JPIChE 46 (2) 2018: 27-31

Journal of The Pakistan Institute of Chemical Engineers

PAKISTAN INSTITUTE OF CHEMICAL ENGINEERS

Since 1969

journal homepage: www.piche.org.pk/journal

Characterisation of Titanium Based Composite Coating Deposited by Air Plasma Sprayed Method on Aluminium Substrate

*A. Salman**

Submitted: 22/03/2018, Accepted: 10/07/2019, Online: 14/07/2019

Abstract

Plasma spraying is most commonly used to produce thick coatings over a wide range of substrates. Thick coatings play an important role in improving the wear and corrosion resistance of a component. In this study, titanium based in-situ composite powder was produced by high energy mechanical milling using Al and TiO_2 powders. The composite powder was then subjected to a self-propagating combustion reaction to produce feedstock for air plasma spraying. Very fine particles within the feedstock were treated using an organic binder to improve the overall flowabilty of the feedstock powder. The feedstock was then sprayed by air plasma spraying on an aluminum substrate. A thick composite coating was successfully deposited on an aluminum substrate. Composite coating was found continuous and uniform over the Al substrate. However, it showed poor adhesion with the substrate Composite coating showed porosities and micro-cracks. Microstructure of the coating revealed presence of three phases, alumina particle, metallic phase Ti(Al,O) and a ceramics phase (Al rich Ti-Al oxide). A longitudinal deformation was observed in case of aluminium particles compared with feedstock powder used for spraying.

***Keywords**:* Feedstock powder, Self-propagating combustion reaction, Mechanical milling, Air Plasma

1. Introduction:

Thermal spraying is a coating process in which particles in molten, semi molten or solid form are deposited on the substrate to form metallic or non-metallic coatings [1]. By the development of the advanced materials such coatings have been used to protect the substrate materials from corrosion, wear and elevated temperature [2]. Plasma spraying is the most widely used spraying process among various thermal spraying processes. In plasma spraying process usually powder feestock is deposited onto the surface of substrate in molten form. The powder feedstock is introduced into the coating chamber which is heated and accelerated (at approximately 800 m/s) in the presence of high temperature plasma. The particles then strike with the substrate surface and cool rapidly [3-4]. The temperature of the plasma spraying process is 6000°C to 15000°C and at this temperature almost all the materials can be melted [5]. Very small heat transfer into the substrate occurs because the splat (the building unit of the coatings) cools down very rapidly during its flight to the substrate of the order of 10^6 K/s [6].

Conventionally plasma spraying process is known as air plasma spraying process (APS) because it is commonly done in normal atmosphere. This process has many advantages over the other thermal

[1]*Department of Metallurgy and Materials Engineering, University of the Punjab, Lahore, Pakistan*

*** Corresponding Author:** asmasalman17(@gyahoo.com)

spraying processes. It can deposit materials which have very high melting points like tungston due to its high temperature. Air plasma is commonly used to deposit any type of ceramic and cermet. It produces more clean and dense coatings than other processes but not denser than the high velocity oxygen fuel (HVOF) sprayed coatings. However, dense plasma sprayed coatings can be produced by post treatment of these coatings by suitable porosity sealing processes such as laser remelting and sol-gel [7,8].

Zhang [9] produced a range of in-situ TiO_2/Al composite powders through powder metallurgy route. The main aim of this study is to produce thick coatings using an in-situ composite feedstock [10,11] for possible marine and industrial applications. The in-situ composite powders have a great advantages of having continous metallic and ceramics phases. Due the nature of this continous interpentarting nextwork , coatings deposited by using these composites are expected to perform better than traditional composites for similar kind of applications.

2. Experimental Procedure:

The details about composite powder production and its characterization have been reported previously [10, 11]. Air plasma spraying (APS) was used to deposit thick coating on an aluminium substrate. The coating thickness was measured using optical microscope. The spraying work was carried using a Gun (G-type Nozzle) out at Holster Engineering Co. Ltd., Tokoroa, New Zealand. The details about spraying parameters are given below;

Fuel pressure (H2) = 10 l/min; air jet = 40 l/min; carrier gas pressure (N2) = 75 l/min; powder feed rate = 35 g/min; voltage = 70 V; current = 500 A; and standoff distance = 76-100m. The coating's characterisation was done using optical microscopy and scanning electron microscopy (SEM, Hitachi S-4700).

