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

Mar 2025| Vol. 5| Issue 1

SPRAYTODAY®

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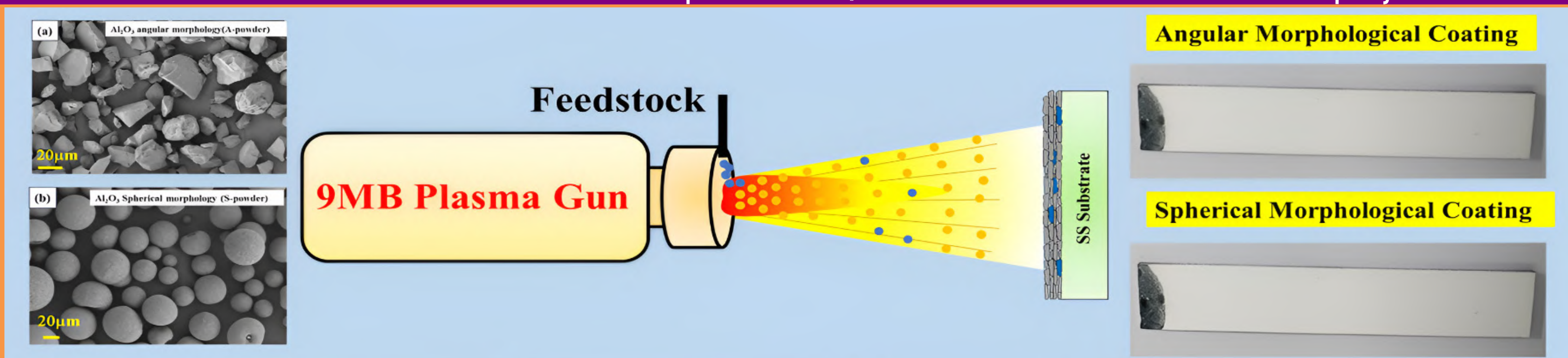

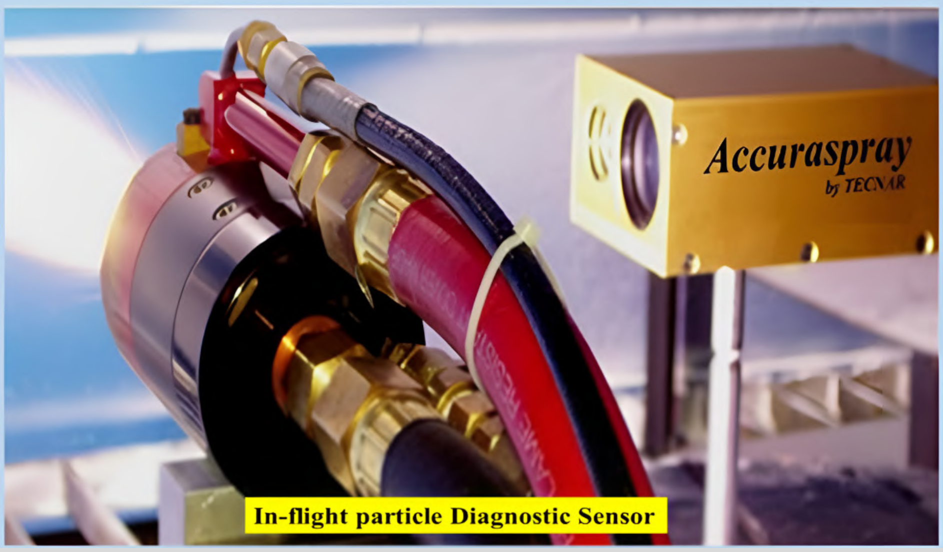

by Chintham Satish,
Anup Kumar Keshri, IIT Patna

Issue Highlights

Featured Articles from NTSC2025 India

- Role of Powder Morphology on α-Phase Content in Plasma Sprayed Alumina Coatings
- Thermo-Mechanical Characterization of Plasma Sprayed YSZ-CeO2 Nano Composite Coatings
- Effect of in-flight particle temperature on the tribological performance of HVOF sprayed WC-12Co coatings.
- Insights of the 2nd National Thermal Spray Conference & Expo 2025 and Pre-Conference course

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with inbuilt heater

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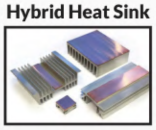
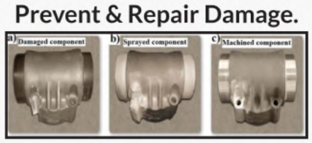


Engine Crank Case

Prevent & Repair Damage.



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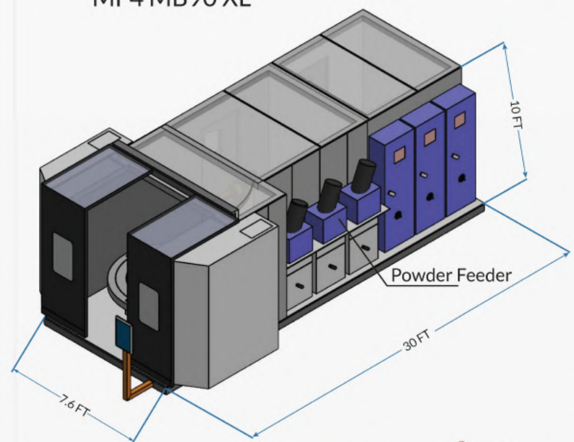
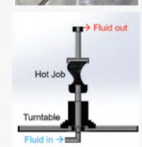
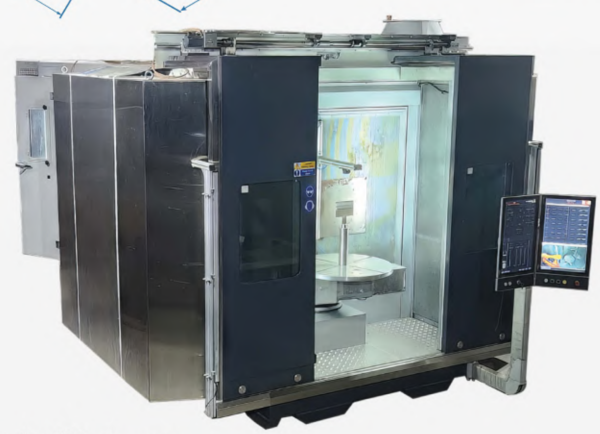
Cascaded Gun

MF4 MB90 XL







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Mission: Our mission is to deliver the most recent thermal spray industry news and keep up to date to the thermal spray community by providing company, event, people, product, research, and membership news of interest to industrial leaders, engineers, researchers, scholars, policymakers, and the public thermal spray community.

