Chapter 1
The Effect of Additional Ceramic Fiber on Wear and Mechanical Properties of Thermal Barrier Coatings

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ABSTRACT

Thermal barrier coatings (TBCs) are intended to defend the engines against excessive heat. The surface of a component is subjected to mechanical degradation, such as wear, in a variety of engineering applications. The majority of equipment used in industrial processes is subjected to abrasive wear at elevated temperatures. In the engineering industry, surface modification and deposition of various coatings are used to improve the tribological characteristics of materials. Reinforced materials offer superior mechanical and thermal qualities as compared to conventional materials. The ceramic matrix and TBCs have low fracture toughness and weak cohesive strength of the ceramic layer, limiting their applicability range. A technique for improving the mechanical properties of ceramic coatings is to incorporate reinforcing materials, such as ceramic whiskers or fibers, into the coating structure, which can improve the coating's wear behavior and mechanical properties through a variety of mechanisms, including fiber pullout and breakage.

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INTRODUCTION AND BACKGROUND

Gas turbines should be operated at as high a temperature as possible to maximize efficiency. Over the last few decades, improved alloy design, the production of blades comprised of textured microstructures, and later internal cooling and single crystals using air circulation via internal channels built within the blade have all led to consistent increases in operating temperatures. Recently, TBCs deposited on engine components have permitted recent temperature increases (Stern, 1996). The technology for thermal barrier coating comes mostly from the aircraft and land-based turbine engine sectors. TBCs are flexible, thick refractory coatings that shield metal from the gas's severe temperatures (Clarke & Phillpot, 2005).

Raising the turbine inlet temperature (TIT) or minimizing the need for cooling in gas turbines is the main reason for employing thermal barrier coatings, resulting in increased engine efficiency, reduced emissions, and better performance. Commercially available TBCs are generally two-layered systems with a metallic bond coat and a ceramic top coat placed on a substrate of superalloy. The ceramic top layer is the true thermal barrier, and its primary role is to reduce heat transmission to the metallic substrate (Bose, 2007).

Coatings allow metallic materials to be employed at temperatures well above their melting points in many gas turbine engines. The coating's thermal conductivity determines the temperature decrease across the TBC under these conditions (Clarke & Phillpot, 2005).

A ceramic layer with low-thermal conductivity is placed over an MCrAlY bond coat to create thermal barrier coatings (TBCs). Since the early 1960s, such coating systems have been extensively studied, and TBCs have evolved steadily ever since. TBCs are mainly utilized as thermal barriers, but the extreme thermomechanical conditions wherein they are often used require that they also meet additional severe performance criteria. To withstand the thermal expansion pressures associated with heating and cooling, whether during normal operation or during a "flame-out," the coatings must be able to withstand enormous strains without failing (Clarke & Phillpot, 2005).

Another less rigorous but still rather practicable condition is that there would be no phase transitions for the material while it cycles between room and elevated temperatures. These phase transitions are frequently followed by expansion and contraction, which reduce the coating's strain tolerance and reversibility, as well as its ability to withstand repeated temperature cycling. Functional TBC materials should be resistant to erosion too, demanding a high degree of fracturing and deformation resistance. For air-breathing engines, coatings would have to be able to endure continuous high temperatures in an oxidizing environment. To meet this need, the quest for innovative TBC materials is focused on refractory oxides (Pakseresht et al., 2016).

Although zirconia (ZrO_2) is the preferred ceramic for TBCs, the phase transition in pure zirconia leads to a significant volume change that may cause internal stresses and result in early coating failure (Pakseresht et al., 2020). To avoid this kind of failure, oxide stabilizers such as yttria, calcia, magnesia, or ceria are added to the zirconia. At the moment, yttria (Y_2O_3) is the most commonly used stabilizer for TBCs, and the material is generally referred to as yttria-stabilized zirconia (YSZ) (Bose, 2007).

In recent years, several studies have focused on three main areas to improve conventional TBCs. First, doping several metallic stabilizers including ceria and yttria into traditional powder coating (ZrO2); second, seeking novel materials with the structures of pyrochlore, fluorite, and perovskite that can be used as TBCs at higher temperatures; and third, expanding TBC architectural design according to double ceramic layered TBCs and functionally graded TBCs (FG-TBCs) (Chen et al., 2011).

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