unique properties, including high sputtering resistance, a high melting point, relatively low tritium retention, and benign activity, tungsten (W) is the primary plasma-facing material (PFM) for future fusion devices such as ITER and DEMO. However, the plasma conditions can cause material erosion, melt damage, and characteristic changes in material and component properties, resulting in a reduced device lifetime. Repairing plasma-facing components (PFCs) in fusion devices is resource-intensive and time-consuming. Therefore, developing efficient in-situ repair methods is highly desirable to minimize overall maintenance-related downtime. Low-pressure plasma spraying (LPPS) allows the deposition of hard melting materials onto various substrates, resulting in high-quality coatings with promising properties. This allows fast and cost-effective repair of damaged PFCs, restoration of the PFM to adequate thickness to increase the device lifetime, or even replacing the existing wall material with tungsten.
In this study, a statistical Design of Experiment approach (DoE) was applied to reduce the total number of coating experiments and to identify and evaluate factors influencing the coating quality on different substrates. Eurofer steel, tungsten, or carbon fiber composite (CFC) were used as substrate materials. The W coatings deposited were evaluated for various quality parameters, including porosity, defects, surface roughness, thickness, and deposition efficiency.
Plasma tests were conducted on 500 µm thick in the linear plasma device PSI-2. The sputtering lifetime of the LPPS coatings was evaluated by exposing the samples to neon (Ne) plasma with an ion energy of 100 eV and a total fluence of 5.2 x 10^{24} ions/m^2. The total mass loss and the surface recession were used to evaluate the sputtering resistance of the coatings. In addition, deuterium (D) plasma with an ion energy of 73 eV and a fluence of 3.0 x 10^{25} ions/m^2 at an exposure temperature of 250°C was used to analyze the fuel retention using thermal desorption spectroscopy and nuclear reaction analysis. Moreover, the sputtering resistance of the LPPS coatings is promising, even outperforming the reference bulk tungsten in terms of hydrogen retention.

Keywords: Low Pressure Plasma Spraying, Nuclear Fusion, Tungsten, Hydrogen Retention, Sputtering Resistance

Day II | THERMAL SPRAY DIAGNOSTIC

Toward real-time trajectory prediction of powder and suspension feedstocks in plasma spraying

Tomasz Kiełczawa [a,b], Karolina Wiatrzyk [a], Jakub Piwowar [a], Marcin Korzeniowski [a,b], Adam Sajbura[a,b], Paweł Sokołowski[a,b]

[a]*Department of Metal Forming, Welding and Metrology, Wroclaw University of Science and Technology, Lukasiewicza 5, 50-371 Wroclaw, Poland*
[b]*Centre of Materials Science and Metal Forming, Wrocław University of Science and Technology, Wrocław, Poland*

The in-flight behavior of feedstock material in plasma spraying is primarily determined by the thermophysical properties of the plasma jet and the injection conditions. While the plasma jet can be controlled through torch design, gas composition, and feedstock power, injection conditions are generally optimized through visual evaluation of feedstock injection. Such qualitative assessments are operator-dependent, time-consuming, and can affect coating quality and reproducibility.
In this study, a powder particle detection algorithm was developed to quantitatively characterize the injection process using shadowgraphy imaging. Real-time analysis of SprayCam images enabled identification and extraction of individual particles, followed by statistical evaluation of their spatial distribution. Parameters such as the mean particle distance from the plasma jet centerline and the plume width were determined to describe injection quality. The short response time of the algorithm allows for rapid optimization of injection settings and prediction of feedstock behavior under varying conditions.
Additionally, particle data acquired from multiple orientations relative to the plasma jet were used to generate three-dimensional visualizations of feedstock dispersion. This provided further insight into injection dynamics and enabled validation of the injection process.
The proposed method offers a quantitative and operator-independent approach for optimizing feedstock injection in plasma spraying, contributing to improved process control and reproducibility.

Keywords: plasma spraying, feedstock injection, shadowgraphy, image analysis, particle detection algorithms

Day II | DEVELOPMENTS IN MATERIALS

Flowability of Yttria-Stabilized Zirconia Powder Produced for Atmospheric Plasma Spraying

Ladislav Čelko[a], Michaela Remešová[a], Karl Körner[b], Christian Hebenstreit[b], Serhii Tkachenko[a], Vendula Bednaříková[a], Matthias Leitner[b], Richard Trache[b]

[a] *Central European Institute of Technology, Brno University of Technology, Purkyňova 656/123, 612 00 Brno, Czech Republic*
[b] *Treibacher Industrie AG, Auer-von-Welsbach-Straße 1, 9330 Althofen, Austria*