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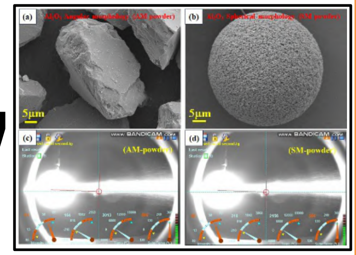

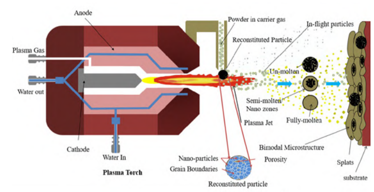

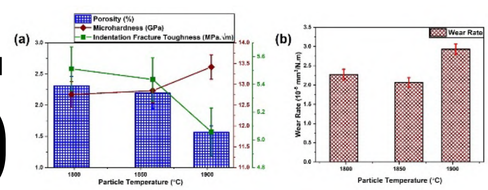

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ABOUT THE COVER

Schematic illustration experimentation procedure

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Editor’s Note

Dear Readers,

Welcome to the latest edition of SPRAYTODAY Magazine, your premier source for all things related to thermal spray technology. We are excited to bring you this special issue, which not only reflects on the latest advancements and trends in the thermal spray field but also provides a glimpse into one of the most significant events on the thermal spray calendar: the 2nd Indian Thermal Spray Conference and Expo (NTSC 2025), held on February 21-22, 2025, at the CSIR-Institute of Minerals & Materials Technology (IMMT) in Bhubaneswar, this conference served as a hub of innovation and collaboration. More than 350+delegates, including leading experts, researchers, and industry professionals from around the globe, attended NTSC2025 to discuss cutting-edge developments, share insights, and explore the future of thermal spray technology in the country. With a robust lineup of plenary & keynote speeches, technical sessions, and an expansive expo were showcasing the latest equipment, materials and recent developments. The conference significantly contributed to learn latest advancements and understanding the new applications of thermal spray technology. In this issue, we are also delighted to feature the outstanding research articles that received Best Paper Awards at NTSC 2025. These award-winning papers represent some of the most innovative and impactful contributions to the field of thermal spray technology, showcasing advancements in materials, processes, and applications. Selected by a panel of esteemed experts, these studies highlight groundbreaking research, novel methodologies, and practical solutions that have the potential to shape the future of the industry. We hope that these insights will inspire further innovation and collaboration within the thermal spray community.

I am particularly pleased to be allowed to recommend to you the latest issue of SPRAYTODAY. This issue includes invited innovative featured articles from NTSC2025 on “Morphology on α-Phase Content in Plasma Sprayed Alumina Coatings, Thermo-Mechanical characterization of plasma Sprayed YSZ-CeO2 Nano Composite Coatings and Effect of in-flight particle temperature on the tribological performance of HVOF sprayed WC-12Co coatings, that illustrate current research trends in thermal spray development.

As we navigate the pages of this magazine, let's collectively embrace the spirit of innovation and collaboration. The thermal spray community in India is not just witnessing change; it is driving it. We hope this edition sparks inspiration, fosters knowledge exchange, and fuels the passion for pushing the boundaries of thermal spray technology.

Thank you for being part of our journey.
Be healthy, active, and curious! Happy Spraying!

Best Regards,

(Satish Tailor | PhD)


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Role of Powder Morphology On α-Phase Content In Plasma Sprayed Alumina Coatings

by ***Chintham Satish, Anup Kumar Keshri***

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Abstract
While extensive research has investigated α-phase retention in plasma-sprayed alumina coatings, the influence of feedstock powder morphology remains insufficiently explored. This study presents a simple yet effective approach to enhance α-phase retention by comparing angular (AM) and spherical (SM) powder morphologies. Using Rietveld refinement, we found that SM coatings retained 82.81% of the α-phase—significantly higher than AM coatings (48.8%). This difference was attributed to reduced melting in SM powder, as confirmed by in-flight particle diagnostics. Consequently, SM coatings exhibited superior mechanical properties (hardness, modulus, toughness) and dielectric strength (37.1 kV/mm vs. 33.4 kV/mm for AM), owing to their higher α-phase content and optimized microstructure. These findings highlight the critical role of powder morphology in tailoring coating properties, offering valuable insights for applications in wear-resistant, thermal barrier, and electrical insulation coatings. The study provides a practical framework for optimizing plasma spray processes by selecting appropriate feedstock characteristics.

Introduction
Plasma-sprayed ceramic coatings are extensively used in industrial applications to protect metal substrates from harsh thermal and environmental conditions. Among these, alumina ($Al2O3$-based coatings are particularly valued for their superior wear resistance, corrosion protection, and mechanical durability, primarily due to the stable corundum α-phase. However, the rapid cooling rates during plasma spraying often lead to the formation of metastable phases (γ, δ, θ, etc.), which compromise mechanical strength, corrosion resistance, and dielectric properties. These undesirable phases can accelerate failure in critical components like bearings and electrical insulation systems. Therefore, maximizing α-phase retention is essential for enhancing the functional properties of alumina coatings. Various strategies have been explored, including process parameter optimization, post-deposition heat treatment, and the addition of secondary oxides like $TiO2$ and $Cr2O3$. However, these approaches have drawbacks optimization is complex, heat treatment can induce residual stresses and cracking, and additives may reduce density and phase stability. An alternative method involves modifying feedstock powder morphology, which influences melting behavior, phase transformation, and coating microstructure.

This study examines the effect of morphology by comparing angular and spherical alumina powders. Plasma-sprayed coatings analysed via Rietveld refinement showed that spherical powders retained a significantly higher α-phase content (82.81%) than angular powders (48.8%), resulting in improved hardness, elastic modulus, fracture toughness, and dielectric strength. These findings demonstrate that feedstock morphology is a crucial factor in enhancing alumina coatings without requiring complex process modifications or additives, offering valuable insights for industrial applications.

