Influence of LPPS Spraying Parameters on Deposition Efficiency of Zirconia Powder

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ABSTRACT

Yttria stabilized zirconia coating is an attractive material for several engineering applications. In order to produce coatings with consistent and reliable performance, it is important to understand the influence of spraying parameters on the coating properties and optimize the spraying parameters. In this paper, the low pressure plasma spray (LPPS) deposition of as-received zirconia powder has been investigated using simple one-factor-at-a-time approach. The deposition efficiency was chosen to evaluate the melting characteristics of the as-received zirconia powder. The results obtained indicated that the deposition efficiency of zirconia powder is very sensitive to the spraying parameters, such as plasma gas flow rate (Argon and Hydrogen), spray distance, chamber pressure and powder carrier gas flow rate and ranges from 24% to 57%. The microstructure and the phase composition of zirconia coating deposited with the different plasma spraying parameters were also examined by SEM and XRD respectively. The relationship between deposition efficiency and the microstructure of zirconia coating was discussed.

1. Introduction

Plasma sprayed zirconia coating is an attractive material for several engineering applications such as thermal barrier coating (TBC) for protecting engine components and wear resistance coating[1-3] because of its superior mechanical properties, high thermal expansion coefficient and low thermal conductivity. Pure zirconia is a polymorphic and undergoes two solid state phase transformations during heating and cooling process, so various oxides such as MgO, CaO, Y_2O_3 and CeO_2 have been used for stabilizing thermally sprayed zirconia powder[1,2]. Many researchers concluded that 6-8 wt % ytrria partially stabilized zirconia powder is the most desirable one for plasma spraying[2,4].The quality of plasma sprayed coating largely depends on the powder characteristics and the spraying parameters. It is necessary to optimize the spraying process in order to produce coatings that possess consistent and reliable performance. There are the control of the powder properties through advanced manufacturing techniques and the determination of spraying parameters. For a given powder, the optimization of spraying parameters needs identifying the parameters, which has significant influence on the properties of the coating. With this view, the simple one-factor-at-a-time experimental method was adopted to investigate the melting degree of as-received zirconia powder during low pressure plasma spraying in this study. The deposition efficiency was chosen to evaluate the particle melting which also closely related to microstructure and properties of a coating.

2. Experimental Procedure

The powder deposited in this study was 7 wt % yttria partially stabilized zirconia. Fig. 1 illustrated the micrograph of the as-received powder. The particles are spherical in shape ranging from 10μm to 106μm, which was produced by spray drying process.

Fig. 1.Morphology of zirconia powder

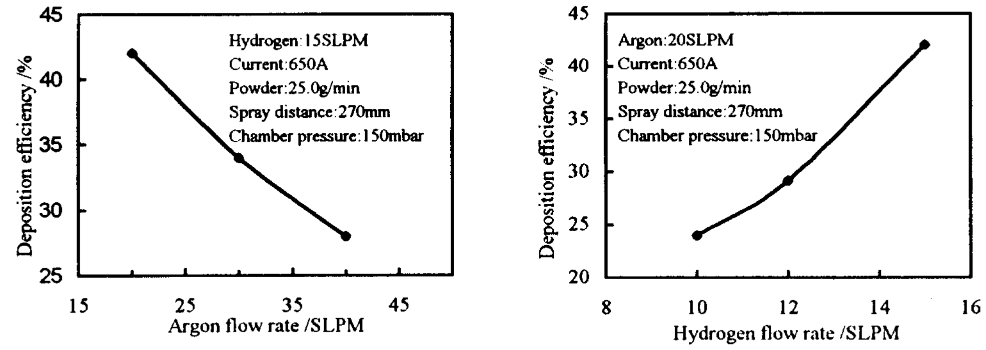
The experiments were done using Sulzer Metco equipment and the coating was deposited on the grit blasted stainless steel. The deposition efficiency was calculated from the coating weight and the powder fed into the plasma gun for a given period of time.

The coating specimen with different deposition efficiency were prepared and observed under a scanning electron microscope. The phase composition was identified by XRD.