The constant and steady transport of a defined amount of powder in a pressurized gas mixture from the hopper to the plasma plume is an essential parameter that determines the efficiency of the spraying process, the coating build-up process, and its reproducibility. This is easier to achieve with metal powders, even though they have a smaller particle size, than with ceramic powders, for which their producers utilize various approaches to ensure their flowability. Therefore, these are flowable compared to most powders synthesized in laboratories, which are almost impossible to feed. What parameters affect the flow of ceramic powders? How are these properties measured, and how do the techniques used and the measured values relate to the flowability of powders during thermal spraying? These few questions raised the motivation for this contribution, and in its hidden complexity, at least some parts have been successfully answered.
Yttria-Stabilized Zirconia powder in a low-density form, i.e. agglomerated and sintered, and spray dried to produce high porosity content, manufactured by TREIBACHER Industrie AG, was used for this study. The powder particles were sieved into several fractions: below 25 μm; 25-36 μm; 36-45 μm; 45-75 μm; 75-125 μm; and above 125 μm, and characterized using various methods to estimate their properties, such as Hall-, Carney- and Gustavsson-flowmeters, GranuDrum, tap density. The commercial GTV GmbH powder feeder was also used to verify the flowability of these powders, which pointed out that there is still no clear relationship between these methods and the behaviour of thermal spray powders.

Keywords: flowability, powder transport, ceramic powders, atmospheric plasma spraying

Day II | DEVELOPMENTS IN MATERIALS

Work Hardening Behavior of Casted, Sintered and Sprayed High Manganese Steels

Thomas Lindner*, Ali Farsiabiemameh, Niclas Hanisch, Aleksandra Malachowska, Hendrik Liborius, Andreas Schubert, Thomas Lampke

Mechanical Department, Chemnitz University of Technology, Reichenhainer Str. 70, 09126 Chemnitz, Germany

Modern production processes enable sustainable use of the limited natural resources. Coordinated manufacturing and finishing processes are of great importance in this context. The variety of process variants in the field of thermal spraying allows flexible adaptation of the coating structure and property profile. In addition to the shape of the feedstock material, kinetic and thermal process variables are of decisive importance. Due to the high surface roughness of the coating systems, finishing processes are often an integral part of the manufacturing chain. Diamond smoothing offers great potential for additional surface functionalization. By deforming existing profile peaks or edges, high quality functional surfaces can be generated. At the same time, the plastic deformation induces residual compressive stresses, which improve mechanical and tribological properties. Materials with a high work hardening capacity are particularly suitable for exploiting the synergy potential of complementary manufacturing technologies. Considering the sustainable use of resources, the diversification of raw material supply chains and REACH compliance, austenitic high-manganese steels (HMnS) are particularly worthy candidates as potential coating materials.

Day II | DEVELOPMENTS IN MATERIALS

New perspectives in metal powder manufacturing: analysis of the ultrasonic atomization process of 316L Steel

Adam Sajbura[a], Paweł Sokołowski[a], Randy Rößler[b], Thomas Lindner[b]

[a] *Mechanical Department, Wrocław University of Science and Technology, Łukasiewicza 5/7, 50-370 Wrocław, Poland*
[b] *Mechanical Department, Chemnitz University of Technology, Reichenhainer Str. 70, 09126 Chemnitz, Germany*

Ultrasonic atomization is gaining attention as a viable route for producing metallic powders and offers several advantages compared with established gas and water atomization processes. In this approach, intense high frequency vibrations are used to destabilize streams of molten metal, breaking them into small droplets that rapidly solidify into powders. The resulting particles exhibit spherical morphology and relatively narrow size distributions. Because droplet formation is governed by the vibration frequency, the average particle size can be tuned with precision, enabling powders engineered for specific manufacturing needs. Another practical benefit is that ultrasonic atomization can be implemented in compact workshops, which supports cost effective small batch runs and is well suited to research and development environments.
This work describes the design and performance assessment of a laboratory ultrasonic atomization system created for the generation of metal powders. We demonstrate that the system reliably produces high quality, defect free particles that meet the requirements of additive manufacturing and other dimension critical applications. Furthermore, we investigate the impact of process variables most notably the frequency of ultrasonic device and three power levels of amplitude on droplet breakup and the characteristics of the final powders. The results underscore the method's flexibility, as particle attributes can be adjusted by choosing appropriate operating conditions, and point to opportunities for scaling the technique while preserving powder quality. Collectively, these findings support ultrasonic atomization as a compelling alternative to existing powder production methods

Keywords: ultrasonic, atomization, powders

Day II | SURFACE ENGINEERING PROCESSES

Dual-phase $Ln_2Zr_2O_7$ + 8YSZ composite thermal barrier coatings – thermal insulation properties and microstructural degradation

Grzegorz Moskal

Silesian University of Technology, Department of Material Technologies, 40-019 Katowice, Krasińskiego str. # 8, Poland
Silesian University of Technology, Materials Innovation Laboratory, 40-019 Katowice, Krasińskiego str. # 8, Poland