Experimentation

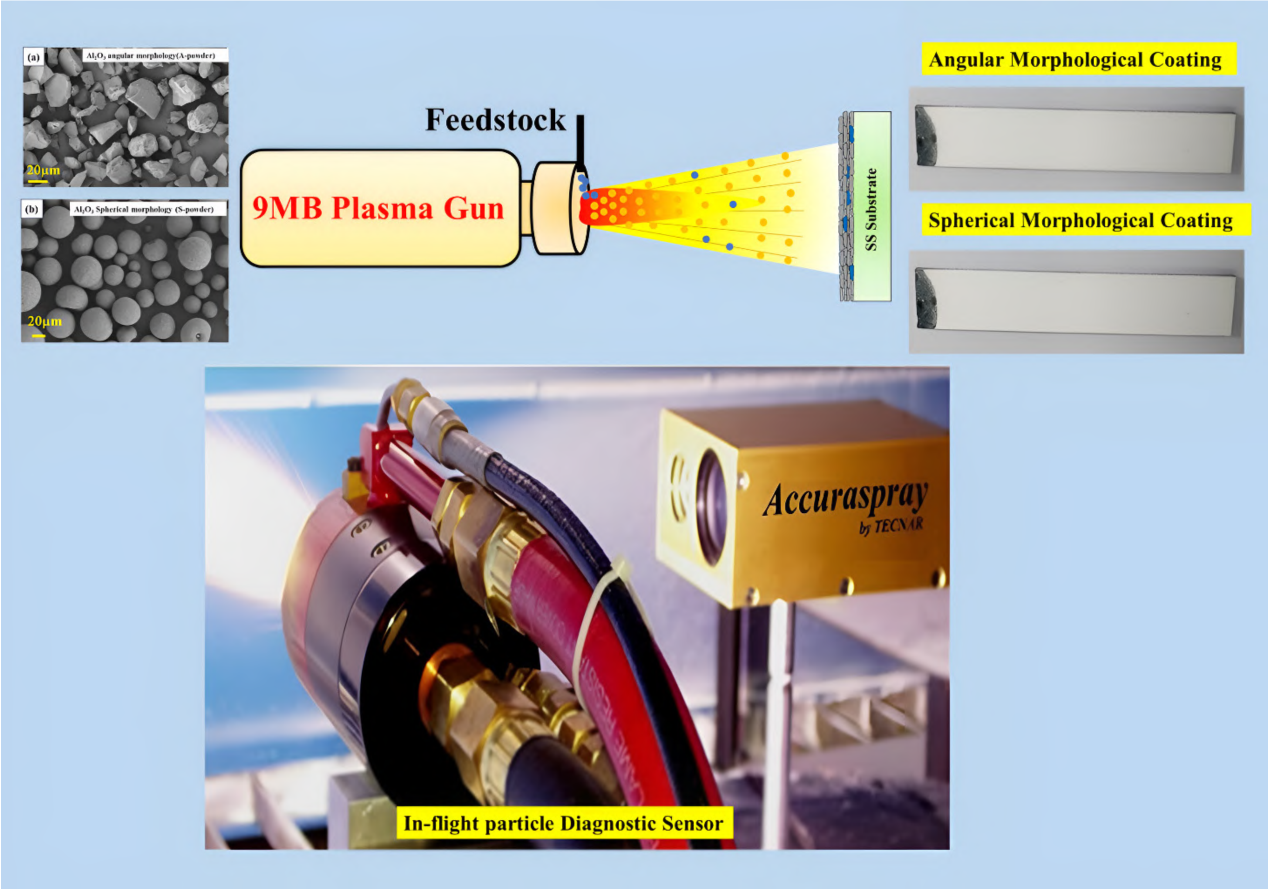

Figure 1: Schematic illustration experimentation procedure

Results and discussion

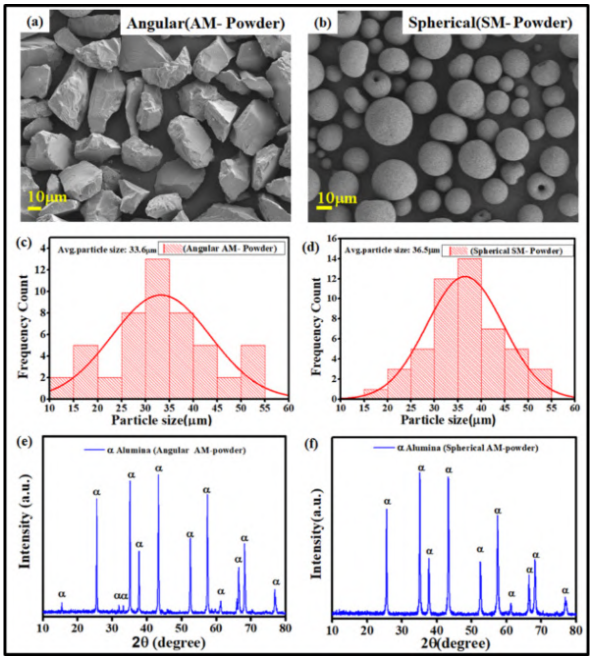

Figure 2: Feedstock morphology and phase analysis

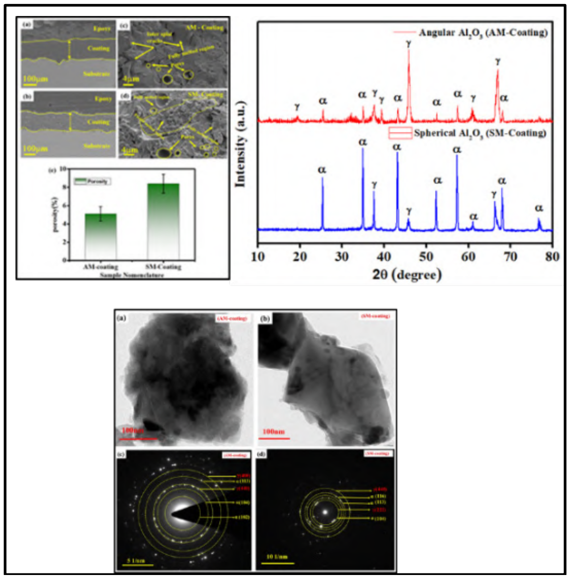

Figure 3: Coatings morphology and phase

Based on the Rietveld refinement analysis, the percentage (%) of retained α-$Al2O3$ phase in AM-coating and SM-coating was evaluated to be 48.88% and 82.81% respectively.

Mechanism

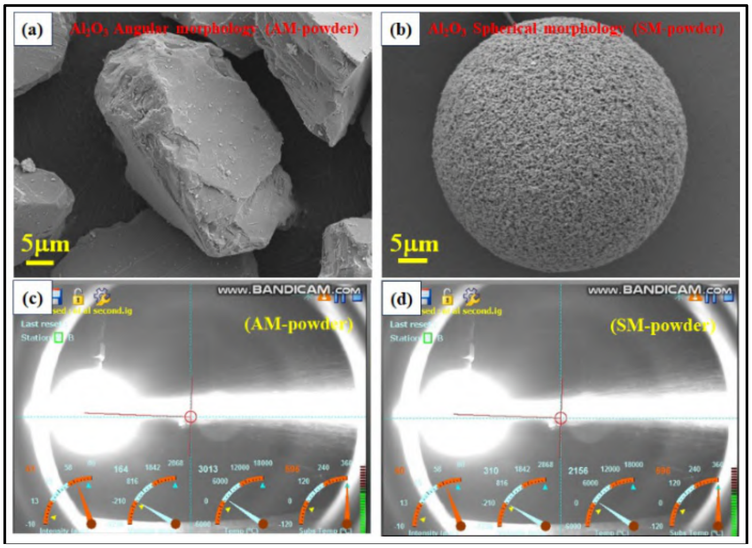

Figure 4: Shows high magnification FE-SEM images of AM and SM powders; (c-d) AccuraspryTM in-flight diagnostic sensor data of AM and SM powders during plasma spray coating

The Rietveld analysis showed α-Al2O3 retention of 48.88% in AM-coating and 82.81% in SM-coating, despite identical spray parameters. This difference stems from powder morphology and melting behavior. Angular AM-powder had poor flowability (17 g/min) and high plasma exposure, reaching 3013°C, leading to full melting and lower α-phase retention. In contrast, spherical SM-powder exhibited better flowability (58 g/min), limiting heat transfer (2156°C) and promoting partial melting, preserving more α-phase. Higher porosity in SM-powder further reduced melting. In-flight diagnostics confirmed these trends, with AM-powder showing higher temperatures but lower velocity than SM-powder, validating the link between powder properties, melting, and phase retention

Mechanical Properties

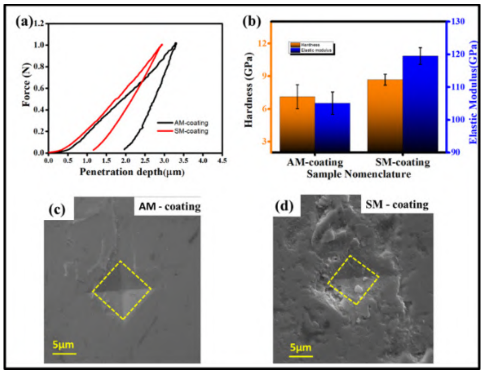

Figure 5: (a) Force and depth penetration curves of the plasma sprayed coatings; (b) and bar diagram of hardness and elastic modulus values of plasmas sprayed coatings; (c-d) Shows the indentation FE-SEM images of AM and SM-coatings

Table 1: Mechanical Properties

Coating	Hardness GPa	Elastic modulus GPa	Fracture toughness MPa.m1/2
AM-coating	7.2±0.9	105±2.4	1.7±0.15
SM-coating	8.68±0.54	119±2.56	2.1±0.31

