Hybrid Composite Nano-sized WC-Co Cemented Carbide

Sun-Yong Park[1,a], Wan-Jae Lee[2,b]

[1,2]Department of Metallurgy and Materials Engineering, Hanyang University,
Ansan, 425-791, Korea
[a]nacozy@lgsiltron.co.kr, [b]wan-lee@hanyang.ac.kr

Abstract

To improve the mechanical properties of WC-Co cemented carbides, the dual composite was studied. The compositions of granule and matrix were nano-sized WC-6 wt% Co(granule) and normal sized WC-20 wt% Co(matrix), respectively. The granules were grouped 50, 100 and 150 ㎛ and mixed with WC and Co powders as the volume fractions of granule to matrix were 50 to 50, 40 to 60 and 30 to 70. These compacts were sintered at 1380℃ for 10 minutes in vacuum. The microstructure, transverse rupture strength and wear resistance were investigated.

Keywords : mechanical properties, dual composite, nano-sized WC, WC-Co granule, sintering, wear resistance

1. Introduction

Dual composite of cemented carbide is composed of granules of cemented carbide in the matrix of WC-Co cemented carbide.[1] The wear resistance of WC-Co is proportional to its hardness, but inversely to the fracture toughness.[2] Improving both of the wear resistance and fracture toughness is very important to mining tools.[3] Recently, the nano-sized WC-Co cemented carbide increased the both of its hardness and toughness.[4]

In this study, we tried to design a microstructure that the granules of nano-sized WC-6 wt% Co cemented carbide imbedded in the matrix of the conventional WC-20 wt% Co cemented carbide. The unique composite microstructure was expected to increase the hardness, transverse-rupture-strength(TRS), fracture toughness and wear resistance of cemented carbide.

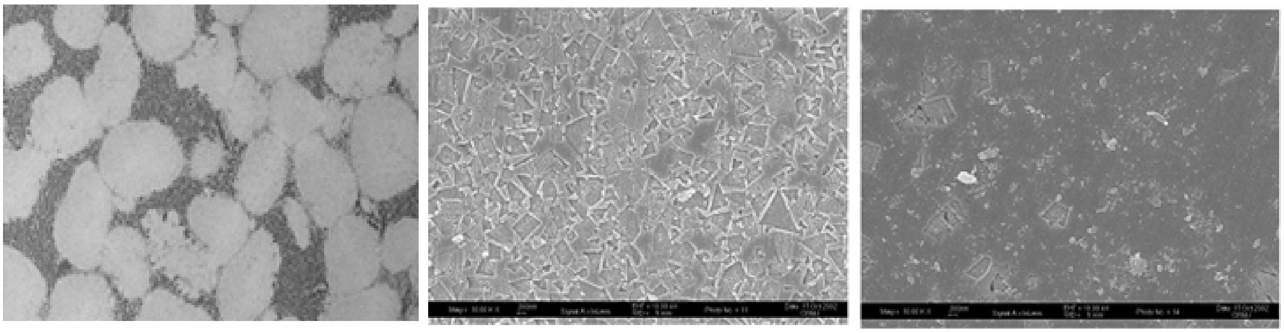
2. Experimental and Results

The nano-sized WC/Co composite powder(Nanotec Co, WC 0.4 ㎛), VC(H.C. Stark, 1.4 ㎛) and Cr_3C_2(H.C. Stark, 2.9 ㎛) were mixed with 2 wt% paraffin in ethyl alcohol by attritor for 20 hours. The contents of VC and Cr_3C_2 were added 1.0 wt% of Co, respectively. The mixed slurry was dried and granulated by a spray dryer. After then the dried granules were de-waxed at 350℃ for 1 hour and sintered at 1380℃ for 10 minutes in vacuum furnace. These granules were sieved to separate the sizes of 50, 100, 150 ㎛. Each size granule was mixed with the conventional WC-20 wt% Co cemented carbide as matrix. The volume fractions of granule to matrix were 50 to 50(named DC1), 40 to 60(DC2) and 30 to 70(DC3). The granules were mixed with the powders of WC(Nanotech Co. 0.4 ㎛), Co(ZouZhou Co., 1.5 ㎛) and paraffin by dry-milling for 2 hours. The mixed powder was pressed with 150 MPa. These compacts were de-waxed at 350℃ for 1 hour and sintered at 1380℃ for 10 minutes in vacuum furnace.