Dual-phase composite thermal barrier coatings (TBCs) offer a promising approach for developing insulation systems with improved performance and longer service life compared to conventional single-phase or two-layer TBC systems. Their superior insulating properties arise from effective utilization of phonon scattering mechanisms, with splat-to-splat interfaces significantly reducing thermal conductivity relative to both single-phase zirconates and conventional 8YSZ.
Composite TBCs also demonstrate enhanced durability under high-temperature exposure, maintaining structural integrity and showing no signs of spallation after long-term testing. Phase stability studies reveal that lanthanum- and neodymium-based zirconates resist thermally induced interactions with 8YSZ, whereas samarium- and gadolinium-based systems tend to transform into non-stoichiometric fluorite compounds. Interestingly, this transformation produces ultrafine voids that relieve stresses and suppress crack formation, contributing positively to durability.
A novel observation in these systems is the interaction between zirconates, 8YSZ, and oxides from the thermally grown oxide (TGO) zone, leading to the formation of rare-earth chromites. These phases are stable at high temperatures and help inhibit critical degradation processes. Since such decomposition and oxide-interaction mechanisms are rarely reported, further microstructural studies are needed to clarify their influence on TBC performance.

Day II | SURFACE ENGINEERING PROCESSES

Laser surface polishing of CVD microcrystalline diamond coatings

Mariusz Frankiewicz[a], Michał Ćwikła[a], Maurycy Kempa[a], Jacek Reiner[a], Christian Stein[b], Kai Weigl[b], Markus Höfer[b], Peter Scholz[c], Sarah Baron[b]

[a] *Department of Advanced Manufacturing Technologies, Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, Lukasiewicza 5, 51-370 Wroclaw, Poland*
[b] *Fraunhofer Institute of Surface Engineering and Thin Films IST, Riedenkamp 2, 38108 Braunschweig, Germany*
[b] *Fraunhofer Institute for Machine Tools and Forming Technology IWU, Reichenhainer Str. 88, 09126 Chemnitz, Germany*

Microcrystalline diamond coatings (MCD) enable the attainment of very high mechanical properties and tribological wear resistance in coated tools, such as sheet metal stamping dies.
However, MCD coatings are characterized by significantly higher roughness than DLC coatings, due to the characteristics of the CVD process in which they are applied. This results in a need for further post-processing, which is challenging because of the diamond's high hardness.
Therefore, in this study, the surfaces of MCD coatings applied to two types of WC-Co substrates, one etched and the other with smooth interlayers, underwent treatment by ultrashort pulse laser surface polishing (LSP).
The effectiveness of LSP was verified by assessing the roughness and tribological properties of the machined surfaces and comparing them with the results obtained for mechanically machined surfaces and reference DLC coatings. The values of Spk and Sa parameters were 0.376µm/0.157µm and 0.214µm/0.112µm, respectively for as-coated/laser polished surfaces. Tribological tests conducted on MCD-treated surfaces using a strip drawing test against EN AW-5182 aluminum alloy sheets presents values of friction coefficients of 0.17–0.21 with lubrication and 0.28–0.35 for dry friction conditions. The values measured for the mechanically polished coatings were 0.18–0.20 and 0.40–0.42, for lubricated and dry tests conditions respectively.
The results obtained indicate that LSP can be used to reduce the roughness of MCD diamond coatings and enhance the technological properties of MCD-coated press-forming tools, which can be employed in the deep drawing of aluminum sheets with minimized lubrication.

Keywords: laser surface polishing, diamond coating, surface roughness, wear

Day II | SURFACE ENGINEERING PROCESSES

Cavitation erosion mechanisms of nickel-based overlays deposited via powder plasma transferred arc method

Mirosław Szala[a], Weronika Henzler[a], Bernard Wyględacz[b], Artur Czupryński[b] and Leszek Łatka[c]

[a] *Department of Materials Engineering, Faculty of Mechanical Engineering, Lublin University of Technology, Nadbystrzycka 36D, 20-618 Lublin, Poland*
[b] *Department of Welding Engineering, Faculty of Mechanical Engineering, Silesian University of Technology, Konarskiego 18A Str., 44-100 Gliwice, Polandd*
[c] *Department of Metal Forming, Welding and Metrology, Faculty of Mechanical Engineering, Wrocław University of Science and Technology, Łukasiewicza St. 5, 50-371 Wroclaw, Poland*

