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THE EFFECT OF VC AND C ADDITIONS ON MICROSTRUCTURE AND PROPERTIES OF ULTRAFINE SINTERED WC-6%CO

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ABSTRACT

Ultrafine, cemented tungsten carbide (WC) possesses exceptional hardness, wear resistance and high strength in various applications such as cutting tool product. In this study, WC (<0.2 µm)-6%Co (1.6µm) was produced through powder metallurgy technique via cold isostatic pressing (CIP). Different inhibitors such as Vanadium Carbide (VC) and Carbon(C) were added in WC-6%Co's ratio to investigate the effects on sintered WC-Co produced in term microstructure and mechanical properties. The processing route was started with mixing process by tubular mixer at 50 r.p.m for 3 hour using ratio (100g powder: 300g of Tungsten ball) which involving 3 formula's of 94wt% WC + 6wt%Co, 93.8wt% WC+ 6wt%Co + 0.2wt%C and 93.2wt% WC+ 6wt%Co + 0.2wt%C+ 0.6 wt%VC. Each formula was added with (1wt% wax parafin, + 60ml heptene) to create the wet mixing powder. After that, wet mixing powder is placed onto microprocessor controlled oven for 1-2hours at 60˚C for dying process to remove of binder. Then, green body samples were produced by cold compaction process at 18.5 tons continued by cold isostatic pressing (CIP) was performed at temperatures 30KPsi tons. After that, the sintering process via Tube furnace 1500 ˚C for 8 – 9 hours at 1400˚C is run using nitrogen-based ($95\%N_2 + 5\%H_2$) gases atmosphere. Finally, the effects of different inhibitors were analyzed and comparable with commercial sample. It showed the carbon content is strongly improved the mechanical and physical properties meanwhile the existence the Vanadium Carbide (VC) content obviously control the microstructure and grain growth of Sintered WC-Co's properties.

General Terms

Cemented carbide.

Keywords

Ultrafine, cemented tungsten carbide (WC), cold isostatic pressing (CIP), nitrogen-based gases atmosphere

1. INTRODUCTION

WC-Co cemented carbides are widely used for machining, cutting, drilling, mining, forming tools and wear resistant parts, for their exceptionally high hardness, excellent wear resistance and better toughness than other hard materials. However, WC is difficult to machine because of its hardness, especially in fabricating products with small sizes and complex shapes. In this study, powder metallurgy technique via compaction process was used because this technique possesses capability to produce of WC carbides with micro-geometrical features, complex shapes at low cost and reduce of secondary finishing [1]

Small amounts of grain growth inhibitors such as VC, Cr3C2, NbC, TaC, Mo2C and other carbides, were added to control the grain growth of WC [2]. Vanadium carbide (VC) is considered the most effective grain growth inhibitor because of its high solubility and diffusivity in liquid cobalt phase at relatively low temperature [2]. The effect of VC as a grain growth inhibitor has been explained in the presence of a liquid metal binder by slowing the mechanism of solution re-precipitation of W and C in a liquid binder phase[2]. By limiting the dissolution of W and C grains in the liquid phase, grain growth is consequently slowed down. Meanwhile, the carbon element has low thermal expansion coefficient, high density and lubricating properties [3].The existence this material is largely affected strength of particle-matrix interface, as well as in term density, mechanical properties, transverse rapture strength and wear properties[4]. In previous studies, WC-Co has been fabricated using fine particle WC (1.2 μm) without addition any different inhibitors[5]. The aim of this study was to investigate the effects of VC as a grain growth inhibitor to control the grain size and effects of C in term on microstructure/mechanical properties of WC produced via CIP method.

2. MATERIALS AND METHODS

WC (<0.2 μm) and Co (1.6μm) supplied by Buffalo Tungsten Inc., New York and VC (99% purity) was manufactured by Changsha Asian Light, China. Meanwhile, the carbon uses activated carbon produce from Malaysian Palm Oil Board (MPOB) oil palm kernel shell produced by pre-carbonization process.

The processing route was started with mixing process by Tubular Shaker Mixer at 50 r.p.m for 3 hours using ratio (100g powder: 300g of Tungsten ball) .The mixing process involves 3 formula of 94wt% WC + 6wt%Co, 93.8wt% WC + 6wt%Co + 0.2wt%C and 93.2wt% WC+ 6wt%Co + 0.2wt%C+ 0.6 wt%VC. To produce the wet mixing, wax paraffin and heptene were added on each formula to produce homogeneous mixture. Wax paraffin acts as binder for compaction process to combine the WC with Co and heptene acts as wetting agent because combination between ultrafine powders was not suitable using the dry mixing. Then,slow heating is done via Microprocessor Controlled Oven for 1-2 hours at 60˚C to remove the organic binder

After that, the mixed powders are compacted to preform of green body sample (15 mm length × 15 mm width) via Hydraulic Press 30T machine at room temperature, pressure at 18.5 tons for 1 minute holding time. Then, each pre-form sample is inserted into balloon to subject the process of ColdIsostatic Pressing (CIP) at temperatures 30KPsi tons. This process involves the pressurized hydrostatically in a chamber using the water and the pressure acted in all direction. Finally, it continued by sintering process via Tube furnace 1500 ˚C that performed in nitrogen-based (95%N_2 + 5%H_2).The cycle sintering steps are introduced (450-1320-1400°C) which heating rate was 5°C/min up to 450°C and 10°C/min for the remainder of the sintering cycle.After the sample have passed the process of powder metallurgy route, it would be evaluated for their physical, mechanical and wear properties .The samples were etched for 5min with Mukarami solution for identifying of microstructure characterization by Scanning Electron Microscope (SEM) and mineralogy element using X-ray Diffraction (XRD) .