The microstructures of sintered compacts were observed by the optical microscope(OM) and SEM(JEOL Co., JSM-6330F). The mean free path(MFP) was calculated by Fullman formula.[5] The shrinkage and density of compacts was measured by Archimedes' method(ASTM B 328). The magnetic saturation($4\pi\sigma$) and coercive force(Hc) were tested by Saturation Induction Measuring System(Model SM-8100). The carbon content of sintered compacts was detected by Carbon Analyzer(Leco WC-200). The binder phase(Co) was analyzed by XRD(Philips Co., PW1730) with CuKα. The mechanical properties, TRS(JIS B4104), Vickers hardness(Matsuzawa Seiki Co., Ltd. MV-1) and wear test(ASTM G99) were carried out. The fracture toughness was calculated by Palmqvist Toughness Test Method after measuring the crack length on hardness indenters.[6]

From the morphology and microstructures of WC-6 wt% Co granules sintered at 1380℃ for 10 minutes, the mean sized of WC grains was about 0.4 ㎛. There was not pore, but some grains were abnormally large. The total carbon was about 5.82 wt%, magnetic saturation about 75 wt%, hardness HRA94. Therefore we thought the microstructure was favorable except the abnormal grains.

Fig. 1 showed typically the morphology and microstructure of the DC2 sample sintered at 1380℃ for 10 minutes. The mean free path(MFP) of granules of WC-6 wt% Co increased as the volume fraction of matrix and the glanule size increased. There were some abnormal grains of WC and the WC grains were not homogeneously distributed in matrix, too. The mean free path(MFP) of 50 ㎛ granules was about 27, 50 and 75 ㎛ in the specimens of DC1, DC2



(a) (b) (c)

Fig. 1. Microstructures of DC2 sample sintered at 1380 for 10 min., (a) DC2, (b) granule and (c) matrix.

and DC3, respectively. The MFP of dual composite was about 10 times higher than conventional cemented carbide. The contents of total carbon were 4.29, 3.95 and 3.45 wt% in the specimens of 50, 100 and 150 ㎛ granules of DC1. And the value of magnetic saturation ($4\pi\sigma$) was about 88.8% of theoretical value, 390(DC1), 467(DC2) and 549 gauss cm^3/g(DC3).

The linear shrinkage of sintered compacts were about 12.8%(150 ㎛) and 16.6%(100 ㎛) in DC1 specimen. The relative density of sintered compacts was about 98% of theoretical density. The relative density increased as the size of granule and the volume fraction of matrix increased.

The lattice parameter of binder phase(Co) was about 3.5484 Å from XRD data. This value was a little lager than 3.3544 Å of metal cobalt in JCPDS. It was thought that the binder phase held the atoms of W and C in solution.

The hardness was increased as the specimens of 50, 100 and 150 ㎛ of DC1 were about HV917, HV860 and HV800, respectively. And the samples of 50 ㎛ of DC1, DC2 and DC3 were about HV917, HV900 and HV750 respectively. The mean free path(MFP) of granules in matrix was increased as the size of granule and matrix volume increased. TRS of sintered compacts was about 2069, 1873 and 1795 MPa in 50, 100 and 150 of DC2, respectively.

The fracture toughness(K_{Ic}) was increased with the volume fraction of matrix, about 37, 41 and 42 MPa$\sqrt{\ }m^2$ in DC1, DC2 and DC3, respectively. The weight loss was decreased as the granule size and the volume fraction of matrix increased. After wear test, the minimum weight loss was about 0.0135 g in the specimen of 50 ㎛ of DC1 and 0.001 g in the specimen of 150 ㎛ of DC1.

According to the morphology of wear tested specimens, the granules resisted the wear and protected the matrix.

3. Summary

The dual composite of cemented carbide was studied in respect to the granule size and matrix volume fraction. The granule of nano-sized WC-6 wt% Co showed the good microstructure with abnormal grain growth. The sintered density of dual composite improved up to 98% of theoretical density as the matrix volume increased. The mean size of WC grains in granule was about 0.4 ㎛. The linear shrinkage of dual composite was about 18.5% in DC3 specimen. The relative density of sintered specimen was about 98% of theoretical density. Vickers hardness of DC1 specimen was HV917 in the granule size of 50 ㎛. Fracture toughness(K_{Ic}) of DC3 specimen was about 42 MPa$\sqrt{m^2}$. The minimum weight loss was about 0.001 g in the specimen of 150 ㎛ of DC1.

4. References

1. Z. Fang, G. Lockwood and A. Griffo: Metallurgical and Materials Transaction A, **30A,** 3231(1999).
2. Z. Fang: *Metals Handbook*, ASTM International, Materials Park, OH, **Vol. 7**, 965(1998).
3. G. Gille, J. Bredthauer, B. Gries, B. Mende, and W. Heinrich: Int. J. Refractory Met. Hard Mater., **18,** 87 (2000).
4. B.K. Kim, G.H. Ha and G.G. Lee: Nanostructured Materials, **9,** 223(1997).
5. R.L. Fullman: J. of Metals, **6,** 447(1953).
6. W.D. Schubert, H. Neumeister, G. Kinger andB. Lux: Int. J. of Refractory Met. & Hard Mater.,**16,** 136(1998).