The focus of this research work is on the cavitation erosion of plasma-surfaced layers. This study examines the impact of microstructure and hardness on the cavitation wear resistance of Powder Plasma Transferred Arc Welded (PPTAW) coatings. The coatings were applied to a substrate of S235JR structural steel, utilizing a set of feedstock powders that included NiCrBSi with 35% WC, X5CrNiMo17-12-2, NiCrBSi, and NiCrBSiMo. Cavitation erosion tests were conducted on a vibratory test rig following the ASTM G32 standard, utilizing the stationary specimen method. Metallographic analyses explored both microstructure and hardness, while the eroded surfaces were examined using Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS) and profilometric techniques. This approach allowed for the identification of erosion mechanisms closely linked to the coatings' microstructure. The results suggest that the progression of erosion can be represented by a formula based on a combination of roughness parameters. Notably, the NiCrBSi hardfacing demonstrates the highest resistance to cavitation erosion, while the austenitic Cr-Ni overlay exhibits the lowest resistance. Overall, there is a correlation indicating that increased hardness leads to enhanced resistance against cavitation erosion.

Keywords: cavitation erosion, failure mechanism, microstructure, hardfacing

P1 **POSTER SESSION**

Mechanical and biological properties of hydroxyapatite-zirconium bilayer coatings deposited by microplasma spraying

Sergii Voinarovych[a], Sergey Maksimov[a], Sergii Kaliuzhnyi[a], Oleksandr Kyslytsia[a], Darya Alontseva[n], Leszek Łatka[c]

[a] *E.O. Paton Electric Welding Institute, National Academy of Sciences of Ukraine, 11 Kazymyr Malevych St., 03150 Kyiv, Ukraine*
[b] *School of Digital Technologies and Artificial Intelligence, D. Serikbayev East Kazakhstan Technical University, 19 Serikbayev St., 070010 Ust-Kamenogorsk, Kazakhstan*
[c] *Department of Metal Forming, Welding and Metrology, Wrocław University of Science and Technology, 7-9 Łukasiewicza St., 50371 Wrocław, Poland*

The development of bacterial infections at the site of orthopaedic implant placement remains a major clinical challenge, necessitating novel solutions that differ fundamentally from conventional antibiotic therapies and exert less systemic toxicity. Particular attention is given to coatings with prolonged antibacterial activity aimed at minimizing infection risk at the interface between the implant surface and living tissue. It is well-established that hydroxyapatite (HA) coatings on metallic implants improve the success rate of osseointegration. Among the advanced surface modification methods, microplasma spraying offers enhanced control over coating structure and composition

Despite HA's excellent biocompatibility, its application as a coating requires reliable adhesion to the metallic substrate. This study investigates the mechanical and biological performance of bilayer metal-ceramic coatings consisting of a zirconium (Zr) interlayer and an outer HA layer deposited via microplasma spraying. The bilayer coatings exhibited strong interfacial bonding, with an average pull-off strength of 28.0 ± 4.2 MPa and shear strength of 32.3 ± 3.2 MPa.

In vitro biocompatibility tests using mesenchymal stem cells (MSCs) revealed a significant enhancement in cell proliferation and viability on the coated surfaces, showing a 45% increase in cell growth over three days compared to the uncoated inert control. Furthermore, the coatings demonstrated pronounced antibacterial activity against Escherichia coli after 14 hours of incubation. These findings highlight the potential of microplasma-sprayed HA-Zr bilayer coatings as a promising strategy to improve both the mechanical stability and biological performance of orthopedic implants.

Acknowledgment. This work was carried out with grant support from the National Research Foundation of Ukraine for the project 032/0070, dated 03.03.2025 "Development of innovative biocompatible antibacterial coatings and technology for their application to orthopaedic implants for using in the treatment of injuries in military personnel and civilians"

Keywords: orthopaedic implants, microplasma spraying, adhesive strength, biocompatibility

P2 **POSTER SESSION**

Evaluation of the influence of material configuration on the tribological wear of mechanical systems of cooperating elements in a scraper conveyor for cullet discharge transport

Artur Czupryński[a], Małgorzata Musztyfaga-Staszuk[b], Anna Woźniak[b]

[a] *Department of Welding Engineering, Silesian University of Technology, Konarskiego 18A, 44-100 Gliwice, Poland*
[b] *Materials Research Laboratory, Silesian University of Technology, Konarskiego Street 18A, 44-100 Gliwice, Poland*