Dielectric properties

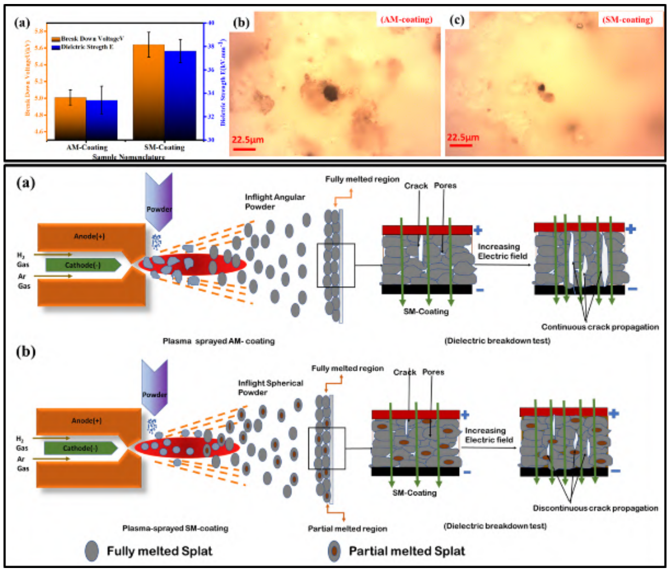

Figure 6: dielectric test alumina coatings

Mechanical properties like hardness and elastic modulus—measured at 1N load—show significant variation between AM and SM coatings. The SM-coating demonstrated superior hardness (8.68±0.54 GPa) and

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elastic modulus (119±2.56 GPa), surpassing the AM-coating by 21.9% and 13.7%, respectively. This enhancement is attributed to its higher α-Al2O3 retention and partially melted (PM) regions, which hinder crack propagation despite greater porosity. During dielectric breakdown testing, the AM-coating's fully melted (FM) structure facilitated continuous crack propagation under electrical stress, lowering its breakdown strength. In contrast, the SM-coating's bimodal (FM+PM) microstructure produced discontinuous cracks, requiring higher localized heat for failure, thereby improving dielectric performance. These findings highlight how microstructure influences both mechanical and dielectric properties, offering critical insights for optimizing coatings in insulation systems and electronic applications. The study underscores the importance of phase composition and melting behavior in tailoring coating performance.

Conclusions

Deposition & Phase Retention: Different morphologies (angular/spherical) of α-Al2O3 powders were plasma-sprayed, retaining 48.8% (AM) and 82.81% (SM) α-phase. Melting Behavior: Higher melting (3013°C) in angular powder (AM) reduced α-phase retention vs. spherical powder (SM, 2156°C). Mechanical Properties: SM-coating showed 21.9% higher hardness, 13.7% higher modulus, and 25% greater toughness due to α-phase retention. Dielectric Strength: SM-coating achieved 37.1±1.2 kV/mm vs. AM's 33.4±1.2 kV/mm, owing to its bimodal microstructure. Key Insight: Powder morphology critically influences melting, phase retention, and coating performance.

References

1. Satish, C., Kumar, K. V., Kiran, P. S., Kumar, S., Indupuri, S., Kumar, R., & Keshri, A. K. (2024). Role of powder morphology on α-phase content in plasma sprayed alumina coatings. Ceramics International, 50(14), 25484-25493.

Thermo-Mechanical characterization of plasma Sprayed YSZ-CeO2 Nano Composite Coatings

by ***Sashikanta Sethi*[1,2], *Sisir Mantry*[1], *Laxmidhar Besra*[1]**

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[2]*Academy of Scientific and Innovative Research (AcSIR) Ghaziabad Uttar Pradesh, 201002, India.*
Email: sashikanta.immt22a@acsir.res.in

Abstract
YSZ-CeO2 nanocomposite coatings were developed using atmospheric plasma spraying with optimized process parameters. The molten state of nano-agglomerates was monitored via particle diagnostics to retain the nanostructure. FESEM revealed a bimodal microstructure with nano-zones in a fully molten matrix. CeO2 addition reduced thermal conductivity by enhancing phonon scattering and inter-splat porosity. XRD confirmed tetragonal zirconia, with an average grain size of 90-120 nm. The coatings exhibited improved thermo-mechanical properties due to higher interfacial toughness, adherent nano-zones, and a compact structure. The study focused on microstructure, thermal diffusivity, and adhesion strength, ensuring enhanced performance over bulk YSZ coatings.

Introduction
Thermal barrier coatings (TBC) can be used to realize increased operating temperatures and improved performance of gas turbines or diesel engines [1-3]. Hot section components have been coated with plasma-sprayed thermal barrier coatings based on yttrium-stabilized zirconia (YSZ). Zirconium-based ceramics are regarded as the most suitable materials for thermal barrier and wear resistance applications due to their low density, high hardness, and low thermal conductivity. YSZ is considered the current industrial standard material for TBCs, given its low thermal conductivity, phase stability at relatively high temperatures, relatively high coefficient of thermal expansion (CTE), and chemical inertness in combustion atmospheres compared to other ceramics [4-6]. A major disadvantage of YSZ is that the limited operation temperature for long-term application (<1200°C). At higher temperatures, phase transformations occur, changing it from t'-tetragonal to tetragonal and cubic (t+c), and then to monoclinic (m), resulting in the formation of cracks in the coating. The corrosion resistance, fracture toughness, and thermal insulation of the coating could be improved by the addition of CeO2 to YSZ [6].

Outstanding mechanical properties, such as exceptional hardness, yield strength, and wear resistance, have been exhibited by bulk nanostructured material (with a grain size of < 100 nm) [7]. Outstanding properties are also exhibited by thermal spray coatings obtained from nano-structured powders. Careful adjustment of spray conditions is required to minimize the coarsening or alteration of the nanograins and to control the chemical reactions and phase stability of materials. It has been reported that lower thermal conductivity, lower Young's modulus, higher CTE, and higher toughness are shown by nanostructured zirconia coatings compared to the microstructured conventional ones [8, 9]. For applications with more severe environments, such as higher temperatures, strains, and corrosion, the doping of La2O3 and CeO2 into YSZ coatings has resulted in a reduction in thermal conductivity and an increase in resistance to sintering [10, 11] and doping of YSZ with multiple dopants has also been reported [12]. Composite coatings of Y2O3-ZrO2-CeO2 are commonly found to be attractive due to their high-temperature stability, high fracture toughness, better corrosion resistance, and thermal insulation. In this context, the scope of the present work is to describe the combined effect of nanostructure and the addition of CeO2 on the microstructure and thermo-mechanical properties of plasma-sprayed YSZ coatings.

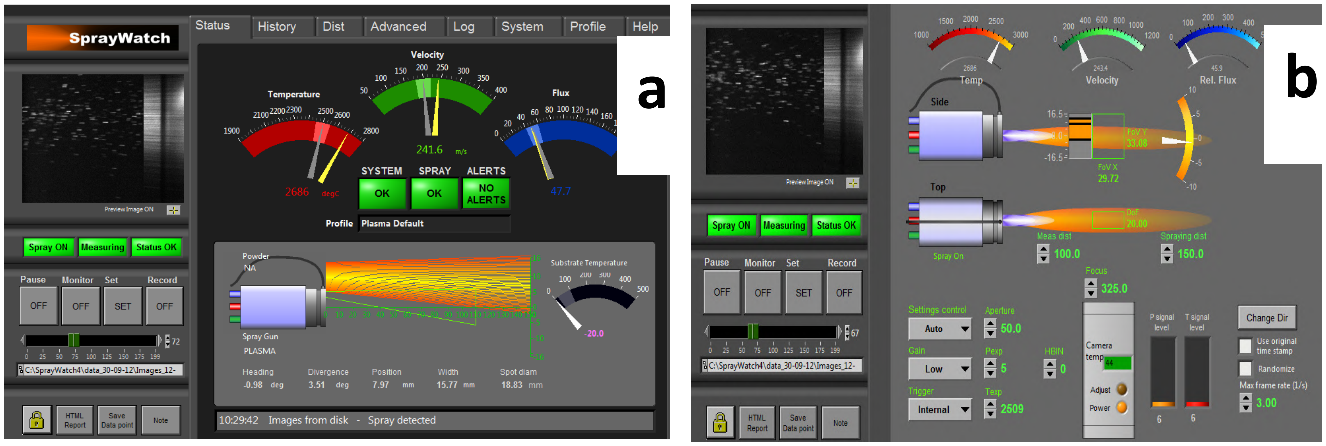

Figure 1: Particle velocity and temperature profile by CCD Camera

Experimental

Nanostructured YSZ powders were synthesized using the sol-gel method, wherein zirconium oxychloride and yttrium oxide were dissolved in a water-based solution with excess nitric acid. The solution was stirred at 100-120°C until it formed a translucent gel, which was further heated at 200-250°C, leading to combustion. The resulting black ash was treated at 350°C for 1 hour and calcined at 600°C for 2 hours to remove volatile residues and carbon. Commercial nano CeO_2 (10-30 nm) was procured from Sky Spring Nanomaterials, USA.

