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The dependency of microstructure and mechanical properties of nanostructured alumina–titania coatings on critical plasma spraying parameter

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ABSTRACT

The critical plasma spraying parameter (CPSP) is a significant factor to influence the quality of plasma-sprayed coatings. The aim of this work was to investigate the effects of the CPSP on microstructure and mechanical properties of nanostructured alumina–13 wt.% titania (n-AT13) coatings prepared by supersonic plasma spray (SPS). The microstructure, phase composition, porosity, micro-hardness, Young's modulus and fracture toughness of coatings were characterized and experimentally measured. The results revealed that the values of porosity, micro-hardness, Young's modulus and fracture toughness followed Weibull distribution and had wide ranges. The microstructure of the coating consisted of fully melted regions and partially melted regions, which resulted in a bimodal distribution characteristic of mechanical properties. With the increase of CPSP, there were two contradictory trends. The mean values and characteristic values of both porosity and fracture toughness decreased rapidly and then slowly to a local minimum, while values of both micro-hardness and Young's modulus were on the contrary trend. Moreover, the characteristic values of micro-hardness and Young's modulus were decreased functions of those of porosity, and the opposite tendency for the characteristic value of fracture toughness.

1. Introduction

Plasma spraying (PS), maturely and successfully used for depositing powders as coating with dense structure and high adhesion, can take good advantage of high temperature and velocity of plasma jet [1,2]. PS is a process, in which powder particles are heated to a melted or partially melted state and propelled in the plasma jet in the form of droplets at high velocities to impact the substrate and then flatten as well as rapidly solidified [3]. The quality of coating is determined by temperature and velocity of plasma jet, melting behaviors of powder particles and degree of droplets flattening.

Plasma-sprayed n-AT13 composite ceramic coating has been put into use in many industry applications ranging from aerospace, remanufacturing, light industry to auto industry for its available performances, including high resistance to wear, corrosion, elevated temperature and oxidation [4–9]. The researchers at home and abroad have concentrated on the comprehensive prospect of application.

The microstructure and mechanical properties of plasma-sprayed ceramic coatings are influenced by many factors, such as spraying power, primary gas flow rate, powder feed rate, shape and dimensions of particles and melting point of powders, etc. These factors affect thermal energy and kinetic energy of particles or droplets during PS. Either excess or lack of them can be deleterious to the quality of coatings. L. Shaw et al. [10] found that when other processing parameters such as flow rate ratio of Ar to H_2, powder flow rate, spraying distance, and gun speed, etc. were held constant, the microstructure and performances of plasma-sprayed ceramic coatings were directly related to the critical plasma spray parameter (CPSP) which can be defined as

$$\mathrm{CPSP} = \frac{\text{Spray power(kW)}}{\text{Primary gas flow rate(SCFH)}} \tag{1}$$

Temperature and velocity of droplets or particles are strongly dependent upon the CPSP, which influences the microstructure and performances of coatings further. It is well known that droplets or

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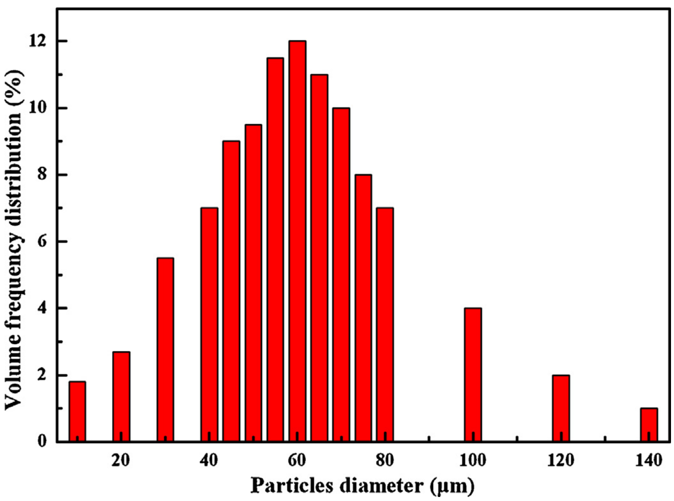

Fig. 1. Volume frequency distribution of particles diameter of n-AT13 powder.