The article presents the results of research on the assessment of the influence of material configuration on the tribological wear of the mechanical systems of cooperating elements on the scraper conveyor intended for the transport of cullet discharge. Comparative tests were carried out on the currently used configuration of materials that form a mechanical system in the form of an element of the transport chain: an alloy steel forging for surface hardening of the 20MnCr5 grade (HSW – Kuźnia, Stalowa Wola, Poland), moving on a steel working plate with a wear resistant layer with a chromium cast iron structure CDP 1001 DP (Castolin Eutectic, Gliwice, Poland) with an alternative proposal creating a material combination of forging moving on a specially designed linear slide made of Hadfield steel grade X120Mn12. Tendencies of materials to wear as a result of dry friction and as a result of the action of loose abrasive material were determined on the basis of tests determining the mechanical and structural properties of the selected material combinations, i.e. hardness tests, tests of sliding friction resistance in reciprocating motion, and metallographic tests microscopic. The effect of material configuration on metal-metal and metal-mineral abrasive wear was evaluated based on the ASTM G99 and ASTM G65 standards, respectively. The tests were carried out with the use of tribometers, devices for testing under laboratory conditions, along with an analysis of the topography of the surface of the wear area. The following were determined, among others: loss of mass, surface roughness, and changes in mechanical properties of the tested materials. After tribological examinations, microscopic analyses of the surface were performed to determine the mechanism of metal-metal and metal-mineral wear. The research provided important information on the behaviour of the material under real-world operation conditions of scraper conveyor parts, which is particularly important in terms of increasing the durability and reliability of machine and equipment parts.

Keywords: linear slide, scraper conveyors, glass cullet, abrasive wear, wear mechanism

P3 **POSTER SESSION**

Influence of TiC addition on microstructure and mechanical properties of Inconel 625 laser cladding overlayers

Ewa Jonda[a], Tomasz Poloczek[b], Leszek Łatka[c], Marcin Godzierz[d], Aleksandra Lont[b]

[a] *Department of Engineering Materials and Biomaterials, Silesian University of Technology, 18a Konarskiego St., 44-100 Gliwice, Poland;*
[b] *Department of Welding Engineering, Silesian University of Technology, 18a Konarskiego St., 44-100 Gliwice, Poland;*
[c] *Department of Metal Forming, Welding and Metrology, Wroclaw University of Science and Technology, 5 Łukasiewicza St., 50-371 Wroclaw, Poland;*
[d] *Centre of Polymer and Carbon Materials Polish Academy of Sciences, 34 M. Curie-Skłodowskiej Str., 41819 Zabrze, Poland;*

Laser hardfacing is one of the most developed method of surface engineering which is used in order to enhance mechanical and functional properties. Nickel-based alloys are well-known feedstock materials for many applications, mainly because of high corrosion resistance. However, its wear and erosion resistance are rather poor. The study investigated the microstructures, phase composition and mechanical properties of composite overlayers manufactured on S235JR structural steel substrate by laser cladding. The hardfacing layers were composite ones, where Inconel 625 was a matrix (labelled as C1) and different addition of TiC as hard phase. In current studies different amount if TiC was added: 5, 10 and 15 wt. % (labelled as: 1Ti5, 1Ti10 and 1Ti15, respectively). The investigations included non-destructive penetrant testing, macro- and microstructure analysis, microhardness testing, phase analysis and solid particle erosion resistance. The values of laser power, welding speed and powder feed rate were the same for all samples. In case of dilution value, apart 1Ti5 sample, it was below 10 %. Phase analysis confirmed presence of TiC phase and γ-phase. The increasing addition of TiC resulted in increase of hardness and elastic modulus values. Similar tendency was observed for solid particle erosion resistance.

Keywords: laser cladding, TiC, Inconel 625, microstructure, erosion resistance, hardfacing

P4 **POSTER SESSION**

Attempts to modify nickel-based welds using carbon nanotubes

Jacek Górka

Department of Welding Engineering/Silesian University of Technology, Konarskiego 18a, 44-100 Gliwice, Poland

The aim of the study was to determine the effect of carbon nanotubes on the properties of nickel-based welds made on austenitic steel 0H18N9 substrate. As part of the study, simple single-pass welds were made on a flat surface. During the weld process, the intensity of the weld current and the type of powder fed were changed: base EuTroLoy 16221, base with 0.5% carbon nanotube content NC7000 and base with 1% carbon nanotube content. Argon was used as the plasma and shielding gas, while the powder transport gas was a mixture of argon with 5% hydrogen. Five welds of approximately 80 mm length were made for each type of powder. The visual, macro and microscopic tests showed that high-quality welds were obtained with an even, smooth face, a relatively even depth of penetration and without porosity. The results of the plasma surfacing process of 0H18N9 steel with EuTroLoy 16221 metal powder with the addition of NC7000 carbon nanotubes have shown:

- the possibility of making surfacing welds using high-quality carbon nanotubes free from external and internal defects,
- the introduction of carbon nanotubes to EuTroLoy 16221 powder has resulted in a change in the microstructure of the surfacing welds,
- hardness measurements have shown that the hardness of the surfacing welds made from the base powder is consistent with the manufacturer's data and is approximately 300 [HV],
- the introduction of carbon nanotubes to the surfacing powder allows for an increase in the hardness of the surfacing welds from 300 HV1 to even 430 HV1 with a content of 1 % of carbon nanotubes.

