GRADIENT DAMAGE SPREADING OF MOLTEN VOLCANIC ASH ON THERMAL BARRIER COATINGS

Shanjie Yang, Beihang University, Department of Material Science and Engineering
shanjiey@sina.com
Wenjia Song, Ludwig Maximilian University of Munich, Department of Earth and Environment Science
Siddharth Lokachari, Ludwig Maximilian University of Munich, Department of Earth and Environment Science
Donald Bruce Dingwell, Ludwig Maximilian University of Munich, Department of Earth and Environment Science
Hongbo Guo, Beihang University, Department of Material Science and Engineering

Key Words: TBCs, volcanic ash, spreading ring

Aviation safety and aero engine life are always threatened by dust or ash suspending in the air route which derive from inevitable natural phenomena (volcanic eruption and sand storm) and human productive activity (run way debris, industrial fumes, and coal ash emission). Those floating silicate ash with the low melt temperature (lower than 1100 ºC) will be easily ingested into jet engine and quickly melted due to the fact that the turbine inlet temperature of the current advanced jet engine at cruising altitude (1200-1450 ºC) far exceed the melting point of those silicate ash. Subsequently, these molten ash are deposited on the surface of thermal barrier coatings (TBCs). TBCs is a refractory ceramic layer deposited on the surface of super alloy and can protect these metal at the hot parts (such as combustion chamber, blade and nozzle) from high temperature. However, these silicate deposits will lead to serious spallation and even failure of TBCs. Once the TBCs exfoliate under stress or chemical corrosion because of ash deposition, the engine may stop running during the flight and cause air disaster. Therefore, silicate ash deposition undoubtedly pose a huge obstacle in the development of jet engine. Here, to comprehensively understand the effect of silicate deposits on TBCs, we investigated the subsurface-transverse spreading ring of re-melted volcanic ash (obtained from Tungurahua Volcano, Ecuador, 2014) with various droplet size on the APS TBCs and EB-PVD TBCs respectively at the temperature from 1200 ºC to 1600 ºC over a wide range of duration (Figs. 1a and b). Our results demonstrate that the gradient change of concentration of volcanic ash melt onto TBCs directly leads to the formation of spreading ring in the subsurface-transverse of molten volcanic ash located in the edge of main spreading area (Fig. 1c). These observations imply that the interaction process of molten silicate ash with TBCs is driven not only by vertical infiltration due to gravitation but also by horizontal spreading owing to capillary force. Notably, the infiltration depth of the ring area was deeper than that of the main liquid area, which closely resembles previously observed in ceramic plate (Figs. 1d and e). Overall, we summaries the influence of temperature, holding time and size of droplet on spreading radius and conclude the mechanism of vertical infiltration. Those work is the first step to improving the TBCs and serve as the basic of developing the new generation of aeroengines.

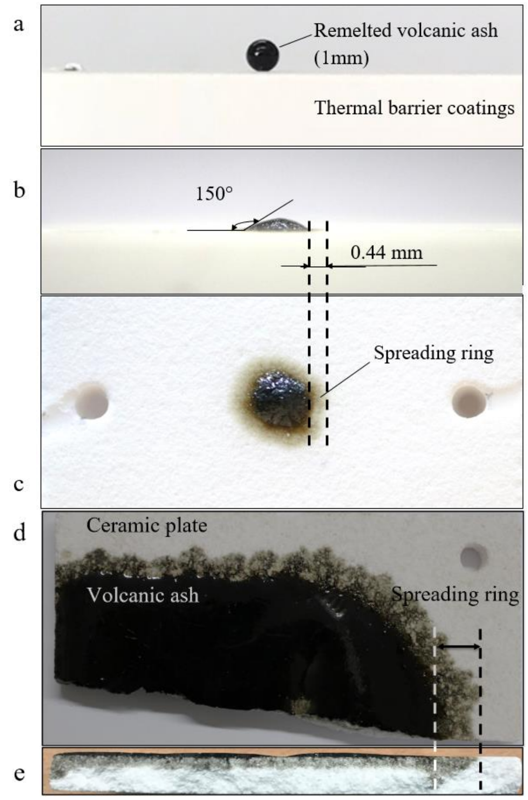

Figure 1. (a) A re-melted volcanic ash with the size of 1mm on TBCs before spreading. (b) The side view of spreading ring after spreading under 1200℃ for 10^4 h. (c) The top view of (b). (d) Spreading ring of volcanic ash on a ceramic plate. (e) Cross section of the ceramic plate.