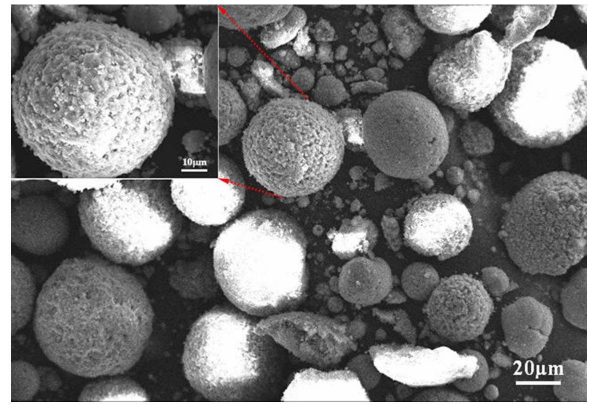

Fig. 2. SEM photograph of n-AT13 agglomerated particles.

particles temperature are sensitive to spraying power. As spraying power increases, droplets' temperature shows an increasing tendency corresponding to the increase of plasma jet temperature. Primary gas flow rate has an important and complicated effect on coating quality by affecting the temperature and velocity of droplets or particles. In general, thorough investigation of the effects of the CPSP on microstructure and mechanical properties of coating is significant and indispensable in the field of PS.

In this paper, the influences of CPSP on the microstructure and mechanical properties of SPS n-AT13 coating were

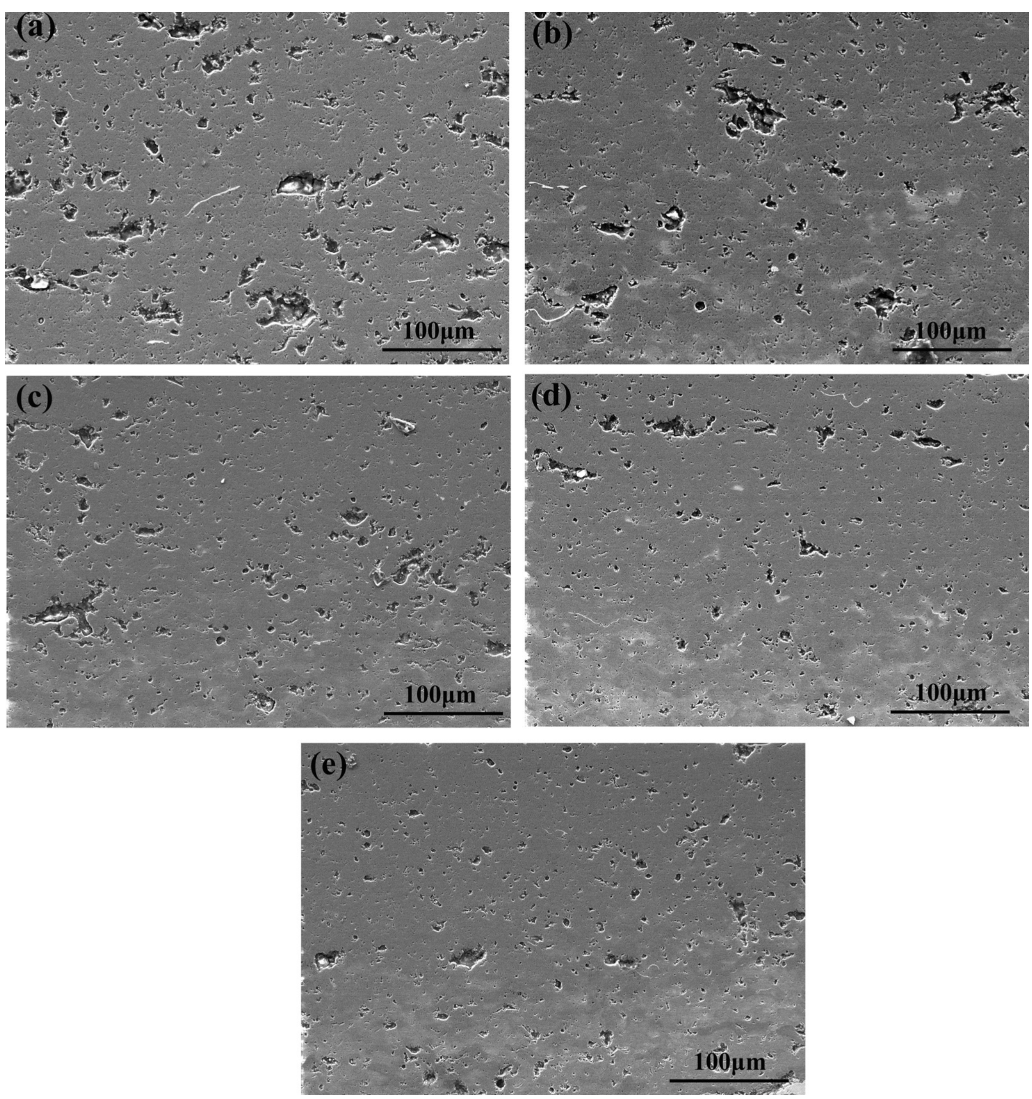

Fig. 3. Cross sectional views of the coatings C1–C5 deposited at different CPSP (kW h m^{-3}) (a) 13.6, (b)14.6, (c)15.7, (d)16.4, (e) 17.2.