# Influence of BC deposition route on the creep performance of TTBCs for aerospace defense applications

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• **Abstract** – Thick thermal barrier coatings (TTBCs) have been considered for aerospace defense applications operating under extreme thermal conditions due to their thermal insulation benefits. However, greater thickness increases residual stress and damage. In these systems, the bond coat is crucial, as it governs thermally grown oxide (TGO) formation, whose excessive growth may accelerate interfacial stresses during high-temperature exposure. Therefore, the bond coat deposition route directly affects coating porosity and oxygen diffusion pathways, influencing its creep performance. This work evaluates the influence of Atmospheric Plasma Spray (APS) and High Velocity Oxy-Fuel (HVOF) bond coats on the creep behavior of TTBCs applied to Ti-6Al-4V alloy. The HVOF bond coat exhibited an 87.5% lower steady-state creep rate and an approximately 483% longer rupture time than the APS-coated specimen under the investigated conditions. These findings support the relationship between bond coat microstructure and creep resistance in aerospace thermal protection systems.

## I. INTRODUCTION

Thermal barrier coatings (TBCs) are multilayer systems composed of a ceramic top coat (TC), metallic bond coat (BC) and thermally grown oxide (TGO), widely applied in aerospace components under severe thermal exposure [1-3], as illustrated in Figure 1. Recently, thick thermal barrier coatings (TTBCs) have gained attention due to their enhanced thermal insulation capability for high-temperature aerospace defense applications, particularly for turbine blades and other propulsion system components [4-5]. However, increased coating thickness promotes higher residual stress accumulation and damage evolution [1,4,6].

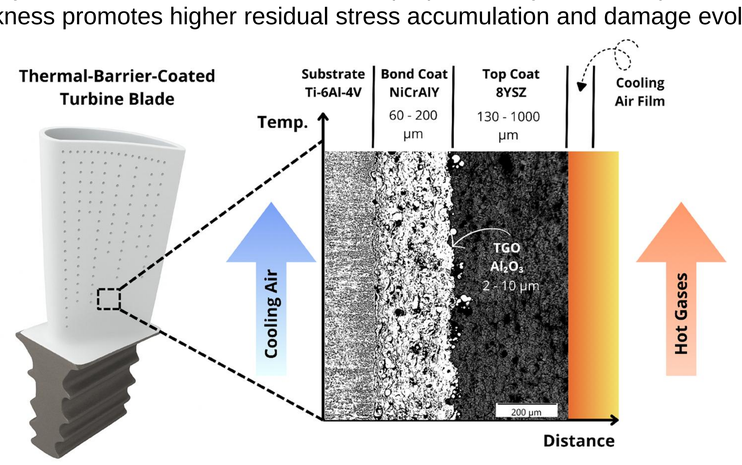



**Fig 1.** Schematic representation of a thermal barrier coating (TBC) system applied to a turbine blade.

In TTBC systems, the bond coat plays a key role in controlling oxygen diffusion pathways and TGO growth, directly affecting creep resistance. APS bond coats generally exhibit higher porosity, whereas HVOF coatings tend to present denser microstructures with reduced oxygen diffusion pathways [3,6]. Therefore, this work investigates the influence of APS and HVOF bond coats on the creep behavior of TTBCs applied to Ti-6Al-4V alloy.

## II. METHODOLOGY

Ti-6Al-4V alloy specimens were machined according to ASTM E139 [7] and coated with TTBC systems composed of a NiCrAlY bond coat (BC) and an 8YSZ top coat (TC). The TC was deposited by APS for all conditions, while the BC was produced using APS and HVOF routes. Both systems presented TC thicknesses above 1 mm, characterizing TTBC configurations. The HVOF coating exhibited BC and TC thicknesses of (128 ± 11) µm and (1117 ± 16) µm, respectively, while the APS coating presented thicknesses of (275 ± 28) µm and (1063 ± 35) µm. Microstructural characterization was performed by optical microscopy and SEM. Constant-load creep tests (n = 1 for each condition) were conducted in air at 500 °C under 125 MPa. Creep parameters and post-creep damage were evaluated by strain-time curves and stereomicroscopy.

## III. PERFORMANCE EVALUATION

Cross-sectional micrographs (Figure 2) revealed significant microstructural differences between the APS and HVOF bond coats. The APS coating exhibited higher porosity and a more heterogeneous interface, whereas the HVOF bond coat presented a denser and more uniform microstructure.

