Mechanical Properties of WC/Co Coatings Prepared by Cold Spraying

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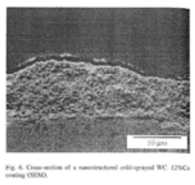
Introduction

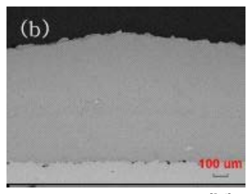
Cold spraying, one of the coating formation techniques can accelerate feedstock powders to deposit onto substrates only using high pressure gas with lower temperature of melting point of the feedstock.[1] Therefore, the low temperature melting metals have been widely investigated, such as Al and Cu up to now. High temperature melting metals of Nb and Ta have become target by the progress of the cold spraying apparatus, such as increasing gas pressure, gas temperature, powder feeding methods and nozzle design. As for hard and brittle materials of ceramic and cermet, this method has been considered to be difficult to apply in general.

Recently, some researches revealed that WC cermet coatings were formed by the cold spraying, where nano-scaled WC particle is effective to increase coating density and hardness. [2-4] However, no investigation has been conducted about wear properties of such a cold sprayed WC cermet coating, as far as we know. In this work, we have investigated influence of WC particle size, powder size and Co content on structural and mechanical properties of cold sprayed WC/Co coatings. Also, the properties have been compared with conventional HVOF coatings.

[1] A.P.Alkimov et al.: USPatent5302414. [2] R.S.Lima et al.: Thin Solid Films 416, p129 (2002). [3] H-J.Kim et al.: Surf. Coat. Technol. 191, p335 (2005). [4] H-J.Kim et al.: Mater. Sci. Eng. A391, p243 (2005).



1st report (WC/12Co)[2]
- Nitrogen gas
- nano-sized WC
- no decarbridization
- 1200HV

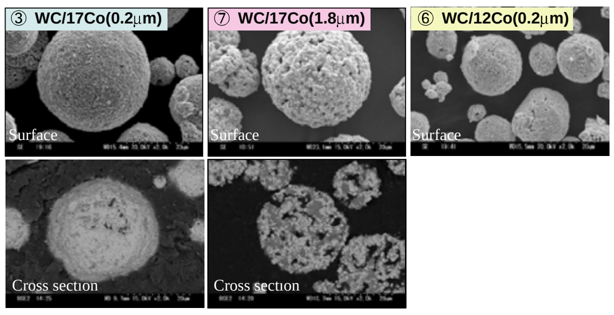


2nd report (WC/12Co)[3-4]
- Helium gas
- nano-sized WC
- no decarbridization
- 2050HV

Experimental procedure

Spray powders (agglomerated-and-sintered WC/Co)

No	Co contents (wt%)	Nominal powder distribution (μm)	Primary WC size (μm)
1	22	-45+15	0.2 (BET)
2		-20+0	
3	17	-45+15	
4		-20+0	
5	12	-45+15	
6		-20+0	
7	17	-45+15	1.8 Fisher sub sieve sizer
8		-10+0	



Spray conditions

Cold Spray (Shinshu Univ.)	Working gas	Gas	He
		Input pressure	3 MPa
		Input temp.	450 ℃
	Powder feed	Gas	He
		Direction	Axial
	Nozzle	Convergent-divergent	370 mm
	Traverse speed		20 mm/s
	Spray distance		15 mm
HVOF JP-5000 (Praxair)	Oxygen flow rate		896 l/min
	Fuel flow rate		0.32 l/min
	Barrel length		203.2 mm
	Spray distance		380 mm

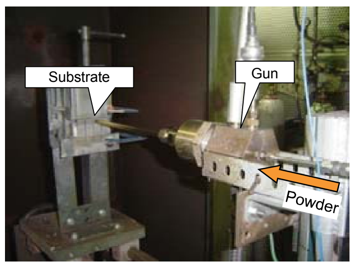
Sample preparation

Substrate material	304 Stainless steel
Substrate size	$30 \times 60 \times 2.5^{t}$ mm
Pretreatment	Blasted (alumina grit #40) Degrease by ultra sonic cleaning

