ARTICLE IN PRESS

Ceramics International xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Ceramics International

journal homepage: www.elsevier.com/locate/ceramint

Effect of powder particle size on vibration damping behaviour of plasma sprayed alumina (Al_2O_3) coating on AISI 304 stainless steel substrate

K.B. Sachidananda[a,*], K. Mahesha[a], Arjun Dey[b]

[a] Department of Mechanical Engineering, Acharya Institute of Technology, Bengaluru 560107, India
[b] Thermal Systems Group, ISRO Satellite Centre, Indian Space Research Organisation, Bengaluru 560017, India

ARTICLE INFO

Keywords:
Alumina (Al_2O_3)
Coating
Air plasma spraying
Damping capacity
Microstructure

ABSTRACT

The damping capacity of plasma sprayed alumina (Al_2O_3) coatings on AISI 304 stainless steel was investigated in this study as a function of particle size of the starting alumina powder. The coatings were prepared from different sizes alumina powder using commercial air plasma spraying (APS) technique. The damping properties of coated samples were characterized by damping capacity (Q^{-1}) measured experimentally using dynamic mechanical analyzer (DMA). The surface morphology of the coatings was studied using scanning electron microscope (SEM). The results revealed that the coating was porous and was able to improve the damping capacity of bare substrate. It was also observed that the powder particle size had a significant effect on the damping characteristics of the coatings. The damping values were found to be increased with the increase in particle size in the measured strain range. This behaviour was correlated with the microstructure investigated by SEM.

1. Introduction

Plasma spraying is preferred to grow the thick protective coatings in a less time due to its high deposition rate [1]. This protective coating is mainly carried out for chemical resistance, wear resistance, thermal resistance, and corrosion resistance etc. [2]. Wide verity of materials (such as metals, alloys, ceramics, polymers and composites) can be coated with plasma spray technique [3].

Plasma sprayed alumina (Al_2O_3) coating is found its application in high temperature, wear resistance, corrosive resistance environment [4]. There are many parameters that can affect the quality of the alumina coating [5,6]. It is important to study the properties like mechanical, physical, coating adhesion strength [7]. Because, many load carrying structures, such as aircraft gas turbine engines blades, typically operate under high temperature, pressure, shock, etc. [8] in such conditions they are exposed to thermal vibration that shorten the service life [9]. To prevent such failure, the excited vibration response needs to be studied and analysed with respect to the damping properties and dynamic mechanical performance. The DMA evaluates the damping behaviour of materials in different loading condition [10].

Several works have been reported about the study of vibration damping behaviour of several bulk materials, composites and polymers [11–16]. However, the reports on study of vibration damping behaviour of coatings in particular on ceramic coatings are scarce in literature [17–20]. As described aforesaid that alumina coating is a potential candidate for many state of art applications due to its superior mechanical and tribological properties and it is well studied and documented in literature. Nevertheless, the damping behaviour of alumina coating not yet explored in the reported literature.

Therefore in the present study, for the first time in-depth damping behaviour of plasma sprayed alumina deposited on AISI 304 stainless steel is investigated. The effect of starting alumina powder particle on damping behaviour of coatings is also studied in the present work.

2. Materials and deposition of coating

The alumina powder was deposited on AISI 304 stainless steel substrates of dimension $45 \times 10 \times 1.6\ mm^3$ by APS technique. The chemical composition of AISI 304 stainless steel substrate is summarized in Table 1 received from supplier. To avoid powder dispenser and/or torch blockage problems, i.e. to achieve smooth powder flow, the powders must be clean, carefully dried and vacuum-degassed before using them, often a heated powder hopper is also employed. Commercially available alumina powders were procured and were sieved to get proper particle size range with the help of a sieve shaker machine by using laboratory test sieves of ASTM C136 standard. The particle size range the powders considered in the study, segregated in the sieving operation are 10–40 µm, 53–75 µm and 74–106 µm. The mechanical properties of AISI 304 stainless steel substrate and alumina powder are given in Table 2 received from the suppliers. The substrates were

* Corresponding author.
E-mail address: sachidananda@acharya.ac.in (K.B. Sachidananda).

http://dx.doi.org/10.1016/j.ceramint.2017.09.153
Received 26 July 2017; Received in revised form 7 September 2017; Accepted 19 September 2017

Table 1
Chemical composition of AISI 304 stainless steel.