Keywords: plasma surfacing, nickel powder, carbon nanotubes, structure modification, hardness

P5 **POSTER SESSION**

Development of additive manufacturing of internal cooling channels using Cold Spray for optimal heat dissipation in injection molds

Sabina Stanco, Veronika Nemcova

Department, Research and Testing Institute Plzen, Pilsen 30100, Czech Republic

This study presents an in-depth investigation into the manufacturing methods of cooling channels, which are essential components in modern technologies, particularly within the aerospace and energy sectors. These channels play a critical role in enabling efficient heat dissipation from thermally stressed components, thereby enhancing their service life and operational reliability.
The primary focus of the research is the additive manufacturing of cooling channels using Cold Spray technology—a process that enables material deposition without significant thermal influence on the substrate. Copper powder was chosen for its excellent thermal conductivity, good machinability, and cost-effectiveness, making it an ideal candidate for applications requiring efficient thermal management, such as the cooling of injection molds.
A key aspect of the work involved selecting appropriate support materials to ensure structural stability and precise geometry during the manufacturing process. Copper and aluminium profiles were employed as supporting structures: the aluminium was removed after deposition, while the copper remained integrated into the final component to further enhance thermal performance. This approach successfully demonstrated the fabrication of cooling channels on flat samples.
Future work will focus on adapting this technology to molds with geometries and dimensions that closely replicate those used in real industrial environments. The study concludes with an evaluation of various production strategies and emphasizes the optimization of Cold Spray technology for functionally effective, economically viable, and technologically feasible manufacturing of cooling channels.

Keywords: cold spray, cooling channels, additive manufacturing, copper, aluminium

P6 **POSTER SESSION**

Corrosion resistance of plasma-sprayed iron-based metallic glass coatings

Aleksandra Małachowska, Marzena Lachowicz, Paweł Sokołowski

Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, ul. Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland

Metallic glasses are materials with a disordered (amorphous) atomic structure, formed by rapid cooling of metallic alloys. They exhibit higher mechanical strength than crystalline alloys of the same chemical composition, as well as excellent resistance to corrosion and wear. A notable subclass is iron-based metallic glasses, which offer the advantage of lower raw material costs compared to, for example, zirconium-based glasses. One of the main challenges in their application as protective coatings is partial crystallization during thermal spray processes, which deteriorates their corrosion resistance. In this study, three types of iron-based metallic glass coatings were deposited using Atmospheric Plasma Spraying (APS) on steel substrates. The chemical compositions of the powders were as follows: i) $Fe_{48}Mo_{14}Cr_{15}Y_2C_{15}B_6$, ii) b) $(Fe_{0.9}Co_{0.1})_{76}Mo_4(P_{0.45}C_{0.2}B_{0.2}Si_{0.15})_{20}$, iii) $Fe_{56.04}Co_{13.45}Nb_{5.5}B_{25}$. The coatings were then evaluated for corrosion resistance in a 3.5 wt.% NaCl solution using potentiodynamic polarization tests. In addition, a cyclic corrosion test was carried out in a salt spray chamber for 480 hours, in accordance with the PN-EN ISO 9227 standard. The microstructure of the coatings was analyzed before and after the corrosion tests.

Keywords: metallic glasses, APS, cyclic corrosion test

P7 **POSTER SESSION**

Image-Based Microstructural Assessment of Plasma-Sprayed Coatings on Hadfield Steel

Klaudiusz Mrozik, Aleksandra Małachowska, Marcin Korzeniowski

Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, ul. Wybrzeze Wyspianskiego 27, 50-370 Wroclaw, Poland

This study addresses the need for an effective, automated method of detecting and characterizing cracks in APS coatings. The objective is to develop an image analysis algorithm capable of processing scanning electron microscopy (SEM) images to identify, measure, and evaluate the spatial distribution of cracks. The proposed solution enables the detection of defects and provides quantitative data regarding the number, length, and arrangement of cracks with respect to varying process parameters such as spraying distance, post-treatment methods, and material composition. The developed algorithm was implemented in Aurora Vision Studio 5.5 Lite and utilizes a sequence of image processing operations including filtering, morphological transformations, and measurement functions. The process allows for efficient segmentation and geometric analysis of cracks in SEM images. The effectiveness and repeatability of the algorithm were validated on a set of real microstructural images from samples prepared under different technological conditions. This tool is intended to support process optimization and quality control in the production of thermally sprayed coatings, offering a reliable and repeatable method for defect quantification.