For plasma spraying, nano 10CeYSZ powder (90 wt.% YSZ + 10 wt.% CeO_2) was agglomerated to 30-90 µm using a Buchi B-290 spray dryer. The spray-drying suspension contained CeO_2, YSZ, 2 wt.% PEG, and 1 wt.% ammonium citrate, ball-milled for 24 hours, followed by magnetic stirring and heating to 300 K. The slurry was spray-dried, yielding spherical agglomerates (~50 µm).

Inconel 718 substrates (120×60×5 mm³) were grit-blasted to a roughness of 6-8 µm before plasma spraying. A NiCrCoAlY bond coat (~100 µm) was applied via HVOF using M/s MEC, Jodhpur's Hipojet 2700 system. The top coat was deposited at CSIR-IMMT, Bhubaneswar, using an 80-kW plasma spray system from M/s Metallization, UK. Process parameters for both coatings were optimized.

Characterization included XRD (Rigaku Ultima IV) for phase analysis and FESEM (Zeiss SupraTM55) for microstructural evaluation. Thermal diffusivity was measured using the laser flash technique (LFA 1000, LINSEIS), and thermal conductivity was derived using standard equations. Adhesion strength was evaluated via ASTM C633 pull-out tests.

The coating properties are influenced by lamellae characteristics, which depend on in-flight particle properties and substrate temperature. Online diagnostics (Fig. 1) using Spray Watch 2i measured particle velocity and temperature at standoff distances of 150 and 200 mm. The recorded particle temperature was 2650 ± 50°C, with a velocity of 200 ± 50 m/s.

Results and discussion

The XRD patterns of bulk YSZ, nanocrystalline YSZ, and CeYSZ nanocomposite coatings are presented in Figure 2. The structural changes in nanocrystalline YSZ and CeYSZ nanocomposite coatings are compared with commercial bulk polycrystalline YSZ, which serves as a reference standard. The nanostructured coating, derived from reconstituted YSZ synthesized through chemical techniques, exhibits a cubic zirconia structure, with minimal impurity phases of Y_2O_3. Notably, the intensified (111) peak shifts toward lower 2θ angles due to strain development in the nanostructured coating. The XRD analysis of nanocrystalline CeYSZ composite powder reveals prominent peaks corresponding to tetragonal YSZ and cubic CeO_2 phases. Upon coating application, the XRD pattern confirms the presence of tetragonal zirconia phases, aligning with JCPDS File No. 30-1468, and no distinct Y_2O_3 peaks are detected. Furthermore, the absence of a monoclinic phase in the nanocomposite coating and the lack of observable CeO_2 peaks confirm that CeO_2 remains in solid solution with ZrO_2 rather than forming separate clusters.

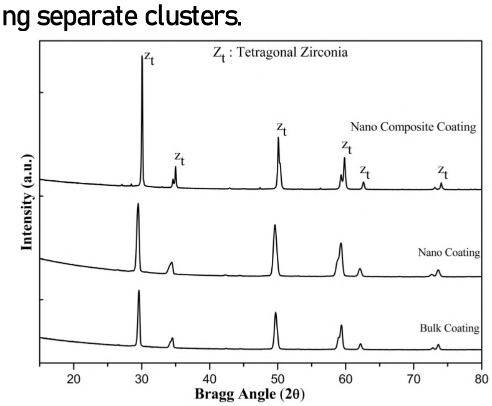

Figure 2: XRD patterns of bulk, nanostructured, and CeYSZ coatings

Field emission scanning electron microscopy (FESEM) images in Figure 3 illustrate the microstructure of YSZ-CeO_2 nanocomposite coatings. Figure 3 presents a fractured cross-section, revealing a bimodal microstructure comprising dense, smooth zones representing well-molten particles and rough, porous zones indicative of unmolten or semi-molten states. Nano-zones and micro-cracks contribute to phonon scattering, thereby reducing thermal diffusivity. High-resolution FESEM images depict densely packed nanograins, with an average grain size of approximately 90–120 nm. The microstructure exhibits closely packed grains with well-defined grain boundaries and an absence of voids or porosity, as seen in Figure 3. Energy dispersive X-ray spectroscopy (EDXS) in Figure 3 confirms the presence of Ce as a dopant, which plays a crucial role in reducing the thermal conductivity of the coating.

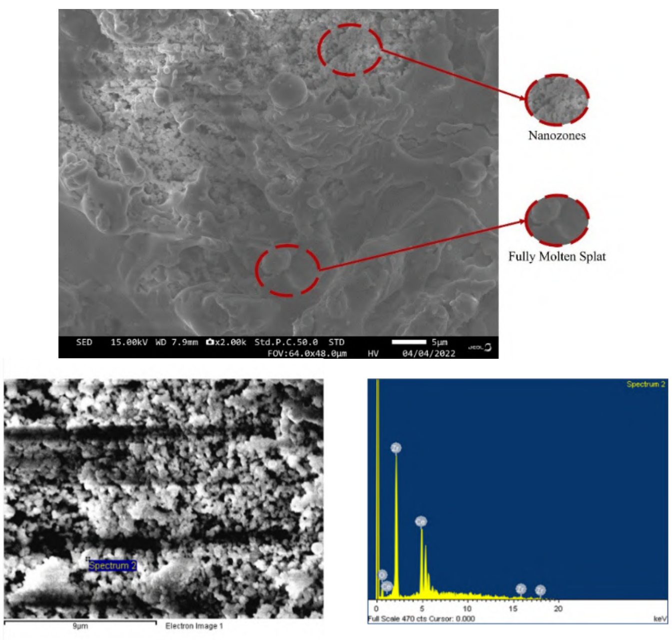

Figure 3: FESEM and EDX analysis of YSZ-CeO_2 coatings

Adhesion test results for atmospheric plasma-sprayed (APS) nano YSZ coatings, analyzed using Taguchi's L16 orthogonal design, indicate a maximum adhesion strength of 40.56 MPa [13]. A similar procedure was followed for CeYSZ nanocomposite coatings using optimized process parameters. The adhesion strength, measured at different input power levels, showed a slight improvement compared to nano YSZ coatings, as illustrated in Figure 4. The enhancement is attributed to the compact and uniform microstructure of the as-sprayed coatings and the formation of Ce-diffusion layers within the splats, which strengthen inter-splat adhesion. Previous studies by Mantry et al. on alumina doped with copper slag reported similar observations [14]. The maximum adhesion strength for nano CeYSZ coatings was recorded at 42.39 MPa at 40 kW torch input power.