Composition	Fe	Cr	Ni	Mn	C	P	S	Si
Percentage, w/w	66.345	18–20	8–10	2	0.08	0.045	0.03	1

Table 2
Mechanical properties of the substrate and alumina powder.

Property	AISI 304 stainless steel	Al_2O_3
Density, g/cm^3	8	3.90
Young's modulus, GPa	193	370
Tensile strength, MPa	215	262
Poisson's ratio	0.29	0.26

Table 3
Process parameters of plasma spraying.

Parameters	Value
Spray torch model	SG 100
Nozzle internal diameter (mm)	3
Plasma gas (Primary-Argon), (lpm)	41
Carrier gas (Secondary-Hydrogen), (lpm)	10
Arc current, (A)	600
Arc voltage, (V)	65
Spray distance, (mm)	120
Powder feed rate, (g/min)	6–8
Traverse speed, (mm/s)	100
Pitch, (mm/step)	5

roughened by grit blasting technique with quartz sands of 16–20 mesh. The blasting was carried out at an air pressure of about 5 kg/cm^2. The standoff distance in the blasting was kept between 120 and 150 mm. These substrate samples were cleaned thoroughly with acetone in a cleaner. Alumina powder is coated immediately after the cleaning. Plasma spray coating parameters are tabulated in Table 3. A constant coating thickness of 150 µm was deposited.

3. Experimental

3.1. Dynamic mechanical analyzer (DMA)

To find the damping capacity (Q^{-1}) of the coatings, damping test was carried out using the DMA (EPLEXOR 500 N, NETZSCH GABO Instruments). According to the ASTM D5023 standard, the sample is fabricated for the 3-point bending mode damping test in DMA machine. The specification of DMA are force range ± 500 N, the dynamic strain is ± 1.5 mm (3 mm), strain rate is up to 35 mm, temperature withstanding capability up to 500 °C and frequency range is 0.01–100 Hz. In the present study, three-point bending mode is applied for carrying out damping test [21]. Tests were carried out in strain-scanning mode and its input parameters are shown in Table 4.

3.2. Microstructural analysis and surface morphology studies

The microstructure of the alumina powder and its phase purity was investigated by SEM and X-ray diffraction (XRD) techniques, respectively. The SEM facility is procured from EVO 50 Carl Zeiss, Germany while the XRD is procured from PANalytical X′pert Pro MPD diffractometer, The Netherlands which utilizes 0.15404 nm wavelength Cu Kα1 radiation. The 2θ was in the range of 20–90°. Further, the elemental study of the powder and the deposited coating was carried out by energy dispersive X-ray spectroscopy (EDX: Oxford Instruments, UK) attached with the aforesaid SEM facility.

4. Results and discussion

4.1. Characterization of alumina powder and coating

Fig. 1 shows the XRD pattern of alumina powder and it is indexed thoroughly as per ICSD standard. The pattern matched with α– Al_2O_3

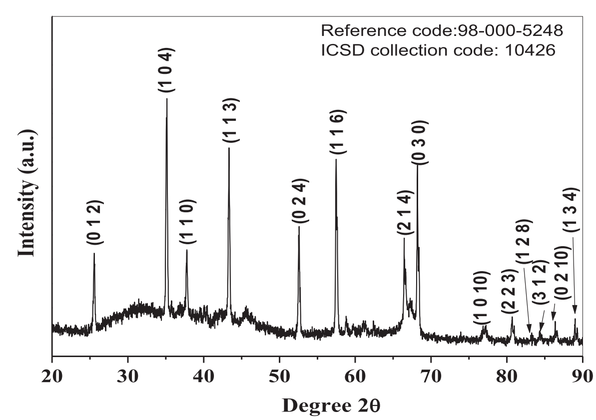

Fig. 1. XRD pattern of alumina powder.

Table 4
Inputs parameters given during damping test.

Input parameters	Static load	Dynamic strain	Static strain	Dynamic strain	Frequency
Values	10 N ± 0.10 N	8 N ± 0.05 (Max)	0.2%	0.1%	0–10 Hz