Acknowledgements

This study received co-funding provided by the National Center for Research and Development in Poland under the MEra-NET project: High-manganese steels to develop gradable coating systems by work hardening for sustainable wear protection applications, M-ERA.NET3/2022/86/IronWorkCoat/2023

Keywords: crack detection, surface treatment, wear resistance, atmospheric plasma spraying

P9 **POSTER SESSION**

H_2O_2 -modified TiO_2 for low pressure cold-spraying

Patryk Słota, Anna Gibas

Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, 5 I. Łukasiewicza Street, 50-371 Wroclaw, Poland

Although cold spraying less commonly utilizes oxides as feedstock materials, their unique properties make them worth further exploration [1]. Titanium dioxide (TiO_2) is a well-known material with promising photocatalytic properties. An interesting case is providing visible-light activity, which can be done using H_2O_2 [2]. Unfortunately, oxygen-rich are thermally sensitive energy which limits their applicability to deposition methods that supply only a limited amount of thermal energy.

In this study, TiO_2 powders were prepared using sol–gel method with titanium isopropoxide (TIPO) as precursor. Hydrogen peroxide (H_2O_2) was added to change the electronic structure of the material. Several variants were produced by changing the reaction medium (acidic, neutral, or alkaline) and the order of adding the reagents. X-ray diffraction (XRD) showed that the powders were mostly amorphous which makes the powders suitable to low pressure cold spraying. Raman spectroscopy confirmed the presence of oxygen-rich groups showing the success of modification with H_2O_2. Scanning electron microscopy (SEM) revealed that powders had very different shapes depending on the synthesis conditions. Acidic solutions produced porous, spherical particles, basic ones led to more regular, layered forms, while neutral media gave dense shapes. Finally, the initial cold spraying test shows that the spraying can preserve heat sensitive groups.

This study shows that the final structure and shape of TiO_2 powders strongly depend on how the synthesis is done, including the pH and sequence of reagent addition. The results can help in designing better TiO_2-based materials for photocatalysis, coatings, or environmental applications [3].

[1] Tregenza, et al., 2025,Adv Manuf Technol, DOI: 10.1007/s00170-025-15022-y
[2] Gibas, et al., 2022, Coatings, DOI: 10.3390/coatings12040475
[3] Słota, 2025, Master Thesis…

Keywords: titanium dioxide, sol-gel synthesis, hydrogen peroxide, oxygen-rich TiO_2, photocatalysis, cold-spraying

P12 **POSTER SESSION**

Deposition of HKUST-1 via low pressure cold spraying (LPCS)

Michał Ozga[a], Marcin Winnicki[b], Agnieszka Baszczuk[a], Marek Jasiorski[a]

[a] *Katedra Mechaniki, Inżynierii Materiałowej i Biomedycznej, Wydział Mechaniczny, Politechnika Wrocławska, Smoluchowskiego 25, 50-370 Wrocław, Polska*
[b] *Katedra Obróbki Plastycznej, Spawalnictwa i Metrologii, Wydział Mechaniczny, Politechnika Wrocławska, Smoluchowskiego 25, 50-370 Wrocław, Polska*

Metal–organic frameworks (MOFs) are crystalline porous materials, made from metal ions and organic building blocks, with exceptionally high surface areas, tuneable pore architectures, and diverse chemical functionalities. These properties make MOFs promising for a wide range of applications, including selective gas adsorption and storage, catalytic transformations, selective separation, detection of specific molecules, and protective functional coatings [1,2] Additionally, due to their limited chemical stability, many MOFs are used as templates for the synthesis of various carbon structures for electrochemical energy applications. A key step toward their practical implementation is the development of methods to integrate these advanced materials onto solid supports in a form that is both mechanically stable and functionally active.

In this study, HKUST-1 (structure made of copper (II) ions coordinated with 1,3,5-benzenetricarboxylate organic ligands) was selected as a representative MOF due to its well-defined structure and broad applicability. To deposit this material, we employed low-pressure cold spray (LPCS), a solid-state technique in which particles are accelerated at high velocity by a compressed gas jet under low-temperature conditions. This approach minimizes thermal degradation, enabling the formation of coatings that retain the framework's crystallinity and surface characteristics.

Characterization of the deposited layers by scanning electron microscopy (SEM) revealed continuous coatings with good adhesion to the metallic substrate. X-ray diffraction (XRD) confirmed that the crystalline structure of HKUST-1 was preserved after deposition, demonstrating the feasibility of LPCS as a coating strategy for MOFs.

The ability to produce stable MOF coatings while maintaining their intrinsic functionality opens pathways for applications such as gas storage and capture, catalytic surfaces for chemical reactions, protective coatings in corrosive environments, and sensing layers in environmental monitoring. These results underline the strong potential of MOF-based coatings and identify LPCS as a promising route for their scalable integration into engineering applications.

