

Thermal Barrier Coatings deposited by Hybrid Suspension+Solution Precursor Plasma Spray: Gadolinium's Role in CMAS and Thermal Cycling Fatigue Resistance

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Thermal Barrier Coatings are critical for protecting turbines from high temperatures and corrosion by molten silicates. New technologies are required, especially taking into consideration the need for an increase of the working temperature to have efficient engines. This study concentrates on coatings fabricated through an innovative SPS+SPPS technique, utilizing an ethanol-based 8YSZ suspension augmented with variable amounts of gadolinium nitrate. Monolayer and bilayer configurations (with conventional APS YSZ underlayers) are examined to understand their responses to thermal cycling fatigue and corrosion by molten calcium-magnesium-aluminosilicate (CMAS). The findings underscore the potential benefits of adding controlled amounts of gadolinium nitrate to the initial suspension, because a fine-grained gadolinium zirconate layer is obtained, which is able to form protective apatite crystals during CMAS attack. The most promising outcomes were obtained using a bilayer sample with a DVC YSZ bottom layer, whilst a porous APS bottom layer provided better thermal cycling fatigue resistance.

Development of a comprehensive Suspension Plasma Spraying Coating Build-up Numerical Model

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Suspension Plasma Spraying (SPS) has gained a lot of traction, particularly in the aerospace industry, in the past few decades because of its capacity to produce a variety of coating microstructures. These different types of microstructures depend on numerous parameters, some more influential than others. With so many parameters involved, the predictability of resultant microstructures can be challenging and tricky.

Researchers have been trying to understand the individual parameters' impact on the coating microstructures, typically using experimental methods. Experimentation, however, proves to be costly because it requires physical space, relevant infrastructure, skilled operators and so forth. Also, steps like substrate procurement, sample preparation, etc., make it very time-consuming.

Thus, there's an evident need for a computer model that could simulate the SPS process and accurately predict resultant microstructures, taking the parameters involved as input functions. Such a simulation tool could then reduce costs and time for future research.

Effect of Spray Distance on the Microstructure, Phase Transformation, Microhardness, and Thermal Conductivity of $ZrO_2-xYO_{1.5-x}TaO_{2.5}$ (YTZ) Coatings Deposited by Suspension Plasma Spraying (SPS)

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The influence of stand-off distance on the microstructure, phase stability, microhardness, fracture toughness and thermal conductivity of YTZ ceramics with non-transformable tetragonal phase (t') in the $ZrO_2-xYO_{1.5-x}TaO_{2.5}$ system ($x = 15.4$ mol% and 16 mol%) deposited by Suspension Plasma Spraying (SPS) technique as topcoat for thermal barrier applications is evaluated. The mechanical activation of the oxide powders used as feedstock was carried out by high-energy ball milling, and the formation of t' -phase in the coatings was studied by X-ray diffraction (XRD). Scanning electron microscopy (SEM) observation indicates that the microstructure is strongly influenced by the stand-off distance. Additionally, the effects of t' -phase content and tetragonality as a function of yttria and tantalum compositions on the fracture toughness values are discussed. Vickers microhardness (HV) increases with increasing spray distance and powder milling conditions. The values of the thermal conductivity measured by laser flash analysis varied with the spray distance.

Transparent alumina coatings elaboration by the Aerosol Deposition ADM method

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The Aerosol Deposition Method (ADM) is an innovative technique for producing dense ceramic coatings at room temperature. Unlike other methods that require high temperatures or sintering, ADM uses ceramic particles in aerosol form, which are accelerated toward a substrate to form a coating with nanometric structures and strong adhesion. This method enables the deposition of micrometer-thick layers with low energy consumption, making it suitable for various materials and applications, such as in the aerospace and optical industries.

A notable ADM application is the transparent alumina coatings deposition on glass substrates. This process preserves the glass transparency while allowing the formation of dense ceramic layers. The resulting coatings possess optical properties ideal for advanced aeronautical applications, such as optical sensors and protective windows for electronic systems. This work examines the deposition conditions and their impact on transparency, demonstrating the potential of ADM transparent ceramic coatings in optical sensors within aerospace environments.