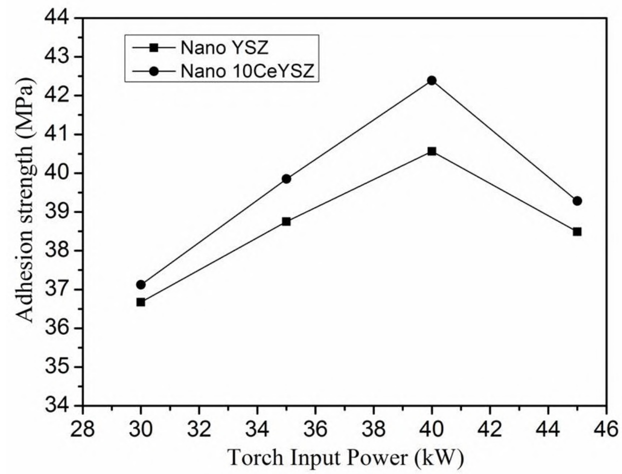

Figure 4: Adhesion strength vs. power in YSZ-CeYSZ coatings

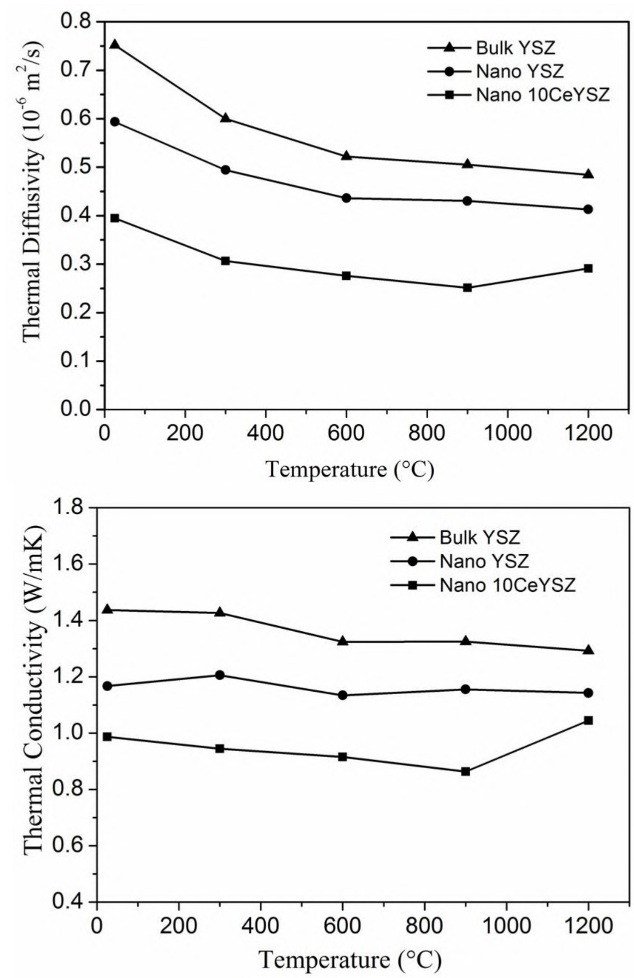

Figure 5: Thermal diffusivity & conductivity vs. temperature for YSZ, nano YSZ, and CeYSZ

The variation in thermal diffusivity for bulk YSZ, nano YSZ, and 10CeYSZ coatings from room temperature to 1200°C is depicted in Figure 5. CeO_2-YSZ nanocomposite coatings exhibit lower thermal diffusivity than both nano YSZ and bulk YSZ coatings on Inconel 718 substrates. At room temperature, the thermal diffusivity was measured at 0.3950 × 10^{-6} m²/sec, decreasing to 0.2512 × 10^{-6} m²/sec at 900°C before gradually increasing to 0.2913 × 10^{-6} m²/sec at 1200°C. This increase at elevated temperatures is attributed to radiative heat transfer through the material [6]. A similar trend is observed in the thermal conductivity measurements shown in Figure 5.

The reduction in thermal diffusivity in nanostructured thermal barrier coatings (TBCs) is primarily due to decreased grain size, which increases grain boundary scattering and shortens the phonon-free path [15]. Below 1200°C, heat conduction in zirconia is dominated by phonon transport, where phonons scatter upon interacting with lattice imperfections such as vacancies, grain boundaries, atomic mass variations, and strain. Additionally, the lower thermal conductivity of nano-coatings is associated with a higher number of intersplat gaps and increased microporosity compared to conventional coatings.

The larger atomic mass and ionic radius differences between the dopant (Ce) and host atom (Zr) enhance phonon scattering due to point defect interactions, further reducing thermal conductivity and improving the effectiveness of the TBC [16]. Doping-induced lattice strain also leads to distortions, causing atomic vibrational waves to scatter at YSZ and rare-earth oxide (dopant) interfaces, thereby limiting the phonon mean free path. A similar phenomenon has been reported in plasma-sprayed nanostructured YSZ coatings doped with La_2O_3 [17].

Conclusions

Atmospheric plasma-sprayed nanostructured 10CeYSZ coatings on Inconel 718 exhibit molten particles, nano-zones, micro-cracks, and high intersplat porosity. The lower thermal diffusivity compared to nano and bulk YSZ is due to phonon scattering at grain boundaries, point defect scattering, and increased porosity. XRD analysis confirms the cubic phase transformation of YSZ, with Ce stabilizing ZrO_2 in solid solution without clustering. FESEM micrographs reveal densely packed grains (~90-120 nm) with distinct boundaries interconnected by tetragonal junctions. Enhanced adhesion strength is attributed to the compact structure, embedded nano zones, and Ce-diffusion layers. The retention of nanostructure is ensured by optimizing process parameters and monitoring the molten state of nano-agglomerates using particle diagnostic tools.

Acknowledgment

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Effect of In-Flight Particle Temperature on Tribological Performance of HVOF Sprayed WC-12Co Coatings

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Abstract

The WC-12Co powders were deposited at different temperatures (~1800°C, 1850°C, and 1900°C) keeping the velocity nearly constant (~600 m.s-1). The X-ray diffraction patterns indicated the presence of W2C, W, and Co3W9C4 apart from the WC phase. An increase in particle temperature resulted in denser microstructure with less porosity and higher microhardness. However, the indentation fracture-toughness deteriorated with increased particle temperature. The fall in fracture toughness with temperature was attributed to the rapid dissolution of carbide grains in a molten binder at elevated temperatures. During the tribological tests, the coating deposited at the intermediate temperatures (~1850°C) suffered minimum wear loss whereas the coating deposited at the highest temperatures (~1900°C) suffered maximum wear loss. The wear resistance of the as-sprayed coatings was determined by a combination of microhardness and indentation fracture toughness.

Introduction

The thermally-sprayed WC-Co coatings are extensively used for their wear resistance application. The industrial applications range from low-pressure compressor discs of aero-engines, hydraulic turbine blades, and high-pressure valves in the oil and gas industry to rollers in the steel industry. The carbide provides the hardness while the toughness comes from the binder matrix [1].

The high-velocity oxy-fuel spray (HVOF) process involves several independent variables or spray parameters, namely oxygen pressure, oxygen flow rate, fuel flow rate, stand-off distance, powder feed rate, etc. Any combination of these parameters produces two measurable outputs namely, particle temperature and velocity. These two further dictate the in-flight reactions or phase composition and defects mainly the porosity present in the coatings. The phase composition and porosity ultimately manifest their effects on the mechanical properties and performance of the coatings [2], [3].