List of additional information:

1. Yusuf, V. F., Malek, N. I., & Kailasa, S. K. (2022). Review on metal–organic framework classification, synthetic approaches, and influencing factors: applications in energy, drug delivery, and wastewater treatment. ACS omega, 7(49), 44507-44531.
2. Kumar, S., Jain, S., Nehra, M., Dilbaghi, N., Marrazza, G., & Kim, K. H. (2020). Green synthesis of metal–organic frameworks: A state-of-the-art review of potential environmental and medical applications. Coordination Chemistry Reviews, 420, 213407

Keywords: HKUST-1, metal–organic frameworks, low pressure cold spray, coatings, catalysis

P13 **POSTER SESSION**

Development of wear-resistant Hadfield steel–based coatings by low-pressure cold spray

Marcin Winnicki[a], Aleksandra Małachowska[a], Wioletta Seremak[b], Piotr Bigott[a]

[a] *Department of Metal Forming, Welding and Metrology, WUST, Poland*
[b] *Department of Mechanics, Materials and Biomedical Engineering, WUST, Poland*

The development of wear-resistant coatings is crucial for extending the service life of engineering components exposed to intensive abrasion. Hadfield steel (X315Mn14V), widely recognized for its exceptional work-hardening behaviour, is difficult to process by low-pressure cold spray (LPCS) due to the limited deformability of its particles. To improve deposition efficiency, Hadfield steel powder was blended with softer metallic constituents, namely iron (Fe) and aluminium (Al), in various proportions. The prepared mixtures included (i) 97.5 wt.% Hadfield steel + 2.5 wt.% Al (2.5_Al); (ii) 75 wt.% Hadfield steel + 25 wt.% Fe (25_Fe); (iii) 50 wt.% Hadfield steel + 50 wt.% Fe (50_Fe), and (iv) pure Fe (as reference).

The coatings were characterized in terms of thickness, porosity, microstructure, hardness, and wear resistance. Light microscopy revealed that aluminium addition facilitated deposition of thick coatings, but with high porosity and microcracks. In contrast, iron admixture promoted denser and more homogeneous structures. Porosity ranged from 0.7 to 7%, with the lowest values obtained for the 50/50 Hadfield steel/iron coating. Hardness values varied between 130 and 380 HV0.3, strongly dependent on composition. The highest hardness (378 HV0.3) was achieved for the 50_Fe coating, while the lowest value (130 HV0.3) was observed for the 2.5_Al coating.

Ball-on-disc tests confirmed the correlation between hardness and wear resistance. The 50_Fe coating demonstrated the lowest wear track depth (37 μm), whereas the Al-modified coating exhibited poor tribological performance. Overall, Hadfield steel/iron coatings combined high hardness, low porosity, and superior abrasion resistance, making them promising candidates for protective applications.

Keywords: cold spraying, manganese steel, wear resistance, composite coating

P14 **POSTER SESSION**

Regenerative Laser Cladding of Tooling in Aerospace Manufacturing – Implementation Analysis

Piotr Koruba[a], Marek Pawlicki[b,c], Jacek Reiner[a]

[a] *Department of Advanced Manufacturing Techniques Wroclaw University of Science and Technology, Lukasiewicza 5 Str., 50-371 Wroclaw, Poland*
[b] *The President Stanislaw Wojciechowski Calisia University, Boguslawskiego 2 Sq., 62-800 Kalisz, Poland*
[c] *Pratt and Whitney Rzeszow, Hetmanska 120 Str., 35-078 Rzeszow, Poland*
...

Regeneration of tooling using additive manufacturing methods is becoming both a challenge and a necessity in today's aerospace industry, driven by the need to minimize material costs, reduce preparation times, and limit metal waste. This study analyzed a 40HM low-alloy steel ring used as a demonstration tooling component for the production of aircraft engine parts requiring repair. The feasibility of using laser cladding process with Metco 15F alloy powder as a regeneration method was investigated.
A laser cladding process was developed based on an optimization task taking into account the geometric parameters of the clad layer, its hardness, and the size of the heat-affected zone. The regeneration process was carried out on a demonstration component across three representative surface types: a flat face, an external cylindrical surface, and an internal cylindrical surface. This approach enabled an evaluation of the machinability of the laser-cladded layers using standard finishing operations applied in aerospace tooling departments—namely, turning, milling, grinding, and center grinding.
To comprehensively assess the outcomes of the regeneration of laser cladding process, surface scans were performed prior to laser cladding, after deposition of the additional material layers, and following the final machining operations. Ultimately, the study presents an assessment of the feasibility of fully remanufacturing an example tooling component using laser cladding combined with selected finishing techniques.

Keywords: laser cladding, additive remanufacturing, tooling, aerospace industry

SPONSORS

CERTECH Gold Sponsor	CERTECH Sp. z o.o. Wilamowice, Poland www.certech.pl
3DCenter Spes 3D Print your own way Gold Sponsor	3D Center Sp. z o. o. Spes3D Sp. z o. o. Wrocław, Poland 3dcenterpolska.pl spes3d.pl
MEDICOAT Bronze Sponsor	Medicoat AG Mägenwil, Switzerland medicoat.com