Oxidation Behaviour an AlCoCr(0.5)Ni High Entropy Alloy, and Performance as a Bond-Coat, during High Temperature Oxidation

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Failure of thermal barrier coatings (TBCs), driven by excessive growth of an oxide layer on the bond-coat surface at high temperatures, limit their service temperature in aerospace applications. Current bond-coat materials, like NiCoCrAlY alloys, have reached their temperature limit. Therefore, new alloy classes able to resist high-temperature oxidation must be identified. The High Entropy Alloy (HEA) is one such class that shows promise as a bond-coat material for TBCs. This study examines the performance of an AlCoCr0.5Ni HEA bond-coat during high-temperature (1100°C) isothermal oxidation, with and without a ceramic (8% YSZ) top-coat, for up to 100 hours. A thermally grown oxide (TGO) layer consisting of alumina and spinel oxides was formed, which suffered no spallation or change in oxide composition during oxidation. Furthermore, no failure of the top-coat/TBC occurred during oxidation. The oxidation and spallation resistance displayed by the HEA highlights its promise as a high-temperature bond-coat material.

Suspension in-flight treatment in Axial Suspension Plasma Spray (ASPS)

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For many years, the aviation industry has employed thermal barrier coatings within the high-temperature components of jet engines, like the combustion chamber. Presently, the primary method for producing these thermal barriers is through the Electron Beam Physical Vapor Deposition (EB-PVD) process. Nevertheless, there has been ongoing research into alternative processes to EB-PVD for the past few years, with a focus on the Suspension Plasma Spray (SPS) process.

In the SPS process, there are two possible approaches to suspension injection: radial and axial. Typically, radial injection is favored due to its adaptability to a wide range of plasma torches. However, in the case of axial injection, specific torch adaptations are required. This is exemplified by the Axial III Plus torch, which employs a configuration of three anode-cathode couples to generate a plasma, with suspension injection occurring at the center of this assembly.

This research study revolves around the assessment and characterization of the axial injection technique using the Axial III Plus torch and explores its impact on the microstructure of thermal barrier coatings. To this end, two diagnostics techniques are used shadowgraphy and PIV ("Particle Image Velocimetry"). This allowed us to characterize the influence of solvent behavior without plasma and to study solvent behavior with plasma by studying the influence of injection.

Thermo-radiatives properties of yttria-stabilized zirconia (YSZ) and yttrium aluminium garnet (YAG)

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The French National Research Agency (ANR) HyMax project aims to develop a hydrogen oxy-combustion chamber. The chamber must allow producing thermal energy without emitting any major greenhouse gases (CO₂, NO_x). The combustion of pure oxygen induces a high temperature ($\approx 2200\text{K}$) and corrosive atmosphere (H₂O vapor). The creation of an environmental and thermal barrier coating (E-TBC) is then mandatory to protect the chamber in the long term. The materials YAG, YSZ, and high-entropy compounds are selected for their good high-temperature stability and corrosion resistance. To optimize this E-TBC, different architectures and microstructures induced by the different shaping methods (reaction-sintering, Spark Plasma Sintering (SPS), Atmospheric Plasma Spraying (APS), etc.) are considered. Thus, the selection of the product (material and architecture) will be determined by their thermo-radiative properties measured at CEMHTI (CNRS).

Application of feature detection algorithms to real-time analysis of feedstock injection during plasma spraying

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Feedstock injection plays an important role in plasma spraying, directly affecting deposition conditions. Poorly handled injection results in a waste of plasma jet energy and decreased deposition efficiency, which affect coating structure.

Typical optimization of feedstock injection includes performing test trials, observation of the in-flight behavior of coating material and metallographical investigations. In this study, real-time particle detection is used to control the injection conditions. Proposed algorithms operate on a signal acquired from SprayCam shadowgraphy system and classify injected particles based on the depth of the plasma jet penetration. This includes real-time analysis of particle position inside the plasma jet and prediction of the landing location. As a result, injection optimization does not depend on operators experience and test trials are reduced. The usefulness of presented algorithm was demonstrated when optimizing deposition efficiency which was measured according to the ISO-17836:2017 standard and correlated with the estimated particle trajectory.