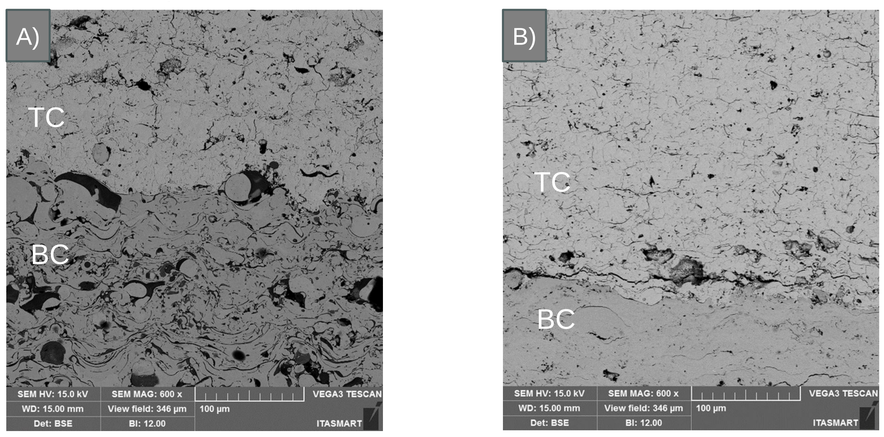



**Fig 2.** Cross-sectional micrographs of thick thermal barrier coatings (TTBCs) deposited on Ti-6Al-4V alloy showing the different bond coat deposition routes: (A) APS bond coat and (B) HVOF bond coat. Detail images highlight the BC/TC interface.

The creep curves (Figure 3) demonstrated a strong influence of the bond coat deposition route on TTBC performance. The HVOF bond coat exhibited a lower steady-state creep rate and longer rupture time than APS coatings (Table 1). Its denser microstructure reduced oxygen diffusion pathways and delayed damage accumulation during creep exposure. Post-creep stereomicroscopy (Figure 4) revealed similar fracture morphology for both systems; however, the HVOF-coated sample exhibited greater reduction in area before rupture, consistent with its longer creep lifetime.

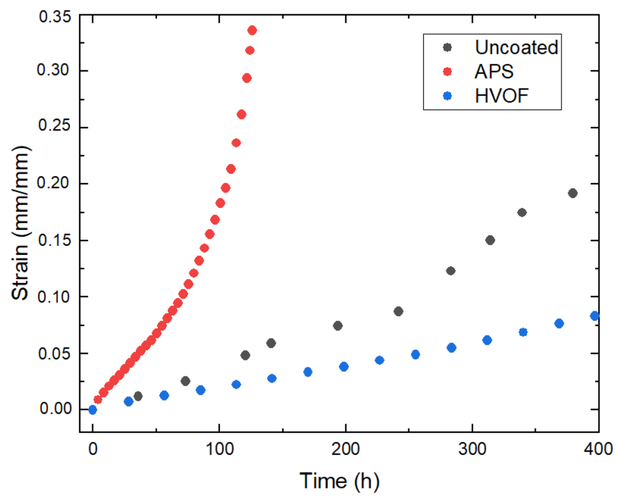



**Fig 3.** Creep strain versus time curves for TTBC systems with APS and HVOF bond coats tested at 500 °C under 125 MPa.

**Table 1.** Creep parameters obtained from constant-load creep tests for the investigated TTBC systems.

| Sample | $t_p$ [h] | $\dot{\varepsilon}_s$ [$h^{-1}$] | $t_r$ [h] | $\varepsilon_f$ [mm/mm] | RA [%] |
|---|---|---|---|---|---|
| Uncoated | 35.84 | 0.0006 | 904.48 | 1.6499 | 84.93 |
| APS | 16.80 | 0.0016 | 126.22 | 0.3359 | 82.67 |
| HVOF | 85.05 | 0.0002 | 737.10 | 0.2800 | 96.70 |

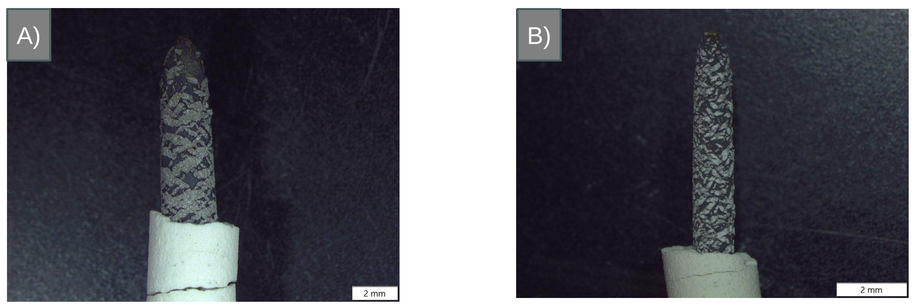



**Fig 4**. Stereomicroscopy images of TTBC systems with (a) APS bond coat and (b) HVOF bond coat after creep rupture.

## IV. CONCLUSION

✓The bond coat deposition route strongly influenced the creep behavior of TTBCs.

✓The denser HVOF bond coat reduced oxygen diffusion pathways, delaying creep damage evolution.

✓The HVOF system exhibited an 87.5% lower steady-state creep rate and an approximately 483% longer rupture time than APS coatings.

✓The improved creep resistance of the HVOF system indicates potential benefits for turbine engine components used in aerospace defense systems.

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