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Research Article

Effect of Air Plasma Spraying Parameters on the Quality of Coating[#]

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Process Variables
Coating
Microstructure

Abstract: In this study, air plasma spraying (APS) has been used to produce a cermet's composite coating based on powder of ceramic oxides (Al_2O_3-3%wtTiO_2) reinforced by mineral powders as bonding material (Ni-20%wtCr6Al) at different rates onto AISI 304 stainless steel substrates. Coating deposition by plasma spraying involves a number of process variables such as powder flow rate, electric current and standoff-distance., which participate in a large way to the best quality of the coating. The obtained results showed that a higher spraying power and a shorter spraying distance result in the higher deposition efficiency, the better microstructure and the higher micro-hardness for the coating. It is concluded that the spraying power and distance are important factors influencing the deposition efficiency, microstructure and micro-hardness of the plasma sprayed (Al_2O_3-3% wt TiO_2) coating.

1. Introduction

Thermal spraying is a technique used in a wide variety of processes and end uses. Atmospheric plasma spraying (APS) is one of these processes [1]. Among different plasma sprayed ceramic and cermet coatings available, alumina-titania ceramic is one of the materials widely used in the APS process. Alumina-titania coatings possess excellent properties on wear resistance and are widely applied in aerospace, textile, chemical, and engineering industries [2-5]. However, all the industrial applications need quality and cost-effective coatings. Since the quality of the coating depends on a large number of parameters [4-6], the optimization of spraying parameters is important for obtaining high-quality coating. The microstructure and the properties of atmospheric plasma sprayed alumina-3wt. % titania composite coating is studied [6-7]. Coatings depend not only on the characteristics of the feeding powder, but are also markedly influenced by various process parameters [3]. In this paper among all parameters of plasma spraying, spraying power and distance are the two main and important factors affect the deposition efficiency, the microstructure and the micro-hardness of coatings.

2.Experimental Procedure

2.1.Materials and substrates preparation

In this experiment an AISI 304 stainless steel substrates was selected for metal substrate. The specimen selected is a technical delivery conditions for general purpose structural steel which is used to build ship, bridge, etc. Ceramic feedstock Al2O3-3%wtTiO2 was used as the main coating. Ni-20%wtCr6Al powder was used as bond coat coating. Table.1 shows materials specifications used for coating measured by Shimadzu 1700 XRF analysis. The substrate specimens were cut to 25x25x2mm; then were sandblasted and cleaned from any oxide and grease with acetone. Grit blasting was carried out with a highly efficient sand blaster with alumina grit size of 10-20 mesh, a sand blaster with a 10 mm nozzle, operating at a blasting pressure of >0.5 MPa. The distance between the substrate and nozzle was 150 mm at a 30° angle. Al_2O_3-3%wtTiO_2 coating was produced onto AISI 304 stainless steel substrate using Sulzer-Metco Atmospheric plasma spray system 9MC equipment,

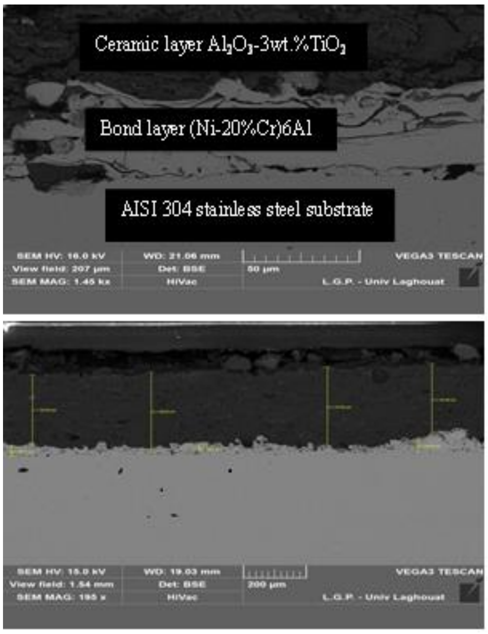


Figure 1. *SEM micrographs of Al_2O_3/3wt.%TiO_2*

Table 1. *Feedstock specification for top powder coating*

Elements	**$Al_2O_3$3%TiO_2**
Al_2O_3	94,5
TiO_2	2,66
SiO_2	2,11
Fe2O_3	0,26
MgO	0,26
others	0,24

using Argon and hydrogen as the plasma arc gases and Argon as the powder carrier gas. Detailed of plasma spraying conditions are listed in Table.2. The effect of spraying power and stand-off-distance, which considered to be the importance parameters spray on the microhardness and the microstructure for these coatings are investigated. Microstructural characterization was carried out with optical microscopy, scanning electron microscopy (SEM). Vickers microhardness tests were performed on polished surfaces of the Al_2O_3-3TiO_2 coatings with a 20gf normal load and a dwell time of 15 s.

