Study on Metal/Diamond Binary Composite Coatings by Cold Spray

H.J. Kim[1,a], D.H. Jung[1,a], J.H. Jang[1,a] and C.H. Lee[2,b]

[1]RIST, Pohang, Korea
[2]Hangyang Univ., Seoul, Korea
[a]khyungj@rist.re.kr, [b]chlee@hanyang.ac.kr

Abstract

Metal/diamond binary composite coatings on Al substrate without grit blasting were deposited by cold spray process with in-situ powder preheating. Microstructural characterization of the as-sprayed coatings with different diamond size, strength and with/without Ti coating on diamond was carried out by OM and SEM. The assessment of basic properties such as tensile bond strength and hardness of the coatings, and the deposition efficiency was also carried out. Particular attention on the composite coatings was on the diamond fracture phenomenon during the cold spray deposition and the interface bonding between the diamond and the Fe-based metal matrix.

Keywords : Cold spray, Metal/diamond composite, Diamond fraction, Diamond fracture

1. Introduction

The cold gas dynamic spray, simply named cold spray, is a relatively new coating process in which coatings of ductile materials can be produced without significant heating of the sprayed powders. The kinetic energy of the impinging particles is sufficient to produce large plastic deformation and high interfacial pressures and temperatures, which appear to produce a solid state bond. The particle kinetic energy at impact is significantly lower than the energy required to melt the particle suggesting that the deposition mechanism is primarily, or perhaps entirely, a solid state process [1-8].

It is possible to produce the ductile metal and ceramic composites (Al and SiC, Al_2O_3, AlN, diamond) as well as the brittle metal and ductile metal composites (W and Cu) by cold spray [5]. In the same sense, it is also possible to make cermet coatings such as WC-Co and Cr_3C_2-NiCr by cold spray deposition [9, 10].

This article describes the diamond/metal (especially SUS 304) binary composite coatings fabricated by the cold spray process. A series of tests were carried out on an Al substrate without sand-blasting to investigate the effects of the diamonds (size, hardness, and presence of Ti coating) on the coating properties.

2. Experimental and Results

Table 1 summarizes the feedstock diamond particles studied for cold spraying. The diamond/metal composite powders were made by mechanical blending of 10 wt.% (~20 vol.%) diamond with metal.

Table 1. Characteristics of the feedstock diamond particles used in this study.

Diamond	Particle Size (μm)	Comments
IMD-BTi	53-63	Ti coated
IMD-B	28-35	
IMD-D	28-35	Harder than B
MBM 8-16	8-16	
MBM-Ti	8-16	Ti coated
MBM 4-6	4-6	

- IMD : Trademark of Iljin Co. (Korea)
- MBM : Trademark of Diamond Innovation Co. (USA)

The cold spray system developed in RIST was used to produce metal/diamond composite coatings in this study. The system includes a powder-carrying gas preheater as well as a main gas preheater, gas pressure regulators, a powder feeder, and a spray gun. The schematic diagram of the cold spray system at RIST can be found in References 9 and 10. The powder feeder used was a commercially available Praxair high pressure powder feeder (Model 1264).

Table 2 summarizes the basic characteristics of the binary composite coatings processed by the cold spray. The deposition efficiency of the coatings and the diamond fraction in the composite coatings are below 46% and ~12% from ~20% in the feedstock powder, respectively.

Table 2. Summary of the coating properties.

Sample code	Deposition Efficiency (%)	Hardness (HV=500 g)	Diamond fraction (Area %)	Tensile bond strength (MPa)
a (SUS/Diamond IMD-BTi)	24	298	4.3	-
b (Fe/Diamond IMD-B)	46	196	5.2	*120
c (SUS/Diamond IMD-D)	35	245	9.5	-
d (SUS/Diamond MBM 8-16)	33	276	11.5	*140
e (SUS/Diamond MBM-Ti)	34	238	6.9	-
f (SUS/Diamond MBM 4-6)	34	190	8.4	-

* Failed in the epoxy

Fig. 1 shows the typical cross-sectional microstructures of the composite coatings processed by cold spray. It seems that the fracturing of diamond particles during impact is mitigated by using finer diamonds although it is difficult to find or differentiate the fractured diamond particles for finer diamonds. It seems that hard diamonds and Ti coated diamonds do not give beneficial effects on the fracturing of diamond during cold spray deposition.

