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ZRO2 REINFORCED ABLATIVE MATERIAL SUITABLE FOR THE THERMAL PROTECTION SYSTEM OF ULTRA-HIGH TEMPERATURE IN SOLID ROCKET MOTOR COMBUSTION CHAMBER

Abstract

When the solid rocket motor (SRM) is working, there is a high-temperature (more than 3000 K) and high-pressure (usually above 5 MPa) two-phase flow in the combustion chamber, and ablative materials used in the thermal protection system (TPS) are required to ensure the safe operation of the motor. With the widespread use of high-energy propellants, the temperature in the combustion chamber has further increased, deteriorating the working environment of TPS materials. Therefore, it is urgent to develop high-performance TPS materials suitable for ultra-high temperature environments. ZrO2 has a high melting point and boiling point, and low thermal conductivity. As a reinforcing filler, ZrO2 is widely used in aerospace TPS as thermal barrier coatings on gas turbine blades, atmospheric entry, and ultra-high temperature ceramics used in hypersonic vehicles, among others. However, limited reports have focused on ZrO2-reinforced polymer–matrix composites (PMCs). In this study, ZrO2 is set as an excellent and potential high-temperature filler for PMCs, which is expected to significantly reduce the ablation rate of PMCs, thereby meeting the requirements of the TPS for ultra-high temperature SRM combustion chambers. Thus, the ablation resistance of ZrO2 reinforced EPDM-based TPS materials was studied, and it was found that ZrO2 could reduce the ablation rate of TPS materials, with a maximum reduction of 30.6%. Furthermore, the study of the ablation mechanism was helpful for the scientific design of reinforcing fillers to further reduce the ablation rate of TPS materials. The reinforcement mechanism of ZrO2 on the ablation resistance performance of TPS materials was revealed from the perspective of char layer characteristics and chemical reactions in the char layer. ZrO2 can increase the residue rate of the char layer, make the char layer compact, and promote the formation of ZrC in the char layer of TPS material. The combined effect of the above factors improves the ablation resistance performance of ZrO2 reinforced TPS materials. The development of ZrO2 reinforced EPDM-based TPS materials is expected to meet the TPS needs of ultra-high temperature SRM combustion chambers and improve performance of the SRM. Moreover, the revelation of ZrO2 ablation mechanism is conducive to the design of high-performance TPS materials and the establishment of mathematical models for simulating the ablation process.