Optimization of APS Process Parameters Using a Design of Experiment for CSZ (Y_2O_3- CeO_2 Stabilized Zirconia) Coatings

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Abstract

Air Plasma Sprayed (APS) Ceria Stabilized Zirconia (CSZ) coatings have been extensively used as alternative material yo Yttria Stabilized Zirconia (YSZ) in the gas turbine industries due to the good mechanical properties and hot corrosion resistance at an elavated temperatures. Due to the high velocity and temperature gradients in the plasma jet, any changes in the process parameters can result in significant changes in the particle properties and consequently in the microstructure of the coating. For increasing coating quality,operational primer process parameters as plasma gas flow rates, plasma current, spray distance must be optimized. The statistically designed taguchi experiments and regression analysis are used to determine the effects of processing parameters on mechanical and microstructural properties of coatings. The effect of changing the processing parameters on properties such as density, thickness, deposition efficiency and the amount of porosity in the coatings has been investigated in this study. Results showed that the CSZ has a higher deposition efficiency and denser microstructure than the YSZ systems.

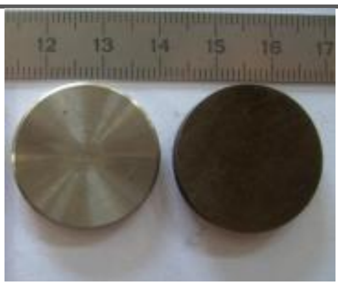
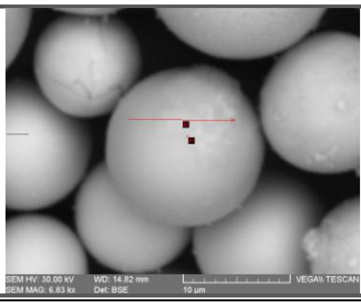
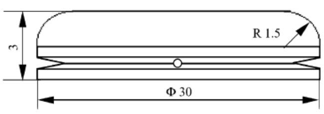
Keywords: Plasma Spraying, Stabilized Zirconia, Coating Quality, Process Optimization, Deposition Efficiency

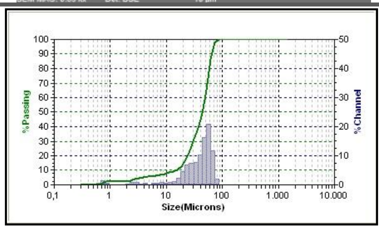
1. Introduction

Yttria stabilized zirconia (YSZ) has been usually chosen for the thermal barrier coating material because of its high coefficient of thermal expansion (CTE), which closely matches that of the Inconel substrate and low thermal conductivity. However, other researches indicate that the Ceria and Yttria stabilized zirconia (CSZ) coating was superior to the YSZ coating due to its phase stability at high temperature, improved thermal insulation, higher CTE and good corrosion resistance [1-4]. The fundamental of the air plasma spray process is heating up the powders above their melting point in a plasma stream and accelerate them toward a substrate. The microstructure of plasma sprayed coatings is a lamellar type structure. Microstructural features are also affected by defects such as pores, unmelted particles and microcracks. Due to the high velocity and temperature gradients in the plasma stream, any changes in the process parameters can result in significant changes in the particle properties and consequently in the microstructure of the coating. For increasing coating quality, operational process variables must be optimized [5-6]. The effect of changing the processing parameters on properties such as, density, deposition efficiency, thickness, and the amount of porosity in the coatings has been investigated in this report.

2. Experimental Study

Inconel 738 superalloy was used as the substrate with the diameter 30mm and thicknes 4mm. The spray powders were commercial NiCoCrAlY powder (Amdry962 Sulzer Metco, 38–75 mm) as bond coat and ZrO_2–8 wt%Y_2O_3 (YSZ:204NS, Sulzer Metco, 50-62 μm), ZrO_2 –25 wt% CeO_2–2.5 wt%Y_2O_3 (CSZ: 205NS, Sulzer Metco, 45-58μm) and were deposited by Multicoat robot controlled air plasma spraying(APS) system with F4MB spray gun (**Fig 1**). Argon gas was the primary plasma gas and hydrogen gas was added as the secondary gas. The microstructure of as sprayed coatings was observed using a scanning electron microscope (SEM), supplied with energy dispersive spectroscopy (EDS) was used.. The phase was analyzed using X-Ray diffractometer (40kV,40mA, CuKα radiation).