Table 2. *APS Coating Parameters*

APS parameters	**Bond coat coating**	**Top coat coating**
Primary gas(Argon & hydrogen) PSI	25	25
Carrier gas (Argon), PSI	90	90-110
Voltage, V	65	65
Current, Amp	550	550-650
Powder flow rate, g/min	20	20-26
Stand-off-distance, mm	90	80-100

3.Result & Dıscussıon

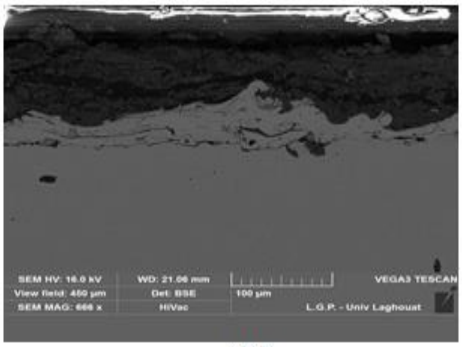
3.1.Characterization of coating

SEM micrographs of: Al_2O_3-3wt.%TiO_2 powder coating is shown in Figure1. There were three different layers seen in Figure 1, namely ceramic layer, intermediate layer and substrate. The coating layers were on average 200 µm and bond layers (Ni-20%Cr)6Al were approximately 50 µm thick. Pores were observed in all coating layers.

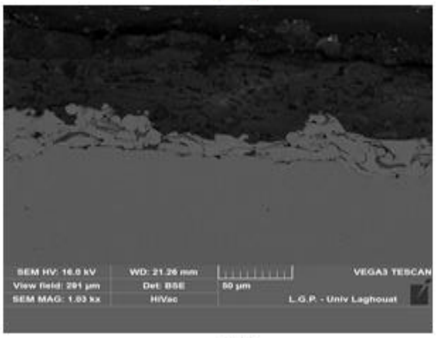
3.2.Effect of Spraying Conditions on microstructure of coating

3.2.1.Effect of spraying Power on microstructure of coating

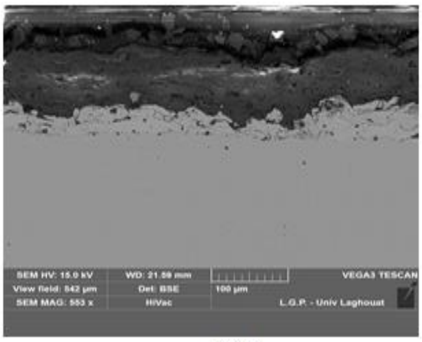
Plasma spray coatings generally contain pores, oxides, un-melted or semi melted particles and some inclusions [10]. Figure 2 shows the optical micrographs of (Al2O3-3wt%TiO2) coatings deposited under different values of the spraying power. It can be seen that the microstructure is apparently related to the spraying power. When the spraying power is the lowest, the sizes of pores are the largest, which can be found in Figure 2(C1). On the contrary, samples deposited with higher spraying powers have better microstructure, which can be seen in Figure 2((C2) & (C3)).



(C1)



(C2)

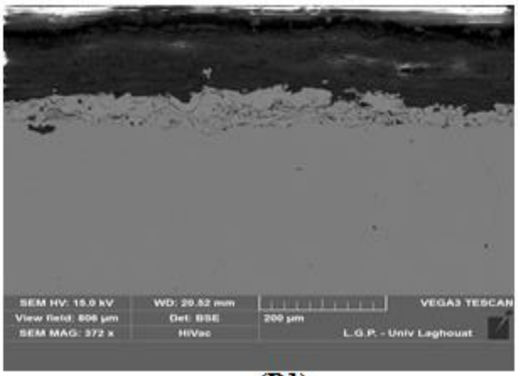


(C3)