3. Results and Discussion:

3.1 Characterisation of feedstock used for air Plasma spraying

The details regarding powder feedstock preparation for spraying have been reported previously [12]. Figure 1 shows large lumps of powder produced by self-propagating combustion reactions using mechanically milled composite powder. The large lumps of the combustion reacted powder were milled for 15 minutes to improve powder flowing through the spray gun. The resultant fine powder feed (with particle size < 75 µm) was then separated and treated with an organic binder for particle agglomeration purposes and to improve the over flowability of the feedstock powder.

Figure 1: *Combustion reacted powder*

Figure 2 shows powder feedstock morphology. The SEM back scattered image (Figure 2a) shows the agglomerated particles by using an organic binder. Fine feed agglomeration resulted in improving the flowability of the feedstock. The main reason for this improvement was spherical nature of the particles as a result of agglomeration. Figure 2b shows the feedstock used for air plasma spraying. From the SEM image, it is very clear that feedstock for spraying mostly consists of particles of size less than 50 m; however, presence of a few large particles with sizes ranging from 50-100 m are also confirmed [10].

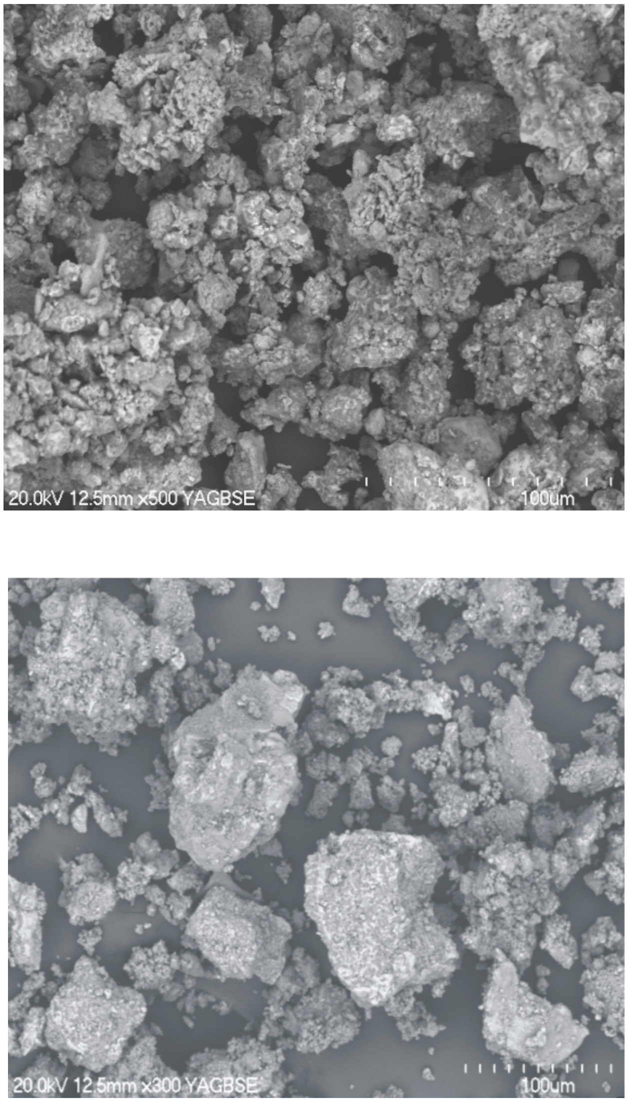

Figure 2: *Feedstock particle morphology (a) Fine feed with spherical particles after agglomeration (b) Feedstock used for air plasma spraying*

An SEM image of feedstock particle confirms the presence of dark and bright phases (Figure 3). Energy Dispersive X-Rays analysis (EDX) analysis of the dark phase confirmed the presence of Al_2O_3 with a small amount of TiO whereas Ti with small amount of Oxygen and Aluminum was confirmed in the bright phase. The presence of three phases was also confirmed by XRD as Al_2O_3, Ti and TiO [10].