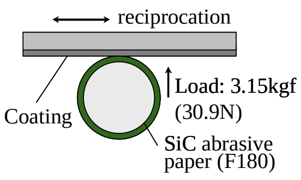
Characterization of the coatings

* Microstructural analysis (Optical microscope, SEM)
* Micro Vickers hardness (1.96 N, 10 s)
* Crystal structure (X-ray diffraction)
* Abrasive wear test (Suga abrasion test)

Cold spraying



Suga abrasion test

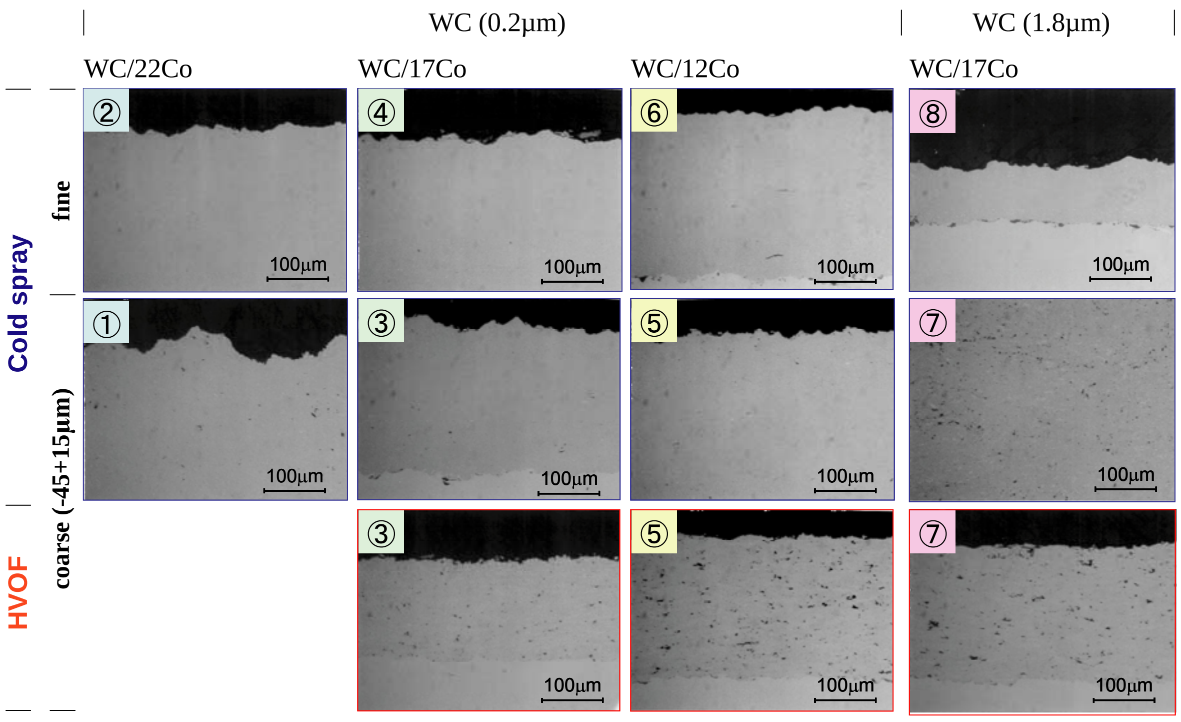


Volume loss of carbon steel (JIS SS400) was set to reference.

