Chapter 8

Tribology of Thermally Sprayed Coatings in the Al$_2$O$_3$–Cr$_2$O$_3$–TiO$_2$ System

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ABSTRACT

With the exception of ZrO$_2$, the individual oxides and binary compositions in the system Al$_2$O$_3$–Cr$_2$O$_3$–TiO$_2$ are the most important oxide materials for thermally sprayed coating solutions. Traditionally, these coatings are prepared by Atmospheric Plasma Spraying (APS), but processes such as Detonation Gun Spraying (DGS) and High Velocity Oxy-Fuel (HVOF) spraying can produce coatings with lower porosity and higher wear resistance. Traditionally, feedstock powders have been used for coating preparation. Recent developments have seen the emergence of suspensions as a new feedstock, but tribological properties of coatings prepared using suspensions have not yet been studied in detail. This chapter summarizes some important issues regarding wear protection applications of coatings in the Al$_2$O$_3$–Cr$_2$O$_3$–TiO$_2$ system, the advantage of alloying the individual oxides, and the influence of different feedstocks and spray processes.

INTRODUCTION

Thermal spray processes represent an important and rapidly growing group of surface modification technologies, which use a very wide range of solid feedstock materials, including metals and alloys, hardmetals, ceramics and polymers. Ceramics have an outstanding role as a group of materials processed by thermal spraying into coatings.
Tribology of Thermally Sprayed Coatings in the Al2O3-Cr2O3-TiO2 System

for a broad variety of applications. Many ceramic coatings show multifunctional properties, they can serve as wear resistant coatings, but also as electrically isolating and conductive coatings as well as thermal barriers. A general overview of thermal spray technologies can be found in several textbooks (Pawlowski, 2008; Mathesius & Krömmer, 2009; Tucker, Jr. (ed.), 2013; Fauchais, Heberlein, & Boulos, 2014) and book chapters (Vuoristo, 2014).

The process of ceramic coating preparation by thermal spraying is illustrated in Figure 1 (Toma, Berger, Langner, & Naumann, 2010). This figure shows that the coating properties are dependent upon both from the properties of the feedstock and the characteristics of the spray process. Conventionally, ceramic coatings are prepared from feedstock powders, commonly in the size range 10–45 µm (see Figure 1, upper part), or with adapted particle size depending on the characteristics of the spray process. Thermal spraying with conventional feedstock powders can be considered as a two-step shaping technology for the preparation of ceramic materials: first step is the preparation of a processable feedstock powder, the second step is the spray process (Berger, 2014). The use of suspensions as the feedstock (see Figure 1, lower part) is a recent trend in coating preparation by thermal spraying, e.g. (Bolelli, Cannillo et al., 2009; Bolelli, Rauch et al., 2009; Toma, Berger, Langner, & Naumann, 2010; Berger, Toma, & Potthoff, 2013). It allows the direct use of finely dispersed ceramic powders with a particle size of a few µm as applied in ceramic technologies for sintered components. Thus, coating manufacturing is transformed into a one-step shaping technology without the additional production step of feedstock powder preparation.

For ceramic materials, full or partial melting of the feedstock material (conventional feedstock powder or finely dispersed powder when using suspensions) occurs during the thermal spray process, while the substrate remains unmelted, i.e. the coating is primarily mechanically bonded to the substrate. The coating thickness typically lies within the range 100-500 µm. The process of coating formation is characterised by high cooling rates, which also, in the case of ceramic coatings, leads to the existence of high-temperature and non-equilibrium phases as well as nanocrystalline and amorphous structures. Thus, heat treatment at high temperatures (including high temperature applications) leads to changes in the microstructure, and, possibly, phase composition. In the case of substoichiometry, a heat treatment in air will also lead to oxidation.

Both bulk ceramics and hardmetals are traditionally manufactured by the principles of powder metallurgy (sintering). At the same time they are used as thermally sprayed coatings. The production of hardmetal (Berger, 2014) and ceramic parts by sintering is limited in size by technical and economical reasons. Thus for larger
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