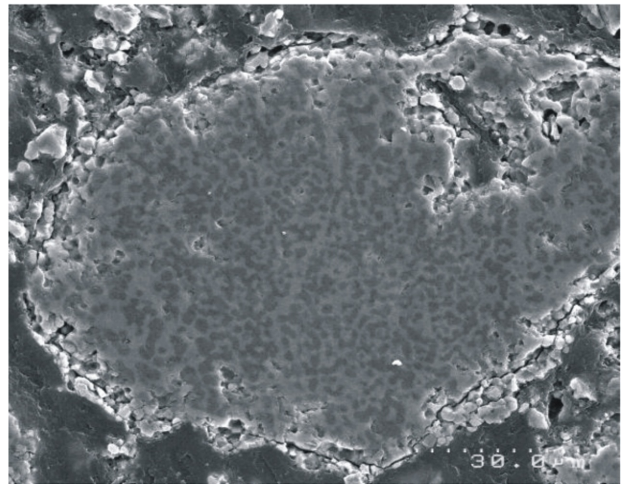

Figure 3: *SEM image of feedstock particle*

3.2 Characterisation of composite coating

Figure 4 shows the surface characteristics of an air plasma sprayed composite coating. The SEM image (with marked arrows) confirms the presence of intra-splat micro cracks, porosities and debris particles on the coating surface.

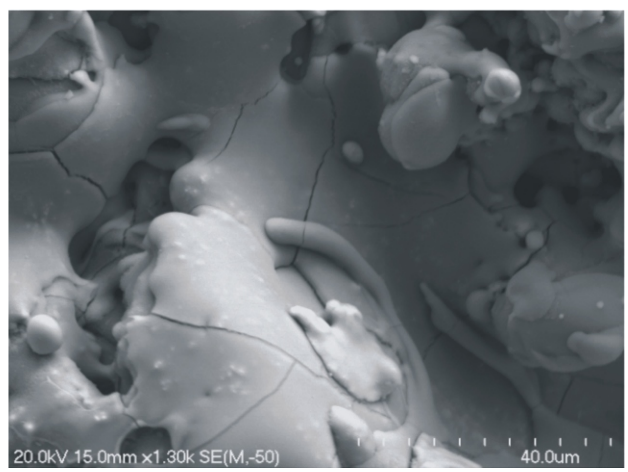

Figure 4: *Plasma sprayed coating surface morphology*

An optical image of composite coating shows a layered structure (figure 5). The thickness of the coating is the range of 100-180 μm. The presence of pores with a size range 10-20 μm is also confirmed. Generally, the coating is continuous and uniform over the substrate as confirmed from Figure 5. The coating shows a poor adhesion due to having small gape with coating/substrate interface. The poor adhesion can be linked with the low velocity of the particle during spraying. A metallic bond can be used as an intermediate layer to improve the coating adhesion.

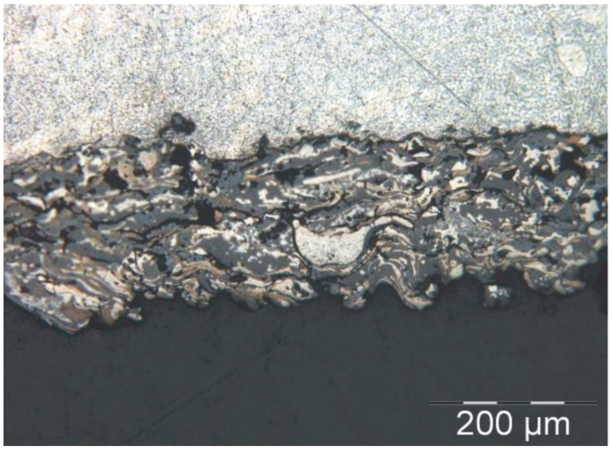

Figure 5: *Optical microscopic image of composite coating's cross section*

Microstructural study of this coating using SEM reveals (figure 6) a layered morphology which is a typical characteristic of thermally sprayed coatings. EDX analysis of the coating confirms the presence of three phases, alumina particles with small amounts of TiO, a bright phase as titanium with solid solution of Al and oxygen and a dark phase as aluminium rich Ti-Al oxide. However, alumina particles showed a longitudinal deformation compared with feedstock powder in figure 3.