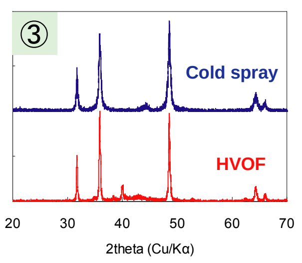
Results and discussion

Micro and crystal structures

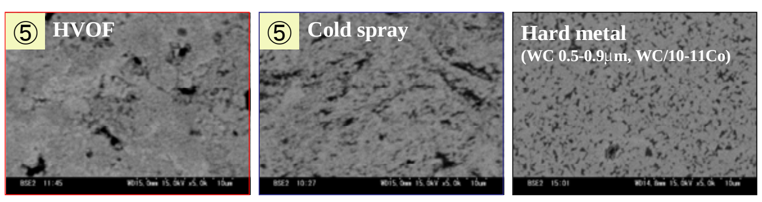
Cross section (optical microscope)



X-ray diffraction patterns

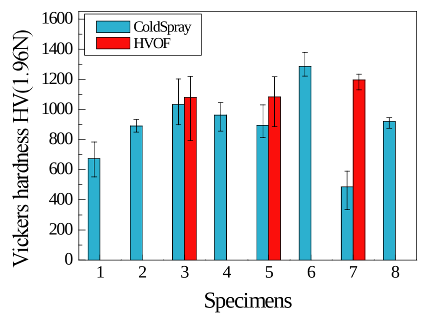


Micro structures (cross-sectional SEM)

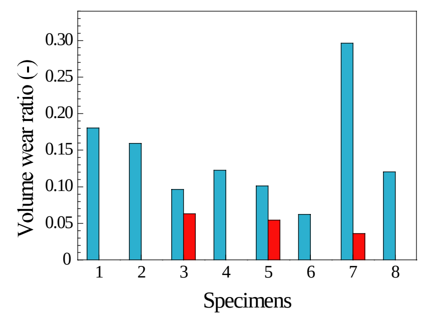


Mechanical properties

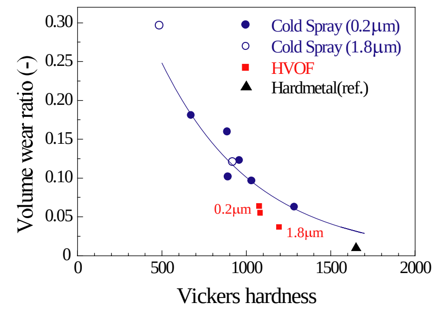
Micro Vickers hardness



Abrasive wear resistance



Abrasive wear vs. hardness



Morphology:
Dense coatings have been formed without large-scaled pores observed in the HVOF coatings. Using smaller powder and smaller WC particle are better to produce dense, hard and wear resistant coatings.

Crystal structure:
No decarburization is identified by XRD analysis. That shows low temperature gas jet is effective to reduce excess heat during spraying.

Mechanical properties:
Wear resistance becomes better with increasing hardness within this study. Both hardness and wear resistance are almost comparable to the HVOF coatings when selecting best powder (No. 6). Both properties are still inferior to hard metal. It is likely that inhomogeneous coating structure and small sized pores seen in SEM image degrade them. Horizontal cracks seen in the No. 6 coating suggest high internal compressive stress. This implies that denser cold sprayed coating is easily detached or peeled off by mechanical impact.
Optimization of powder properties as well as spray parameters is further required to improve the coating characteristics.

Influence of powder properties:
Smaller powder, smaller WC particle and lower Co content materials are effective to make hard and wear resistant coatings. Cold sprayed coatings formed by larger WC particle (standard in HVOF) have quite lower mechanical properties.

Conslusions

It has been found that powder properties in right table should be used to make harder and highly wear resistant coatings by cold spraying. WC/12Co (No. 6, WC size: 0.2 μm and powder size: -20+0 μm) powder produces the best coating within this study. Wear resistance of the No. 6 coating is almost comparable to the HVOF coating but it was still inferior to hard metal. Optimization of both powder properties and spray parameters should be conducted to improve the mechanical properties.

To produce hard and high wear resistance

Powder size	Fine
WC size	Fine
Co content	Low

Coating characteristics (Compared to HVOF)

Morphology	Denser
Crystal structure	No decarburization
Hardness	Comparable/Higher
Wear resistance	Comparable

Acknowledgement
"Feasibility Study for the Development of Innovative Materials by Cold Spray" was subsidized by Japan Keirin Association through its Promotion funds from KEIRIN RACE and was supported by the Mechanical Social Systems Foundation and the Ministry of Economy, Trade and Industry.