2. Results and Discussion

3.1 Influence of plasma gases

The plasma flame was formed using a gas mixture of argon and hydrogen. Fig.2 shows the influence of the plasma gas flow rate on the deposition efficiency of zirconia powder. From Fig.2., it can be seen that with an increase in argon flow rate, the deposition efficiency decreases largely, while increasing the hydrogen flow rate from 10 SLPM to 15 SLPM, the deposition efficiency increases from 24% to 42%. It means that the better melting of the particles can be obtained by decreasing argon flow rate or/and increasing hydrogen flow rate in the plasma gas mixture. This can be explained that hydrogen has a higher enthalpy at the same temperature than argon. The increasing of argon flow rate may enlarge the velocity of plasma flame, which shortens the dwell time of the powder in plasma flame.



a

b

Fig.2.The influence of plasma gas flow rate on deposition efficiency of zirconia powder (a). Argon flow rate and (b). Hydrogen flow rate

3.2 Influence of chamber pressure

The plasma flame profile and temperature in low pressure plasma spraying process were mainly controlled by the chamber pressure when the other parameters keep constant. The energy density in the plasma flame is quietly different even with the equal power input at different chamber pressure. The relationship between deposition efficiency and chamber pressure is shown in Fig.3. The higher the chamber pressure, the higher the deposition efficiency. The plasma flame has higher energy density and lower velocity at high pressure than that at low pressure, which favors the melting of particles[5].

3.3 Influence of spray distance

Spray distance is one of the significant factors that influence the deposition efficiency[7]. Fig. 4 shows that an increase in spray distance from 250mm to 320mm decreases the deposition efficiency from 57% to 47.1%. Although a longer spray distance results in greater dwell time of the particles, the deposition efficiency reduces. S. V. Joshi in his study revealed that the particles surface can already begin to cool down and solidify at a longer spray distance by the time they impact on the substrate[4]. This is unfavorable for the deposition of particles. It should be pointed out that spraying

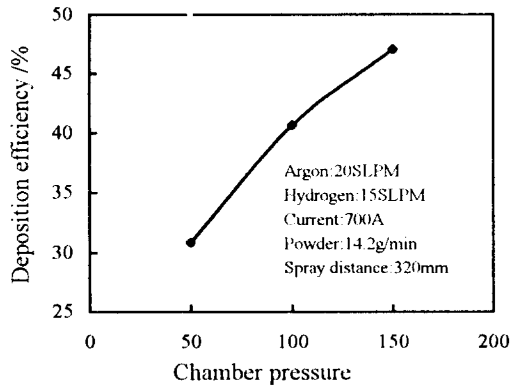


Fig.3. Deposition efficiency vs. chamber pressure

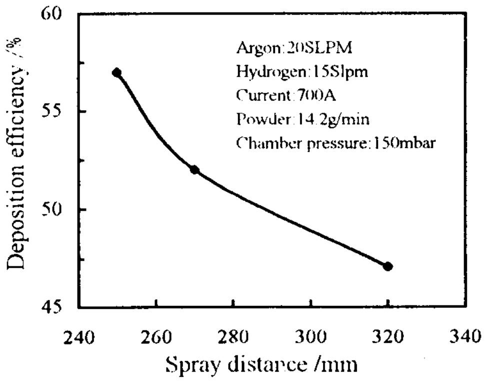


Fig.4. Deposition efficiency vs. spray distance

zirconia powder with a short spray distance would largely cause the increase in substrate temperature which affects the properties of the coating.

3.4 Influences of powder carrier gas flow rate and powder feed rate

The influences of powder carrier gas flow rate and the powder feed rate on deposition efficiency are shown in Fig. 5 and Fig. 6, respectively. As can be seen from Fig. 5, the carrier gas flow rate significantly influences the deposition efficiency because the particle velocity and trajectory depend on the powder carrier gas flow rate. It was clearly observed during spraying that the particle trajectory greatly deviated from the plasma flame centerline when the powder carrier gas increased more than 1.5 SLPM. It is well known that the plasma jet possesses high temperature as well as strong temperature gradient[8].The deposition efficiency decreased, when the particles deviated from the hottest part of the plasma flame. On the contrary, the powder feed rate doesn't show great influence on deposition efficiency because the maximum difference in deposition efficiency is only 2%. The data of deposition efficiency in Fig.6 are less than 40%, which can be attributed to low energy input, high velocity of plasma flame and powder size.