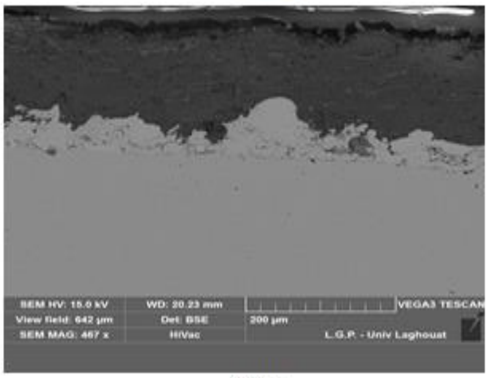
Figure 2. *Effect of spraying Power*

3.2.2.Effect of spraying distance on microstructure of coating

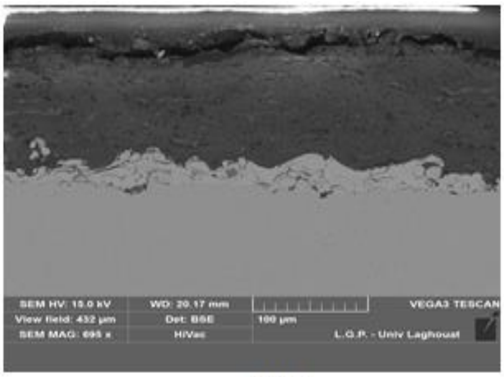
The spraying distances influence apparently the microstructure of the coatings too, as shown in Figure.3. The sizes of pores increase with the increasing of spraying distance. The spraying distance is closely related to the velocity of molten powders when these impact the target substrate. Because the velocity of molten powders from the plasma flow at the spraying distance is higher, less small size pores were found as shown in Figure 3(D1). In turn, some larger pores were observed clearly in the sprayed coating deposited at longer spraying distance such as in the sample shown in Figure 3(D2 & D3).



(D1)



(D2)



(D3)

***Figure 3**. Effect of spraying distance*

3.3.Hardness

Al_2O_3 3%wt TiO_2 coating was measured for the hardness at the polished cross section surface. Vickers micro-hardness measurements were performed under a 20 gf load for 15 s on the cross-sections of the coatings. A total of the diamond indentation tip area was determined by measuring the indentation size after the sample being unloaded.

3.3.1. Hardness VS stand-off-distance

The results demonstrate that spraying distance is an important parameter that influenced on the hardness. Figure 4 shows a graph of hardness versus stand-off-distance set at 80mm and 100mm. The highest and lowest hardness of coating specimens at spraying distance of 80mm were 721.91Hv (P2) and 518.03Hv (P3). The highest and lowest hardness of coating specimens at spraying distance of 100mm were 774.16Hv (P6) and 661.71Hv (P7). The highest hardness of samples for both spraying distance (80mm and 100mm) was identified at current setting of 650A and powder flow rate of 26 g/min. The graph pattern shows that by increasing the spraying distance, the hardness of coating will increase. At shorter distances the plasma beam hits the substrate and overheats it considerably, causing excessively molten particles to splash, creating a less dense coating [9]. It is believed that longer spraying distance provided sufficient time for the powder to dwell and melt properly and hence produced high hardness of coating [8].

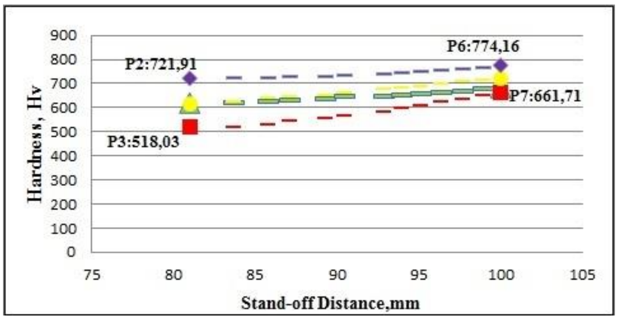


Figure 4. *Hardness Vs Stand-Off-Distance*

3.3.2.Hardness VS Current

Figure 5 shows a graph of hardness versus current setting at 550A and 650A. The highest and lowest hardness of specimens at current set at 550A were 631.87Hv (P8) and 486.15Hv (P3). The highest and lowest hardness of specimens at current setting of 650A were 774.16Hv (P6) and 649.00Hv (P1). The highest hardness of specimens for both current setting (650A and 550A) was identified at spraying distance of 100mm and powder flow rate of 26 g/min. The graph pattern shows that by increasing the current setting, it will increase the hardness of coating. By increasing the current setting, more energy was provided to the plasma beam. As a result, more particles melted and hence the hardness of coating increased [8].