Hence, to reduce the number of independent variables in this current work the HVOF-sprayed WC-12Co coatings were deposited at three different particle temperatures at a nearly constant velocity. Thereafter, the effect of particle temperature on properties and tribological performance was evaluated.

Experimental

The WC-12Co powders (particle size: 25.8±5 µm) were deposited on Inconel 718 substrates. The spray parameters are presented in Table 1. The particle temperature and velocity were monitored using AccuraSpray 4.0 (Tecnar Automation Ltd., Montreal, Canada).

Table 1: Spray Parameters

Spray gun: MJP 5000
Stand-off distance (mm): 350 & powder feed rate (g.min-1): 30

Coatings	Oxygen flow rate (SLPM)	Fuel flow rate (l/min)	Particle Temperature (°C)	Particle Velocity (m.s-1)
S1	700	430	1798±5	598±9.9
S2	750	455	1859±15.4	609±9.3
S3	700	465	1903±15.7	603±9.8

The phase compositions of the costings were examined using a high-resolution X-ray diffractometer (PANalytical, Empyrean, DY1705, Netherlands). The pore fraction was estimated from the SEM (SE) micrographs using the ImageJ software (NIH, Bethesda, USA) software. The microhardness was measured using a Vicker's microhardness tester (Leco LM 700) at 300g load and 15s of dwell time. The indentation fracture-toughness (IFT) was estimated using Vickers micro indentation at a 2 kg load for 15 seconds of holding time. Thereafter the crack lengths and indentation diagonals were measured using an optical microscope (Zeiss Vert. A1, Gottingen, Germany). The IFT was estimated using the following relationship [4], [5]:

$$IFT = \frac{0.113\, HD^{1/2}}{\left(1+{C_L}/{2D}\right)^{3/2}} \qquad (1)$$

Where H denotes the Vickers hardness (GPa), D is the Vickers indentation diagonal in (µm), and CL stands for total crack length coming from all corners of Vickers indentation (µm).

The tribological performance was evaluated using a Pin-on-disk test carried out in a tribometer (Ducom, TR-20 M24). The tests were performed at 50 N normal load, 0.5 m.s-1 sliding velocity and 2500 m sliding distance. A 6 mm diameter WC ball was used as a counter body.

Results and discussion

The X-ray diffraction pattern of the as-sprayed coatings presented in Fig 1 revealed the presence of W2C, W and Co3W9C4 phases in the as-sprayed coatings. The decarburization WC resulted in the formation of W2C and, W phases while the dissolution of carbide in the binder resulted in the formation of the Co3W9C4 phase. The XRD patterns of as-sprayed coatings did not show any traces of crystalline cobalt owing to amorphization of the binder phase [2].

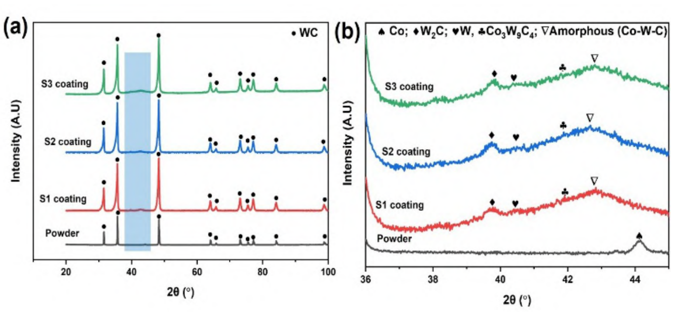

Figure 1: XRD pattern of the powder and as-sprayed coatings in (a) 20°-100°, and (b) 36°-45° range

The porosity, microhardness and, indentation fracture toughness of the as-sprayed coatings are presented in Fig 2a. An increase in the particle temperature resulted in dense and harder coatings while the fracture toughness was compromised owing to the formation of brittle phases like (W2C and Co3W9C4). The specific wear rate of the coatings is presented in Fig 2b. An increase in particle temperature from 1800° C to 1850° C improved the wear resistance of the as-sprayed coatings. However, at 1900° C the sudden drop in indentation fracture toughness caused severe wear despite having the highest microhardness.

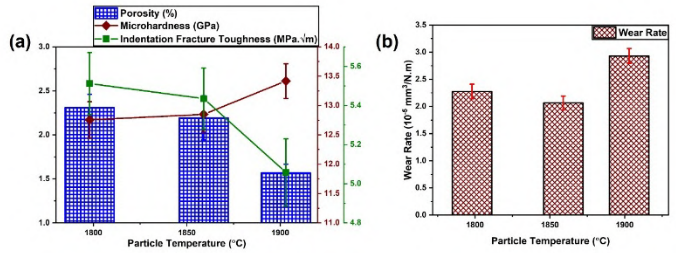

Figure 2: (a) The porosity, microhardness and indentation fracture toughness, and (b) the tribological performance of the as-sprayed coatings

Conclusions

1. The coatings comprised WC, W2C, W, Co3W9C4 and amorphous (Co-W-C) phase.
2. An increase in particle temperature reduced the porosity fraction and improved the microhardness. At the same time fracture toughness was reduced.
3. The coatings deposited at 1900° C suffered the highest wear loss owing to its high brittleness.

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Insights on NTSC·2025: Advancing Thermal Spray Innovations for a Sustainable Future

"NTSC2025: A Grand Celebration of Innovation and Collaboration in Thermal Spray Technology"

The 2nd National Thermal Spray Conference & EXPO (NTSC 2025) was nothing short of a spectacular success! Hosted by Indian Thermal Spray Association (iTSA) and CSIR – Institute of Minerals and Materials Technology (IMMT), this prestigious event brought together some of the brightest minds in thermal spray coatings and surface engineering from 21st - 23rd Feb at CSIR-IMMT, Bhubaneswar. Over the course of three days, scientists, researchers, industry professionals, policymakers, and students engaged in thought-provoking discussions, cutting-edge exhibitions, inspiring keynote sessions, and impactful networking opportunities. The conference was preceded by a highly engaging Pre-Conference Course, setting the stage for what would become an unforgettable experience.

Messages of Appreciation and Greetings:
NTSC 2025 received prestigious messages of appreciation and greetings from The Hon'ble President of India, Smt. Droupadi Murmu, The Governor of Odisha, Shri Kamapathi Babu, The Minister of Food Supply & Consumer Welfare, Shri Krushna Chandra Patra, and The Minister of State for Industry (In-Charge), Shri Sampad Charan Swain, all recognizing the conference's role in advancing thermal spray technology and material science. Dr. (Mrs.) N. Kalaselvi, Director General of CSIR, Dr. Ramanuj Narayan, Director of iTSA and CSIR-IMMT, Prof. Harpreet Singh, President of iTSA, Dr. Sisir Mantry, Convenor of NTSC 2025, and Dr. Satish Tailor, Secretary of NTSC 2025 also conveyed their appreciation and support for the event. These messages reinforced India's growing leadership in surface engineering and advanced coatings research, setting the stage for discussions on new technological advancements and industrial applications.

Pre-Conference Course: Laying the Foundation for Innovation:
Before the main conference began, NTSC 2025 kicked off with a highly interactive Pre-Conference Course, inaugurated by Dr. Sisir Mantry, Convenor of NTSC 2025. This specialized session provided attendees with fundamental and advanced knowledge in thermal spray coatings. Led by renowned experts Prof. Shrikant Joshi (University West, Sweden) and Dr. Nicholas Curry (METTECH Corp.), the course covered critical aspects such as:

- Fundamentals of Coating Formation and material deposition techniques.
- Axial Plasma Spray Systems and their evolution in industrial applications.
- Fine Powder Spraying Techniques and advancements in suspension thermal spray coatings.
- Economic and Industrial Aspects of Thermal Spraying, with insights into cost benefit analysis.

