MOLTEN VOLCAN ASH DEPOSITION IN JET ENGINES

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Safe air travel activity requires clean flight corridors. But in earth's atmosphere, volcanic ash is undoubtedly the major source to contaminate airspace by volcanic activity and thus present critical risks to aviation safety. A Jet engine is the central part to dominate the highest level of aviation safety but also the most vulnerable part by volcanic ash. The nature of volcanic ash damage to jet engines is the molten ash deposition on the hot-section airfoils in jet engines. These ash deposits can lead to the premature failure of the components in hot-section airfoils due to heat accumulation and, more importantly, can attack the protective ceramic thermal barrier coatings (TBCs). In a real jet engine, if few of the volcanic ash particles can adhere to the surface of hot-section airfoils and form an initial molten volcanic ash deposition layer, large ash deposition nodules (several cubic centimeters in volume) can quickly build up. Therefore, the formation of initial volcanic ash deposition layer plays a key role to mitigate the its detrimental effects on jet engines. However, constraining the initial formation process of volcanic ash deposition layer in jet engines is currently unknown due to harsh operation condition. Here, we present the formation process of initial volcanic ash deposition layer by applying the atmospheric plasma thermal spray technology to stimulate the 'in-flame generation' volcanic ash particles (from the 2010 eruption of Eyjafjallajökull volcano due to its potential hazard for current aircraft safety) with high-energy (e.g., temperature 1833 ºC ≤ 2828 ºC; velocity 146 m s^{-1} ≤ 325 m s^{-1}; and particles size ≤ 62 μm) to imping onto a solid substrate (Fig.1a). Subsequently, we quantitatively compared adhesive ability (i.e., deposition rate) of volcanic ash particles onto three categories of substrates (including traditional APS YSZ TBC, EB-PVD YSZ TBC and alumina substrate) under its increasing distance (50 ≤ 125 mm) to nozzle. Finally, we analysed the formation mechanism of initial volcanic ash deposition layer. Our results demonstrate substrate characteristics (e.g., roughness, *Ra*) and impact particle properties (represented by Reynold number) directly affect the adhesive ability of volcanic ash particle and subsequent layer formation. The deposition rate of volcanic ash particles decreased exponentially with increasing the distance with nozzle for all of substrates and also linearly decreasing with increasing the substrate surface roughness, *Ra* at each same distance to nozzle (Fig.1b). These observations indicate that volume density of particles and substrate surface roughness dramatically enhance the deposition rate of volcanic ash particles under plasma conditions. In addition, the final morphology of splats deposited by volcanic ash particles onto the different substrates were changed from disk-like to splash-like as decreased in roughness (Fig.1c). Overall, these observations and models offer important insights into the initial formation of molten volcanic ash layer for the tailoring of next-generation APS and EB-PVD TBCs that will be required to resist attack by volcanic ash in future higher-temperature jet engines.

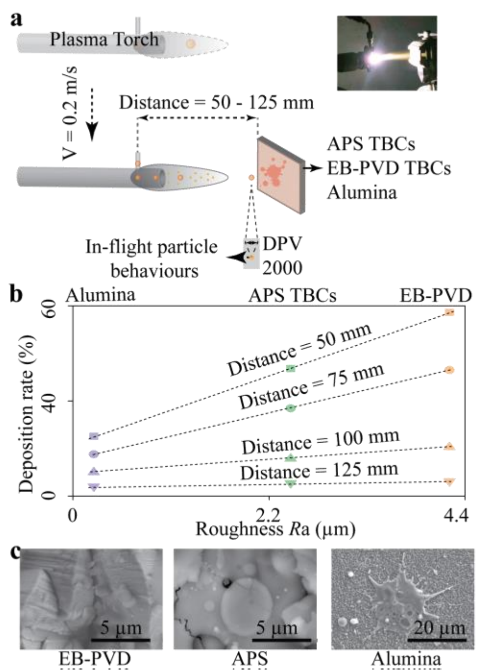

Figure 1. (a) A schematic of the experimental setup for capturing initial formation of molten volcanic ash layer under plasma spray conditions. (b) Roughness-deposition rate relationship for EB-PVD TBCs, APS TBCs and alumina substrate under different distance to nozzle, (c) The morphology of splats onto various substrates.