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A study on sliding and erosive wear behaviour of atmospheric plasma sprayed conventional and nanostructured alumina coatings

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ABSTRACT

Alumina coatings on stainless steel substrate (SS304) were deposited by using atmospheric plasma spray technique with a feed stock of manually granulated and sieved nano Al_2O_3 powder. The hardness, sliding, and erosive wear of the nanostructured alumina coatings (NC) were investigated and compared with that of conventional alumina coatings (CC). Pin-on disc type sliding wear test on the alumina coatings (NC and CC) was performed with load varying from 30 N to 80 N at a sliding speed of 0.5 m/s. Pot type slurry erosion test of the coatings was conducted for different concentrations of Al_2O_3 and a mixture of Al_2O_3 and SiO_2 slurry. The microstructural features of both NC and CC of alumina were characterized by using FE-SEM/EDS and SEM analysis to substantiate the failure of coatings due to wear. Wear and erosion resistance of nano alumina coating is better than the conventional alumina coating as observed in the present work. The bimodal structure of NC contributes for the enhanced wear resistance. The high fracture toughness of NC is due to suppression of cracks by partially melted particles in the coatings.

1. Introduction

Wear and friction are responsible for about 50% of energy loss in an automotive engine. Their reduction in an engine is a major scientific and technological challenge, which is continuously being addressed by both automotive companies and research institutes [1,2]. It is well known that surface modification especially coating technologies are very efficient to impart protection to the components for combating wear and corrosion during service conditions.

Wear and corrosion resistant coatings are predominantly based on transition metal carbides (WC, TiC, Mo_2C, TaC, NbC, Cr_3C_2) and hard oxides (Al_2O_3, TiO_2, Cr_2O_3), which are deposited by thermal spray deposition techniques such as atmospheric plasma spraying (APS), flame spraying, and high velocity oxyfuel (HVOF) deposition. Atmospheric plasma spraying is the most flexible or versatile thermal spray technique and it enables deposition of many ceramic materials such as titania, zirconia, alumina and its mixture using high temperature plasma flame. Oxide ceramic coatings such as alumina and chromia developed by plasma spray technique, exhibit very high hardness, excellent wear resistance, and high temperature stability, which are essential for tribological and high temperature erosion applications [3,4]. In recent times, the plasma spray technologies are evolving towards developing nanostructured ceramic coatings due to their superior mechanical properties compared to the conventional coatings. It is due to the effective hindrance of dislocation movements, which leads to enhanced hardness and creep resistance of the nanostructured coatings [5]. Nanostructured ceramic coatings are deposited using agglomerates of nano-sized particles in a mushy state or suspensions of nano-sized particles as reported in the literature [6]. Plasma spraying of nano particles is a difficult task due to lack of momentum of powder particles. Spray drying is used as an effective powder granulation technique for obtaining flowable agglomerated powders, for the development of nanoceramic coatings, from the nanopowders as reported in the literature [7–9]. However, it is an expensive route [10,11].

Zois et al. [12] carried out a comparative study of the microstructure of plasma sprayed nanostructured and conventional Al_2O_3 coatings on 304 stainless steel substrate. The nanocoatings retained a higher percentage of semimolten particles than the conventional coatings owing to the higher porosity of the nanoparticle agglomerates. It exhibited lower adhesion strength as compared to their conventional counterparts. The molten part of both conventional and nanostructured coatings consisted of γ-Al_2O_3 of columnar morphology. Bolelli et al. [13] studied the wear behaviour of Al_2O_3 coatings thermally sprayed using micron and nano sized powder suspension. They observed that the tribological behaviour of the coatings is dominated by the formation of a surface tribofilm and by its progressive removal, which leads to the accumulation of wear loss. Plastic flow of the coating material and the trapped debris particles between the contacting bodies produces the tribo layer. In both as-deposited and polished coatings, tribofilm delamination is affected by the presence of defects and by the residual

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