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Plasma spray for forming nanostructured thermal barrier coatings

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Abstract: Nanocrystalline powders of yttrium partially stabilized zirconia (YPSZ) are reprocessed into agglomerated feedstocks for plasma spraying thermal barrier coatings (TBCs), using the methods of ball milling, slurry dispersion, spray drying, and heat treatment. Atmospheric plasma is used to spray the agglomerated nanocrystalline particle feedstocks and coatings were deposited on the substrate of Ni-based superalloy. Scanning electron microscopy (SEM) is used to examine the morphology and cross-section of the agglomerated feedstocks and the free-section and cross-section of the nanostructured TBCs. Experimental results show that the agglomerated nanocrystalline particles are spherical and dense. Unlike conventional plasma-sprayed coatings, the micron/nano/micron sandwich structure can be found in the nanostructured YPSZ coatings deposited by atmospheric plasma spraying.

Key words: Nanostructured; Thermal Barrier Coatings; Plasma Spraying; YPSZ

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1 Introduction

Plasma sprayed coatings include anti-wear coating, corrosion-resistant coating, high temperature oxidation-resistant coating, thermal barrier coating, and abradable seal coating, and lubrication coating. Most of the coating materials are ceramic[1, 2]. Coating thickness is usually in the range of 200-500 μm. To increase the bonding between ceramic coatings and substrates, intermediate metallic coatings are often applied to the substrates prior to the deposition of the top ceramic coatings[3-5].

YPSZ is a kind of ceramic coating material used in the gas turbine engines for the purpose of thermal barrier. Conventional coating consists of laminar layers with high brittleness. Microcracks are frequently found in the coating after plasma spraying[6,7]. The conventional coating fails after losing laminar layers gradually. Nanocrystalline materials could be applied to future gas turbine engines. Nanostructured ceramic materials could be deformed by the way of grain boundary sliding[8, 9].

Reprocessing of YPSZ nanocrystalline powders and plasma spray for forming nanostructured thermal barrier coatings are the aims of this study.

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Biography: LIN Feng(born in 1978), Male, Engineer, Master.

2 Materials and methods

2.1 Materials

Nanocrystalline YPSZ powders purchased at market have low free holding density and poor flow ability. These powders can be used neither for plasma spraying nor for pressing and sintering. They must be reprocessed to improve the density and flow ability.

First, the mixed powders were ball-milled, with the addition of deionized water. Secondly, slurry was prepared using an organic compound as binder. Thirdly, spray drying was used to make agglomerated particles. Finally, heat treatment was applied toremove the binder, keeping the agglomerates integrated.

A typical SEM micrograph of the agglomerated powder is shown in Fig. 1. Almost all of the particles are spherical. A few apple-like particles can be found that resulted from non-uniform evaporation of water during spray drying. The agglomerated particles are in the range from 10 μm to 90 μm. The surface of the large particles is smooth. Flow ability of the agglomerated powder is significantly improved after the reprocessing.

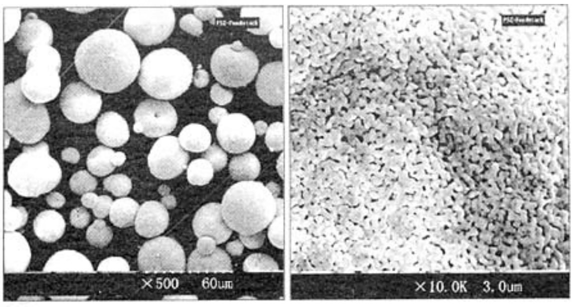

Fig. 1 Morphology of the PSZ nanostructured powder feed stocks

2.2 Forming and testing

Plasma spray for forming the nanostructured thermal barrier coatings is conducted by DC plasma spraying system (Metco3MB). DC plasma was used. Argon was used as plasma gas. Substrate material is stainless steel with metallic bond coating.

The morphology and cross-sectional microstructure of the plasma spraying YPSZ coatings are observed with a scanning electron microscope(SEM)(HITACHI S-3500N, Japanese).

3 Results and discussion

The ceramic coating is approximately 150 μm. A small piece of sample was cut from the cross section of the coating. The coating sample was examined by scanning electron microscopy after being ground and polished. SEM micrograph of the coating is shown in Fig. 2. There is about 10% porosity in the coating. Unlike conventional coatings, no obvious laminar layers can be seen in the coating, giving rise to high coherent strength of the coating. Two regions can be identified from the coating. One is dense block region, and another is porous nanostructured region. Because the plasma powered at about 40 kW had the very high temperature (~10000℃) at center and the very low temperature at surroundings, some of the injected particles were melted in the plasma when traveling through the center, while others were not melted when traveling at different trajectories. As a result, the melted particles constructed the dense block region in which the nano-

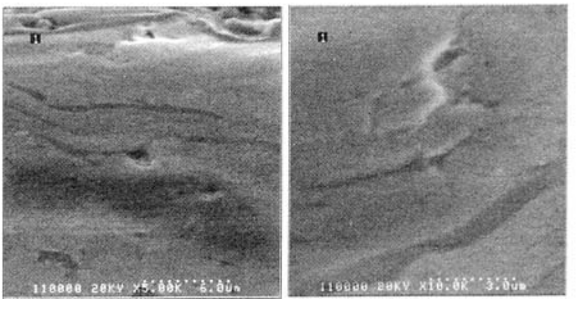

Fig. 2 SEM of the nanostructured TBCs fabricated by plasma spraying

crystalline grains disappeared. Non-melted or partially melted particles formed nanostructure region in the coating after impacted and deformed on the substrate.

4 Conclusions

The large particles size powders are suitable for plasma spraying and sintering. The coatings deposited by DC plasma spraying of the agglomerated nanocrystalline powders mainly consist of nanostructure. No obvious laminar layers are presented in the coatings. Unlike conventional plasma-sprayed coatings, the micron/nano/micron sandwich structure can be found in the nanostructured YPSZ coatings.

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