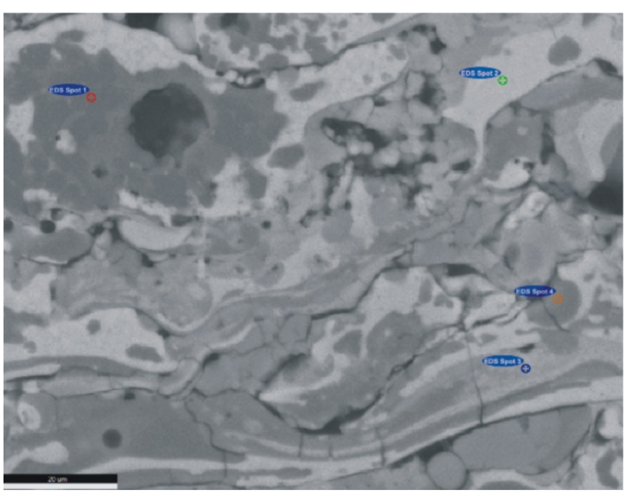

Figure 6: *Microstructures of plasma sprayed composite coating.*

4. Conclusions:

A thick plasma sprayed titanium based composite coating was successfully deposited on an aluminum substrate. Microstructure of the coating confirmed the presence three phases, alumina particles with small amounts of TiO, a metallic lamellar phase consisting of Ti (Al,O), and a ceramic phase consisting of aluminium rich Ti-Al oxide. A longitudinal deformation was observed in case of aluminium particles compared with the feedstock powder. The coating showed poor adhesion with the aluminium substrate. By using a metallic bond coat as an intermediate layer, coating adhesion can be improved.

Acknowledgment:

This work is supported by Foundation for Research, Science and Technology, New Zealand. The authors would like to thank and acknowledge Dr. Ian Brown and Bill Ower from Callaghan Innovation for their full support and help towards plasma sprayed coating's characterisation work.

References:

1 Pawlowski, L. The Science and Engineering of Thermal Spray Coatings, France, John Wiley & Sons Ltd, (2008) 93.

2 T. Sahraoui, N. Fenineche, G. Montavon and C. Coddet, “Alternative to Chromium: Characteristics and Wear Behavior of HVOF Coatings for Gas Turbine Shafts Repair (heavy-duty)”, Journal of Materials Processing Technology, 152 (1) (2004) 43-55.

3 P. Fauchais, “Understanding plasma spraying,” Journal of Physics D, 37(2004) 86108.

4 C. Moreau, Thermal Spray Industrial Applications, ASM International, Materials Park, Ohio, USA, 1994.

5 R. B. Heimann, Plasma Spray Coating: Principles and Applications, WILEY-VCH, New York, NY, USA, 2008.

6 R.C. Tucker, Thermal Spray Coatings, Surf.

Eng.5, ASM Handbook, ASM International (1994) 497509.

7 K.M. Deen, M. Afzal, UY. Liu, A. Farroq, A. Ahmad, E. Asselin, Improved corrosion resistance plasma sprayed WC-12%Co coatings by laser remelting process, Materials letters,191(2017) 34-37.

8 T. Troczynski, Q. Yang, G. John,Post deposition treatment of zirconia thermal barrier coatings using sol-gel alumina, Journal of thermal spray Technology, 8 (1999) 229-234.

9 D. L. Zhang, Z. H. Cai, G. Adam, The mechanical milling of Al/TiO2 composite powders, JOM. 56 (2004) 53-56.

10 A. Salman, B. Gabbitas, P. Cao, D. L. Zhang, The performance of thermally sprayed titanium based composite coatings in molten aluminium, Surface and Coatings Technology. 205 (2011) 5000-5008.

11 A. Salman, B. Gabbitas, D.L. Zhang, Titanium based composite coatings produced by high velocity fuel and plasma spraying methods, Key Engineering Materials, 551 (2013) 127-132

12 A. Salman, B. Gabbitas, D. L. Zhang, P. Cao, S. Raynova, Characterisation of Ti(Al,O)/Al2O3 composite powders and thermally sprayed coatings, Advanced Materials Research. 29-30 (2007) 135-138.