Effect of Powder Characteristics on the Microstructure and Abrasive Wear Performance of HVOF Sprayed Cr_3C_2-25%NiCr Coatings

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KEY WORDS: (Powder characteristics), (HVOF), (Cr_3C_2-NiCr coating), (Microstructure), (Abrasive wear)

1. Introduction

Cr_3C_2-NiCr materials are generally employed to produce hard coating for wear applications including sliding, fretting, abrasion, and erosion either at elevated temperatures, or at room temperature [1, 2]. Cr_3C_2-NiCr coatings deposited by high velocity oxy-fuel (HVOF) technique exhibit excellent wear and corrosion resistance properties [3, 4]. It was well known that coating performance is strongly dependent on the coating microstructure, which in turn is dependent on the characteristics of the feedstock powder [5-7]. Therefore, the objective of this study is to investigate the influence of powder characteristics on the microstructure of sprayed coatings and thus on abrasive wear performance of the coatings. In addition, the wear conditions such as wear load and abrasive particle size on the abrasive wear performance of the HVOF Cr_3C_2-NiCr coatings was also investigated.

2. Experimental Material and Procedure

2.1 Materials

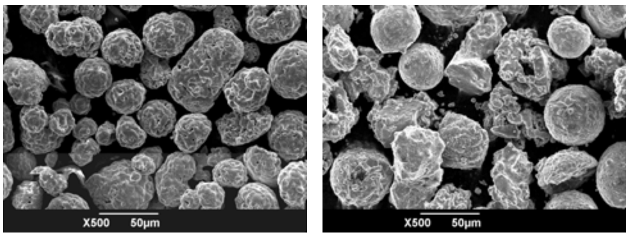
Two types of commercially available Cr_3C_2-25NiCr (wt.%) powders manufactured by agglomerated-sintered and sintered-coated techniques, respectively were studied. Micrographs of the two powders are presented in Fig. 1. The powders are near-spherical and the average particle size was -50+15 μm.

All coatings were deposited using the HVOF spray system (CH-2000) developed in Xi'an Jiaotong University. A detailed description of the system can be found elsewhere [8]. For convenience, the coatings were labeled C1 and C2 signifying agglomerated-sintered and sintered-coated feedstock powder, respectively. Mild steel plate with dimensions of 45mm×20mm×3 mm was used as substrate. Prior to spraying, the substrate surface was cleaned using acetone and sand-blasted using 24 mesh alumina grits. The propane and nitrogen gases were used as fuel and powder carrier gases. The pressures of propane, oxygen, and nitrogen were fixed at 0.4, 0.55, and 0.35 MPa, the flow rate was 33 L/min, 549 L/min and 33 L/min, respectively.

2.2 Abrasive Wear Test and Microhardness

The abrasive wear test was performed with a dry sand rubber wheel abrasion wear tester following the ASTM standard (ASTM Designation G 65–85). The abrasives used in the experiment were alumina with a nominal size of 150 μm and the test conditions are shown in Table 1. The abrasive wear was evaluated by the average weight loss of three samples. For comparison, abrasive wear test was also done on boiler steel (20g) under the same test condition.

Microhardness measurements were done on the transverse section of the coatings using a micro-hardness tester (HXD-1000TMC/LCD) at a load of 2.94 N g and a holding time of 15 s. The average value of ten tests results was used as an indicator of coating hardness.



(a) (b)

Fig. 1 Morphologies of the two feedstock powders: (a) agglomerated-sintered and (b) sintered-coated.

Table 1 Conditions for abrasive wear test

Wheel diameter (mm)	250
Wheel speed (r/min)	60
Load (N)	5, 13
Abrasives (alumina) size (μm)	150, 250
Feed rate of abrasives (mg/min)	100
Test duration (min)	15

3. Results and Discussion

3.1 Microstructures

Fig. 2 shows SEM images of the cross-sections of the HVOF sprayed Cr_3C_2-NiCr coatings. Two coatings show two phases with different contrasts: the Cr_3C_2 particles in dark contrast and the NiCr metallic phase in light contrast. As can be observed, the Cr_3C_2 particles presented an angular shape are well distributed and embedded into the NiCr matrix. Generally, agglomerated-sintered powder has a higher porosity compared to sintered-coated powder, which would result in full flattening of melted or semi-melted particles during HVOF process. Therefore, C1 coating

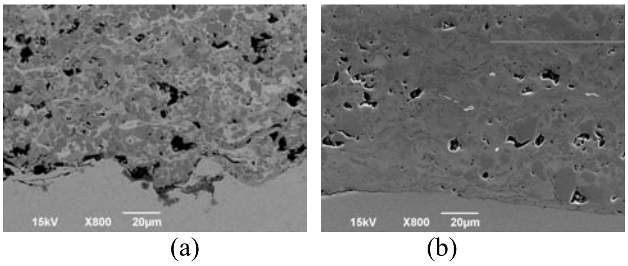


Fig. 2 Microstructure of HVOF sprayed Cr_3C_2-25NiCr coatings: (a) C1 and (b) C2.

exhibits a typical lamellar structure which is formed by the stacking of splats elongated in the direction parallel to substrate surface.

