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Influence of Gas Temperature on Microstructure and Properties of Cold Spray 304SS Coating

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In the present study, 304 stainless steel coatings were deposited on interstitial-free steel substrates by cold gas dynamic spray technology. The effect of gas temperature on microstructure, micro-hardness, cohesive strength, and electrochemical property of the coatings were investigated and compared. The results showed that increasing gas temperature had a great contribution to enhancing the bonding strength between the deposited particles and making the microstructure more density. Therefore, the porosity of the coatings decreased from 6%±0.5% to 2%±0.3%, and the tensile strength of the coatings increased from 56±4 MPa up to 73±3 MPa. In addition, the corrosion resistance of the coatings was also deeply influenced by process gas temperature. The corrosion kinetics of the coatings were affected by both of the plastic deformation of deposited particles and the porosity in the coatings.

KEY WORDS: Cold spray; Gas temperature; 304 stainless steel coating; Microstructure; Property

1. Introduction

Austenite stainless steel coatings deposited by thermal spray technology were widely used for improving corrosion resistance because of their low cost and high efficiency[1–3], but the thermal spray coatings contained high amounts of porosity and micro-cracks which could reduce the corrosion resistance of the coatings used in various corrosive environments[4,5]. Cold gas dynamic spraying (CGDS) is a low temperature deposition process in which particles are accelerated through a De-Laval type nozzle impacting onto the substrate, the bonding of particles is due to extensive plastic deformation at the interface[6], and it has received attention just because it can produce higher quality coatings without significant heating influence[7–12]. Thus, many recent studies were focused on the cold-sprayed austenite stainless steel coatings and most of the previous studies were focused on the deformation mechanism of the impacted particles, microstructure and properties of the coatings, and the effect of annealing treatment on the cold-sprayed coatings[13–19].

In addition, to produce an excellent coating, the cold spraying parameters which are in relation to the coatings physical properties are also very important. Lee *et al.*[20] investigated the influence of gas temperature on critical velocity and deposition characteristics in cold spraying and concluded that increasing gas temperature not only increased the particle deposition efficiency but also decreased the particles critical velocity. Binder *et al.*[21] compared the bonding strength of the cold sprayed Ti coatings deposited by different gas temperature and found that the coating produced at higher gas temperature exhibited a higher bonding strength compared to the lower ones. Phani *et al.*[22] compared the porosity, microhardness and conductivity property of the cold sprayed copper coatings produced at different gas temperature and found that increasing gas temperature could increase the microhardness and conductivity property of the coatings, and also reduce the porosity of the coatings. Zahiri *et al.*[23] reported the effect of processing

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Table 1 Cold gas spray conditions for the experiments

Process gas	Stagnation temperature /°C	Stagnation pressure /MPa	Standoff distance /mm	Powder fade rate /(g/min)
N_2	450	3.0	25	80
N_2	500	3.0	25	80
N_2	550	3.0	25	80

conditions on porosity formation in cold gas dynamic spraying of copper and also found that an increase in gas temperature led to a decline in volume fraction of porosity. Sansoucy *et al.*[24] investigated the mechanical characteristics of Al-Co-Ce coatings produced by different cold spraying parameters but they concluded that no apparent reduction of the porosity and no significant change in the microhardness were noticed by varying the gas temperature. The effect of spray conditions on coating formation by the cold spray process was studied by Han *et al.*[25] and observed that the deposition efficiency of the large aluminum particles increased linearly with increasing gas temperature, and this can be attributed to both increased particle velocity and enhanced particle temperature. Furthermore, the process gas temperature is also very important for the industrial coating process. However, the effect of process gas temperature on the microstructure and mechanical property of 304 stainless steel coatings has not been systematically studied, and the influence of gas temperature on the electrochemical property of the coating is still lacking. Thus, in order to produce an excellent 304 stainless steel coating, it is very significant to analysis the effect of process gas temperature on the microstructure and property of the cold sprayed 304 stainless steel coatings.

In this research, 304 stainless steel coatings were deposited by cold spray technology. The effect of process gas temperature on the microstructure, porosity, micro-hardness, ultimate strength and electrochemical property of the coatings were investigated.

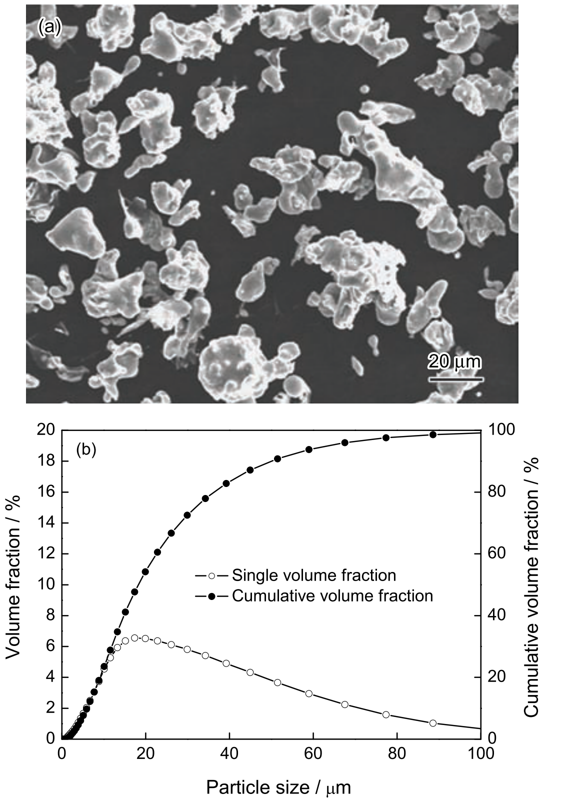

Fig. 1 Characterization of 304SS powder: (a) morphology, (b) particle size distribution

2. Experimental

2.1 Materials and coating deposition

A CGT Kinetic 3000M cold-spray system was used to deposit 304 stainless steel particles onto interstitial-free steel substrate. The cold gas spray conditions were listed in Table 1. The sprayed particles have irregular shape morphology, as illustrated in Fig. 1(a).

The particle size distributions were measured using a Mastersizer 2000E, and outlined in Fig. 1(b). It indicates that the powder has an average diameter of 23.6 μm, the powder size range is about 1.5–100 μm, and about 90% of the particles have a size below 52 μm.

2.2 Characterization

A Hitachi S-4200 field emission scanning electron microscope was used for microscopy studies of powder and coatings. X-ray diffraction (XRD) studies of the powder and the coatings were carried out using a Rigaku D/max-2500PC X-ray diffractometer (Cu$K\alpha$ radiation).

Samples were polished (using an automated Struers Phoenix 4000 polishing machine, Buehler, USA) with 1000, 2000, and 2500 grit SiC papers for 2 min. And then this was followed by 5, 2.5 and 1 μm diamond polishing. Colloidal Al_2O_3 (0.5 μm) was used for final polishing. A small force (15 N) was applied to prevent particle ejection from the specimen surface. The polished samples were prepared for image analysis in which dark areas (representing porosity) scattered in a bright matrix. An image analyzer system (Image Pro Plus, Media Cyber Netics, USA) was used to estimate the volume fraction of porosities for at least 7 random images for each experiment. Moreover, the porosity of thermal spray coatings and also the cold sprayed coatings[22,23,26,27] are normally characterized by using optical microscopy method and the same accepted procedure is followed.