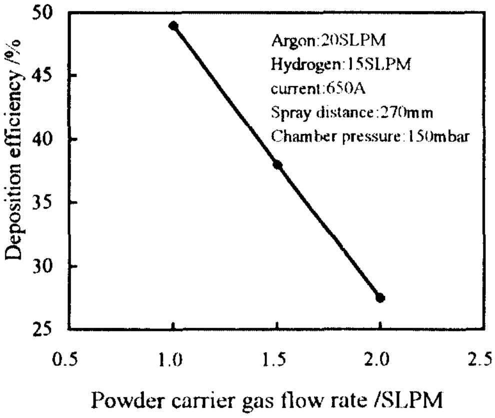


Fig.5. Deposition efficiency vs. powder carrier gas flow rate

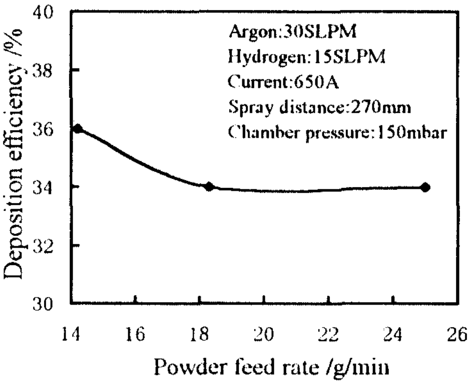


Fig.6. Deposition efficiency vs. powder feed rate

3.5 Influence of gun current

Fig.7 gives the results of deposition efficiency versus gun current. Generally, the increase in current allows a great extent of melting of each powder and/or complete melting of a higher fraction of the powder particles[4]. However, the deposition efficiency in our experiments was improved only by 6% when the current increased from 600 A to 700 A. Insignificant influence of the gun current may caused by the powder characteristic, especially the size distribution.

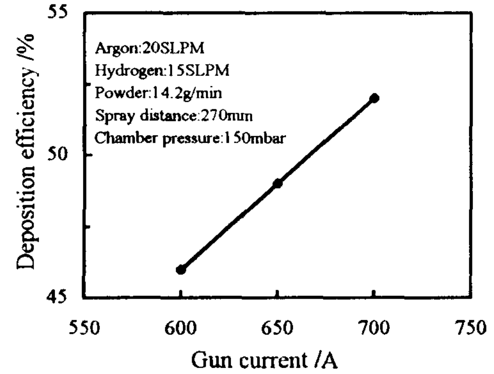
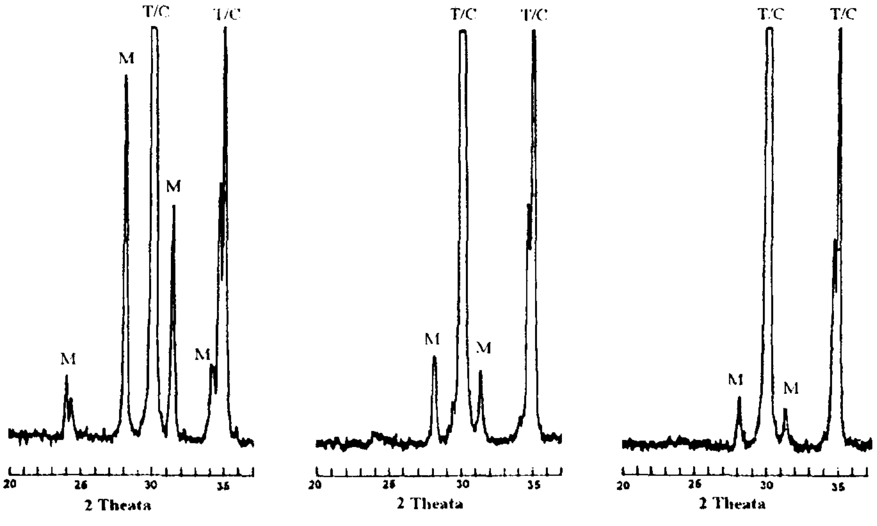