Participants engaged in interactive hands-on sessions and Q&A discussions, making the pre-conference course an enriching learning experience that set a strong foundation for the main event.

A Grand Opening with Distinguished Guests:
The inauguration ceremony was graced by His Excellency Dr. Kambhampati Hari Babu (Hon'ble Governor of Odisha), Shri Krushna Chandra Patra (Hon'ble Cabinet Minister of Science & Technology, Govt. of Odisha), and Shri Sampad Chandra Swain (Hon'ble Minister of Industries, Govt. of Odisha). Also in attendance were Prof. T.N. Singh (Director, IIT Patna) and Dr. Ramanuj Narayan (Director, iTSA and CSIR-IMMT), who emphasized the role of thermal spray coatings in driving industrial innovation and economic growth. Their speeches resonated deeply with the audience, reaffirming India's commitment to research and technological advancement.

Powerful Plenary Talks and Keynote Sessions:
The conference was enriched by world-renowned experts delivering plenary talks, covering the latest advancements and applications in thermal spray technology. Global pioneers like Prof. Christopher Berndt, Prof. Shrikant Joshi, Prof. Tanvir Hussain, Prof. Ladislav Celko, Prof. Yuichi Otsuka, and Mr. Komal Laul shared

their expertise, providing deep insights into emerging trends and future possibilities. Keynote sessions by Dr. Ashutosh Suresh Gandhi, Dr. Kantesh Balani, Dr. Harpreet Singh G, Dr. Sivakumar, Dr. Ing-Karl Konstantin von Niessen, Jean Nicholas Robert, Dr. Jyotsna Majumdar, Dr. Srinivasa Rao Bakshi, Dr. Bharat Bhushan Jha, Dr. Serhy Tkachenko, Dr. Anup Kumar Keshri, Dr. Aruna ST, Dr. Stefan Björklund, Prof. Ashish Ganvir, and Dr. Nicholas Curry explored cutting-edge applications of thermal spray coatings in aerospace, defense, healthcare, and manufacturing.

Engaging Discussions and Industry Collaborations:

One of the highlights of NTSC 2025 was the panel discussion on the future of thermal spray coatings, featuring experts like Dr. Dheepa Srinivasan (PhD), Prof. Tanvir Hussain, Sishir Patra, Dr. Nicholas Curry, Dr. R.M. Mohanty, Mr. Ankur Modi, Mr. Nilesh Patil, Mr. Santosh Kumar A.R., and Dr. Soobhankar Pati. These discussions explored critical challenges such as sustainability in coatings, process optimization, and AI-driven advancements in thermal spray technology. The conference also saw the signing of an MoU with IMMT-IIT Patna and IMMT-Metallizing Equipment Co. Pvt. Ltd. (MECPL), Jodhpur, marking a significant step toward strengthening industry-academia collaborations and accelerating technology transfers.

Recognizing Excellence: iTSA Awards & Research Achievements:

NTSC 2025 honored remarkable contributions to the field with the iTSA Awards 2025

1. Thermal Spray Excellence Award – Dr. Aruna S.T. (CSIR-NAL, Bangalore)
2. Emerging Researcher Award in Thermal Spray – Prof. Ayan Bhowmik (IIT Delhi)

Additionally, the Best Oral and Poster Presentation Awards were presented to young researchers for their outstanding contributions:

🎖 Best Oral Presentation Awards – Vinay Polimetla, Moumita Mistri, Manoj Kumar, Sashikanth Sethi, and Subham Sarkar for groundbreaking work in thermal spray coatings and aerospace applications.

🎖 Best Poster Presentation Awards – J. Sharath Kumar, Barsha Priyadarshini, Varun Kumar, Shradha Suman, Chintan Satish, and Anna Zharnikova for exceptional research on nano-structured coatings, corrosion-resistant materials, and advanced thermal barrier coatings.

NTSC 2025 EXPO: A Showcase of Innovation:

The NTSC 2025 EXPO was a hotspot for technological innovation, featuring exhibits from leading companies, research institutions, and universities from India, Europe, and North America. Participants had the opportunity to explore state-of-the-art thermal spray equipment, automation solutions, and advanced coatings materials. Notable exhibitors included GTV Verschleißschutz (Germany), Metallizing Equipment Co. Pvt. Ltd. (India), ARCI (India), and Tecnar (Canada), each showcasing their latest advancements in thermal spray technology. The expo was a meeting point where researchers and industry professionals interacted, sparking ideas for future collaborations and applications in high- performance coatings.

Valedictory Session and Sightseeing in Puri & Konark:

The concluding Valedictory Session of NTSC 2025 was a moment of reflection and celebration, where key takeaways from the conference were shared, and participants expressed their gratitude for the knowledge and collaborations fostered during the event. Dr. Sisir Mantry (Convenor) and Dr. Satish Tailor (iTSA Secretary) delivered heartfelt closing remarks, emphasizing the importance of continued research, innovation, and global partnerships in thermal spray technology.

To provide an immersive cultural experience, a sightseeing tour to Puri and Konark was organized for delegates, allowing them to explore Odisha's rich heritage. Attendees visited the iconic Jagannath Temple in Puri and the UNESCO World Heritage Site, Konark Sun Temple, offering them a perfect blend of knowledge exchange and cultural enrichment.

President iTSA Prof. Harpreet Singh's Address and Closing Remarks:

As the President of iTSA, Prof. Harpreet Singh delivered a heartfelt address during the valedictory session. He emphasized the critical role of thermal spray technology in modern industry and the importance of fostering global collaborations between academia, research institutions, and industries. He acknowledged the groundbreaking research, engaging discussions, and strong partnerships that emerged from NTSC 2025, highlighting the commitment of the Indian scientific community to driving technological advancements. Prof. Harpreet Singh extended his gratitude to all dignitaries, speakers, participants, sponsors, and organizing committee members, appreciating their efforts in making NTSC 2025 a resounding success. He encouraged young researchers to continue pushing the boundaries of innovation and called upon industries to support cutting-edge research in thermal spray coatings. His words left the audience inspired and motivated for the future of surface engineering.

A Lasting Impact and Future Outlook:

As NTSC 2025 ended, it was clear that this event had set a new benchmark for innovation, collaboration, and knowledge-sharing in the field of thermal spray and surface engineering. The conference successfully bridged the gap between academia and industry, fostering collaborations that will shape the future of aerospace, defense, healthcare, and manufacturing sectors.

With the enthusiasm and momentum gained from this year's event, the next edition of NTSC promises to be even bigger and more impactful. As researchers, engineers, and industry leaders look ahead, the discussions from NTSC 2025 will continue to inspire progress in advanced coatings, energy-efficient materials, and cutting-edge manufacturing techniques.

A Heartfelt Thanks to all

The Indian Thermal Spray Association (iTSA) and CSIR-IMMT extend their deepest gratitude to all participants, esteemed speakers, industry leaders, and research scholars who contributed to the grand success of NTSC 2025. Special thanks go to the organizing committee, sponsors, and volunteers for their dedication and hard work in ensuring a seamless and impactful conference.

Until we meet again at the next edition of NTSC, let us continue to innovate, collaborate, and drive the future of thermal spray technology forward!

Happy Spraying!

Best regards,

Prof. Harpreet Singh, President iTSA | IIT Ropar
Dr. Satish Tailor, General Secretary, iTSA | MECPL Jodhpur
Dr. Sisir Mantry, Joint Secretary, iTSA | CSIR-IMMT

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