<table>
<tr><td>Surface preparation</td><td>Spraying powder in plasma plume</td><td>Coated sample</td></tr>
<tr><td>
</td><td></td><td>
Macro surface view</td></tr>
<tr><td>Inconel 738 substrate
Before grit blasted


Substrate geometry</td><td>

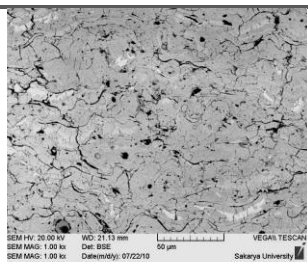
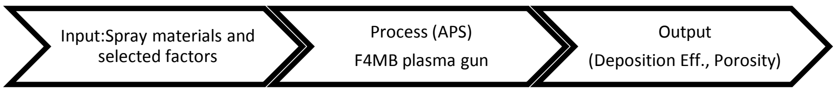
CSZ feed stock powder and Its size distribution</td><td>
Cross section of coating</td></tr>
<tr><td>Deposition and adhesion surface
↔</td><td>Melt and acceleration of powder
→</td><td>Rapid cooling and soldification</td></tr>
</table>

Fig.1 Experimetal materials

Design of experiment (L9 Taguchi design) has been used to obtain the spray parameters in the minimum possible number of experiments. For finding the range of various parameters selected such as plasma current, spray distance, plasma gases flow rate, some preliminary experiments have been performed. In order to carry out varied characterization for a given type of experiment, a number of samples have been made (**Table 1**.).

Table 1. Spray parameters (Plan for Taguchi design of experiment, L9)

Variab.	**Plasma Current (Ampere)**			**Primar gas flow rate Ar (nlpm)**			**Secondar gas flow rate H_2 (nlpm)**			**Spray Distance (cm)**		
Level	1	2	3	1	2	3	1	2	3	1	2	3
Value	575	600	625	35	45	55	7.5	10	12.5	10	15	20



3. Primary Results and Discusssion

Deposition efficiency is defined as the ratio of the weight of coating deposited on the substrate to the weight of the expended feedback. The deposition efficiency of coatings has a strong dependence on spray distance, primar gas flow rate, plasma current respectively among the spray parameters. Increasing porosity decreases the deposition efficiency. DE of the CSZ is higher than the DE of YSZ coatings.

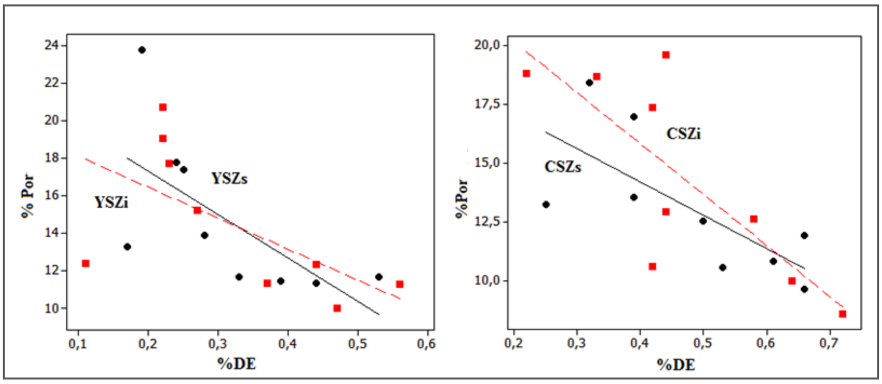


Fig. 2. Deposition Efficiency vs Porosity graphics for YSZ and CSZ based coatings

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