Fig. 7. Influence of gun current on deposition efficiency

3.6 Phase composition and microstructure

The XRD results of powder and as-sprayed coating with different deposition efficiency are shown in Fig. 8. The powder and coating are composed of monoclinic (M), tetragonal (T) and cubic (C) phases and the M phase fraction greatly reduced after spraying, which inferred from the relativity intensity of the peak in the XRD patterns. As compared of the XRD results, It has been indicated that the content of monoclinic phase decreases with the increases in deposition efficiency. Fig. 9 shows the microstructure of the as-sprayed coating, the coatings exhibit a layer structure with some larger voids and some elongated and flat voids between lamellae. The coating with 57% deposition efficiency is denser that with 24% deposition efficiency due to good melting of the particles.



a b c

Fig.8. XRD patterns of zirconia powder and coatings (a). powder (b). coating with 24% deposition efficiency (c). coating with 57% deposition efficiency

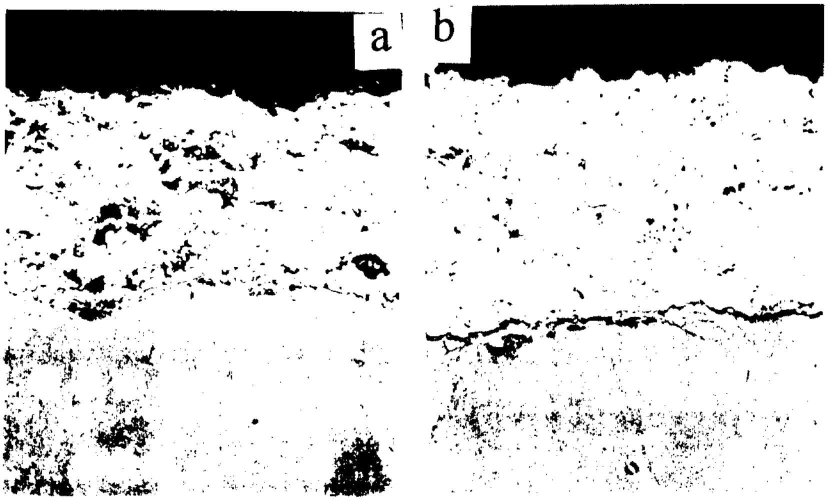


Fig. 9. Microstructure of coatings with different deposition efficiency (200×)
(a) 24% and (b) 57%

4. Conclusions

Zirconia coating deposited by low pressure plasma spraying process was carried out in this study. The results indicated that zirconia powder is very sensitive to spraying parameters. The deposition efficiencies of zirconia powder ranged from 24% to 57%. The plasma gas flow rate (argon and hydrogen), the chamber pressure, the spray distance and the powder carrier gas flow rate were identified to significantly influence the deposition efficiency, whereas the gun current and powder feed rate had a slightly influence on the deposition efficiency in our experiments. The coating deposited with higher deposition efficiency contain less monoclinic phase and exhibits relatively less amount of porosity than that with lower deposition efficiency.

References

1.R.A. Miller, J. Therm. Spray Technol. Vol. 6 (1997), 35
2.S. Bose and J. Demasi-Marcin, J. Therm. Spray Technol., Vol. 6 (1997), 99
3. Ahn, H. S.,Kwon,O.K.,Wear,Vol.162-64, (1993), 636
4. S.V.Joshi and M.P.Srivastava, Sur.& Coat. Technol.,56 (1993),215
5 R. Kingswell, K.T.Scott, and L.L.Wassell, J. Therm. Spray Technol., Vol. 2 (1993), 179
6 D.K.Das,M..P.Srivastava and R.Sivakumar, in Proc. ITSC'86, P23
7. M. Dorfman and J. De Barro, in Proc. ITSC'92, 439
8. G.barbezat, A.R. Nicoll and A.Sichinger, Wear, Vol.162-64, (1993), 52