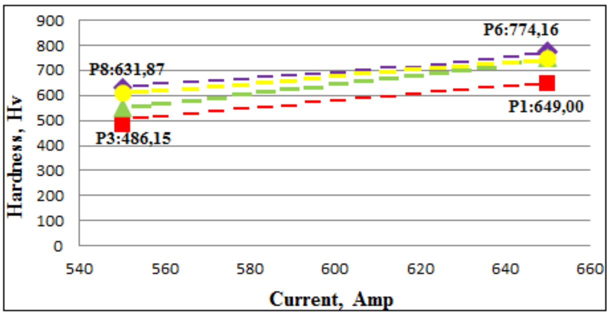


Figure 5. *Hardness VS Current*

3.3.3 Hardness VS Powder flow rate

The effect of the powder flow rate on the microstructure of plasma sprayed coatings is shown in Figure 6 set at 22.5 g/min and 26 g/min. The highest and lowest hardness of specimens at powder flow rate of 22.5 g/min were 726.72Hv (P5) and 460.85Hv (P3). The highest and lowest hardness of specimens at powder flow rate set at 26 g/min were 774.16Hv (P6) and 560.41Hv (P4). The graph pattern shows that by increasing powder flow rate, it will increase the hardness of coating. It is expected that by increasing the powder flow rate, rate of deposited material increased. Therefore, the hardness of coating increased. However, in ensuring homogenous and less porosity coating layers, the current also should be increased to ensure the powders is melted properly when the powder flow rate was increased. The highest hardness of specimens for both setting powder flow rate (22.5 g/min and 26 g/min) was identified at spraying distance of 100mm and current of 650A.

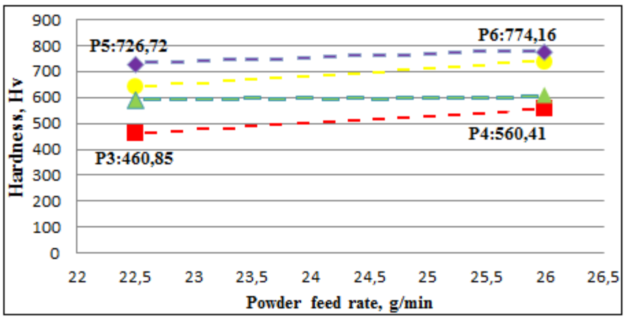


Figure 6. *Hardness VS Powder flow rate*

4.Conclusion

- The parameters setting such as powder flow rate, current and stand-off-distance has provided evidence to directly influence the properties and performance of Al2O3-3%wt TiO2 coating.
- The results indicate, that microstructure, and micro-hardness for plasma sprayed Al_2O_3-3%wtTiO_2 coating depends on spraying power, powder flow rate and distance. It is clear that all the coating process variables and the resulting microstructures strongly effect on the quality of the coating. Other elements such as substrate preparation, bond coating and substrate heating during coating process have to be crucially considered in order to produce good coating quality.

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5. References

[1] M. Cadenas, R. Vijande, H. I. Montes, I. M. Siena, Wear: behavior of laser cladded plasma sprayed WC-Co coatings, Wear 212 (1997) 244-253.

[2] M. Wang, L. L. Shaw, Effects of the powder manufacturing method on microstructure and wear performance of plasma sprayed alumina–titania coatings,Surface and Coatings Technology,202 (2007)1,34–44.

[3] P. Ctibor , P. Boháč, M. Stranyánek, R. Čtvrtlík, Structure and mechanical properties of plasma sprayed coatings of titania and alumina, Journal of the European Ceramic Society 26 (2006) 3509–3514.

[4] M. F. Morks, K. Akimoto, The role of nozzle diameter on the microstructure and abrasion wear

resistance of plasma sprayed image composite coatings, Journal of Manufacturing Processes 10 (2008) 1-5.

[5] S. T. Aruna, N. Balaji, J. Shedthi, V. K. W. Grips, Effect of critical plasma spray parameters on the microstructure, microhardness and wear and corrosion resistance of plasma sprayed alumina coatings, Surface & Coatings Technology 208 (2012)92–100.

[6] E. H. Jordan, M. Gell, Y. H. Sohn, D. Goberman, L.Shaw, S. Jiang, M. Wang, T. D. Xiao, Y. Wang, P. Strutt, Fabrication and evaluation of plasma sprayed nanostructured alumina–titania coatings with superior properties, Materials Science and Engineering A 301 (2001) 80-89.

[7] F.-I. Trifa, G. Montavon, C. Coddet, On the relationships between the geometric processing parameters of APS and the Al2O3–TiO2 deposit shapes, Surface and Coatings Technology 195 (2005) 54-69.

[8] A. R. M. Sahab, N. H. Saad, S. Kasolang & J. Saedon,. Impact of plasma spray variables parameters on mechanical and wear behaviour of plasma sprayed Al2O3-3% wt TiO2 coating in abrasion and erosion application, In Procedia Engineering 41 (2012) 1689-1695.

[9] D. Matejka, B. Benko, Plasma Spraying of Metallic and Ceramic Materials. 1989 John Wiley & Sons, United Kingdom.

[10] D. Wang, Z. Tian, L. Shen, Z. Liu, Y. Huang, Microstructural characteristics and formation mechanism of Al2O3–13 wt.% TiO2 coatings plasma-sprayed with nanostructured agglomerated powders, Surface and Coatings Technology 203 (2009) 1298-1303.