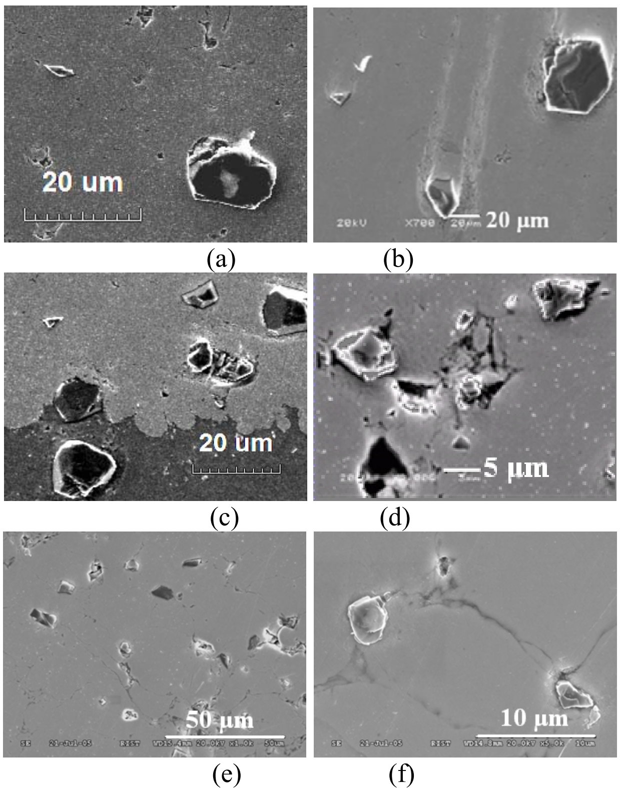

Fig. 1. Cross-sectional microstructures of the composite coatings by cold spray. (Specimen codes in Tabe 2)

3. Summary

The production of the metal (Fe, SUS) and the diamond binary composite coatings by the cold spray was successful. However, the deposition efficiency of the coatings and the diamond fraction in the coatings were below 46% and ~12%, respectively. All of the tensile bond strength of the composite coatings tested were above 100 MPa and all of the coating samples failed in the epoxy. It was difficult to see the pronounced linear effects of diamond size and the strength on the properties of the binary composite coatings by cold spray. There are some metallic/covalent bonding between the Fe-based metal matrix and the diamond particles with/without Ti coating on the diamond in the binary composite coatings. It is observed that some of the diamond particles are fractured in the composite coatings assuming that fracturing of the diamond occurred during cold spray deposition.

4. References

1. A. Papyrin: Advanced Materials & Processes, **159** (2001), 49-51.
2. T.H.V. Steenkiste: Key Engineering Materials, **197** (2001), 59-86.
3. R.C. McCune, W.T. Donlon, O.O. Popoola, and E.L. Cartwright: J. of Thermal Spray Technology, **9** (2000), 73-82.
4. H.K. Kang and S.B. Kang: Scripta Materialia, **49** (2003), 1169-1174.
5. R.S. Rima, J. Karthikeyan, C.M. Kay, J. Lindemann, and C.C. Berndt: Thin Solid Films, **416** (2002), 129-135.
6. R.C. Dykhuizen and M.F. Smith: J. of Thermal Spray Technology, **7** (1998), 205-212.
7. R.C. Dykhuizen, M.F. Smith, D.L. Gilmore, R.A. Neiser, X. Jiang, and S. Sampath: J. of Thermal Spray Technology, **8** (1999), 559-564.
8. H.J. Kim, D.H. Jung, S.C. Bae, and C.H. Lee: J. Kor. Inst. Met. & Mater., **43** (2005), 660-666..
9. H.J. Kim, C.H. Lee, and S.Y. Hwang: Materials Science and Engineering, **A391** (2005), 243-248.
10. H.J. Kim, C.H. Lee, and S.Y. Hwang: Surface and Coatings Technology, **191** (2005), 335-340.