3.2 Porosity and Microhardness

It was well known that the pore existed in the HVOF coating would significantly degraded coating property such as microhardness. The porosity and microhardness of C1 and C2 coating were shown in Table 2. It can be seen that the porosity of C1 and C2 coating was 1.97% and 1.23%, respectively, which was in consisted with microstructure observation shown in Fig.2. As a result, the C2 coating exhibited a higher microhardess about 1013.64$Hv_{0.3}$.

Table 2 Coating porosity and microhardness

Coating	Property	
	Microhardness /$Hv_{0.3}$	Porosity /%
C1	727.62	1.97
C2	1013.64	1.23

3.3 Abrasive wear Test

The influence of abrasive particle size on the weight wear loss of two Cr_3C_2-NiCr coatings and 20g boiler steel under the wear load (13 N) is presented in Fig. 3. It can be seen that both of the coatings exhibited lower weight wear loss in comparison with boiler steel. The wear resistance of C1 and C2 coating under abrasive particle size 150 μm were higher than that of 20g boiler steel by a factor of 36 and 46, respectively. By comparison, the C2 coating exhibited the lower weight loss. Abrasive particle size had significantly influence on the wear performance of Cr_3C_2-NiCr coatings and 20g boiler steel. With raising the abrasive particle size from 150 μm to 250 μm, the weight loss of both coatings and 20g boiler steel significantly increased.

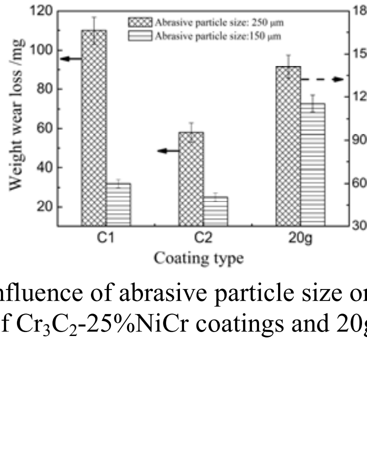


Fig. 3 Influence of abrasive particle size on the weight wear loss of Cr_3C_2-25%NiCr coatings and 20g boiler steel.

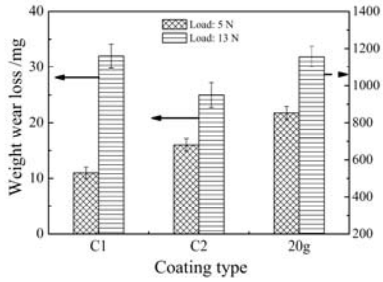


Fig. 4 Influence of wear load on the weight wear loss of different coatings and 20g boiler steel

The influence of wear load on the wear performance of Cr_3C_2-NiCr coatings and 20g boiler steel under the same abrasive particle size (150 μm) is presented in Fig. 4. It can be seen that both of the coatings exhibited lower weight wear loss in comparison with boiler steel. By comparison to C1 coating, the C2 coating exhibits the lower weight loss under wear load 13 N. With raising the wear load from 5 N to 13 N, the weight loss of both coatings and 20g boiler steel significantly increased.

4. Conclusion

Cr_3C_2-25%NiCr coatings were prepared by high velocity oxy-fuel (HVOF) spraying of agglomerated-sintered and sintered-coated feedstock powder. The results indicated that the Cr_3C_2-25%NiCr coating deposited using the sintered-coated feedstock had the lower porosity, higher microhardness and better abrasive wear resistance than those of the coating deposited using the agglomerated-sintered feedstock. The weight wear loss of two coatings increased with increasing wear load and abrasive particle size.

References

[1] B.Q. Wang and Z.R. Shui, Wear. 253 (2002) 550-775.

[2] B.G. Seong, S.Y. Hwang, and K.Y. Kim, Surf. Coat. Technol. 126 (2000) 256-265.

[3] H.J. Kim, Y.G. Kweon, and R.W. Chang, J. Therm. Spray Technol. 3 (1994) 169-178.

[4] Q. Wang, Z.H. Chen, and Z.X. Ding, Tribol. int. 42 (2009) 1046-1051.

[5] M.F. Morks, Y. Gao, and N.F. Fahim, Surf. Coat. Technol. 199 (2005) 66-71.

[6] G. Sundararajan, K.U.M. Prasad, and D.S. Rao, J. Mater. Eng. 7 (1998) 343-351.

[7] S. Wirojanupatump, P.H. Shipway, and D.G. McCartney, Wear. 249 (2001) 829-837.

[8] C.J. Li, H. Yang, and H. Li, Mater. Manuf. Process. 14 (1999) 383-395.