Chapter 2
Role of Carbon Nanotube on Multi-Length Scale Tribological Properties of Al^2O^3-Based Thermal Barrier Coating

Ariharan S.
FunGlass – Centre for Functional and Surface Functionalized Glass, Alexander Dubček University of Trenčín, Slovakia

Rita Maurya
Department of Materials Science and Engineering, National Institute of Technology-Hamirpur, India

ABSTRACT

Magnificently developed Al^2O^3, 3YSZ, 8YSZ, and CNT-based thermal barrier coatings (TBCs) were subjected to study multi-length scale tribological behaviour (fretting wear and micro-scratch) of the composite coatings. Subsequently, the role of constituents of the composite on the tribological behaviour of the coatings has been recognized. Fretting wear rate and the dominative wear mechanism are identified. The fretting wear behaviour is evaluated with a distinct representation (frictional force mapping) to understand the transition of regimes. Further, micro-scratching is used to assess the composite coatings against the sharp edges. The critical load of failure and scratch characteristics (scratch hardness, toughness, and scratch resistance) are appraised to find the suitability of the composite in TBC. Notably, the role of CNT in a multi-length scale is reported quantitatively. Thus, the chapter provides a comprehensive overview of the Al2O3-based composites that deal with the understanding of the multi-length scale tribological properties at room temperature.

DOI: 10.4018/978-1-7998-9683-8.ch002

INTRODUCTION

The application of thermal barrier coatings (TBCs) on turbine engine components, such as combustors, high-temperature turbine (HPT) blades and nozzles is increasing in commercial and military jet engines. The insulating capability of TBC enables high operating temperatures, thereby improving efficiency, reducing emission and increasing the thrust/weight ratio of the turbine and combustors (Bikramjit & Kantesh, 2013; Hassanzadeh et al., 2018; Musalek et al., 2020; Amir Hossein Pakseresht et al., 2016). The structure of TBC is a complex system of functionally graded materials, that contains a metallic bond coat and ceramic coat over a metallic substrate (engine components) (Amir Hossein Pakseresht, 2018). The TBC aims to improve the structural stability of the metallic components which are exposed to a high-temperature or extreme condition. It mandates the utilization of high thermal insulation to the metallic components and the structural stability of these components are eventually conserved. So, thermally insulating TBC materials must possess sufficient thickness with durability to withstand at an exposed temperature of the load-bearing materials. Ultimately, it should possess good mechanical, thermal and tribological properties at high-temperature or working temperature. Among the aforementioned properties, thermal properties are the prerequisite for the selection of TBC materials. Low thermal conductivity and thermal expansion coefficient (CTE) mismatch with the substrate are the prime assets for TBCs. Low thermal conductivity will increase the temperature gradient across the coating and ultimately decreases the exposure temperature. Thus it improves the efficiency or working temperature of the engine by giving structural stability to the engine components. After several working hours of engine, the TBCs lose their properties and start to fail.

The failure is caused in two ways: (i) internally and (ii) externally induced failures. Among the internally induced failure, the formation of thermally grown oxide (TGO) and stress accumulation at the interface due to relatively high CTE mismatch with the underneath layer is the major cause for failure. Especially, high CTE mismatch between the ceramic top coat (ZrO_2 based ceramic) and TGO (continuous & thin layer of Al_2O_3) lead to premature failure of coating at the interface. But, the existence of TGO is unavoidable and it is intensely grown layer to avoid the oxidation of underneath bond coat and substrate. Thin and continuous layer of TGO will act as a barrier to the atmospheric oxygen. So, the main objective of the TBC system i.e. protection at high-temperature will be attained. On the other hand, there will be accumulation of stresses at TGO-ceramic top coat interface due to the CTE mismatch that leads to failure of the coating. So, the scientist have put efforts to increase the life span of the TBCs by tailoring the microstructure, chemistry and other properties of the interface. One of the ways to improve the life span of the TBCs is tailoring the chemistry of the top ceramic layer without compromising its prime characteristics, such as thermal insulation and thermal stability. The scientific community has studied several materials for the top layer of TBCs. After controlling several process parameters, several materials have been used in place of conventional TBCs, such as $BaTiO_3$, $La_2Ce_2O_7$, SiO_2, and Al_2O_3 reinforced composites (Ariharan et al., 2013; Hassanzadeh et al., 2018; Musalek et al., 2020; A H Pakseresht et al., 2015, 2016; Y. Wang et al., 2009). Based on the primary prerequisite properties for TBC, conventional Y_2O_3 stabilized ZrO_2 (YSZ) was replaced with Al_2O_3-YSZ based ceramic matrix composites (CMCs). It showed excellent stability against the impact of foreign particles and corrosive salt (hot corrosion) (A H Pakseresht et al., 2020; X. Wang et al., 2015).

Ceramic-matrix composites (CMCs) with customized properties are also can replace the ceramic materials. Al_2O_3 based composites are chosen as the top insulating layer to achieve chemical integrity over the TGO layer (A H Pakseresht et al., 2020, 2021). So, the TGO and top layer will be assumed as