Then, relative density of the sample are measured by using Electronic Densimeter. Hardness was conducted using Vickers Hardness (HV) tester at load 500 gram. Transverse rupture strength (TRS) test was done using Universal Testing Machine (UTM) type INSTRON 3369. All the characterization results were calculated as the average of at least three readings. Lastly, all data were analyzed and comparable with commercial sample (cutting tool insert).

3. RESULTS AND DISCUSSION

3.1 Density Test

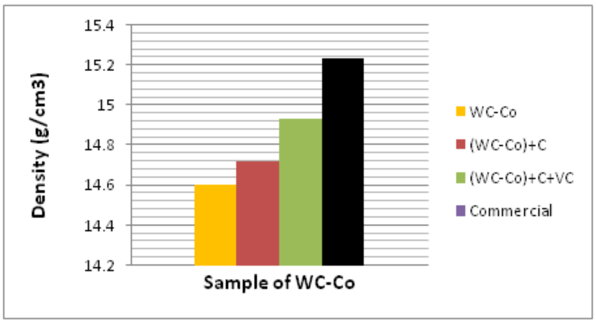


Fig. 1. Density of each WC-Co sample and commercial sample.

Figure 1 shows density result the each WC-Co sample is produced via CIP process and commercial sample. It indicated the density value of each different WC-Co sample did not achive the standard testing result of commercial sample (15.231g/cm3) , but [(WC - Co)+C+VC] sample have the best density if compared with [(WC-Co)+C] and (WC-Co).The main factor to influence the density value due the volume of the samples and degree of porosity. It can be concluded the commercial sample possess an excellent characterization in term higher packing ratio condition because higher density value. Similar conclusion are found in the research done by *Zhigang Zak Fang* [6].

3.2 Hardness Test

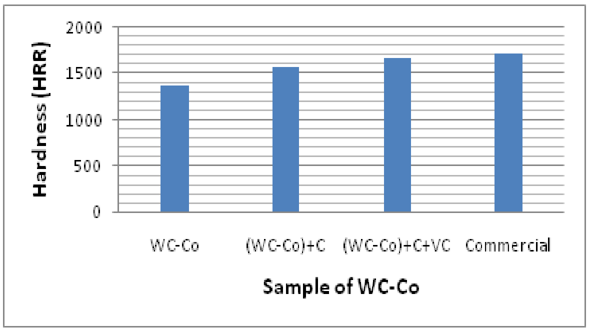


Fig. 2: Hardness of each WC-Co sample and commercial sample.

The hardness results of each WC-Co sample that produced and commercial sample are tabulated in figure

2. In term of effect the VC and C additions condition, it showed the hardness value of WC-Co using VC and C addition (1671 HV) is higher if compared WC-Co using C addition only and pure WC-Co. Besides that, there is not much different hardness value between commercial sample (1723 HV) and WC-Co using VC and C addition. It demonstrated, the existence of VC and C element are strongly affected in term mechanical and physical properties.

3.3 Transverse Rupture Strength (TRS)

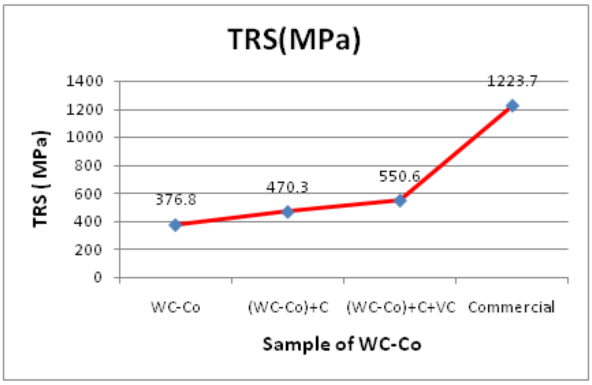
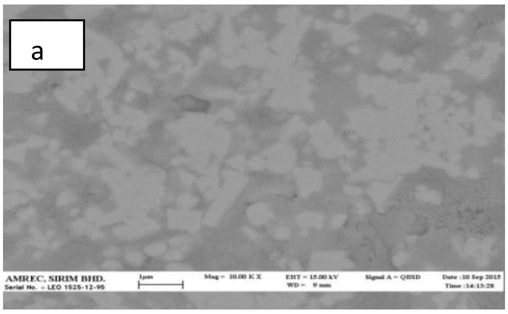


Fig. 3: Transverse rupture strength (TRS) of each WC-Co sample and commercial sample.

Figure 3 represents the Transverse rupture strength (TRS) of WC-Co sample for each addition element and commercial sample. In term comparison between each addition element of WC-Co, the highest TRS result is [(WC-Co) +C+VC)], with 550.6 MPa followed up [(WC-Co)+C] with (470.3MPa) and pure WC-Co (376.8MPa). It demonstrated, (VC and C) additions element provide a special characterization in term strength properties because value of TRS is higher. However, the TRS value of each different WC-Co sample did not achive the standard result of commercial sample .It probability related the structure of cross-section of the sample. This declaration was proven in previous research from Zhigang in his paper had declared when the porosity level is higher in cross-section sample, the density and TRS properties will become lower [6].

3.4 SEM Micrographs



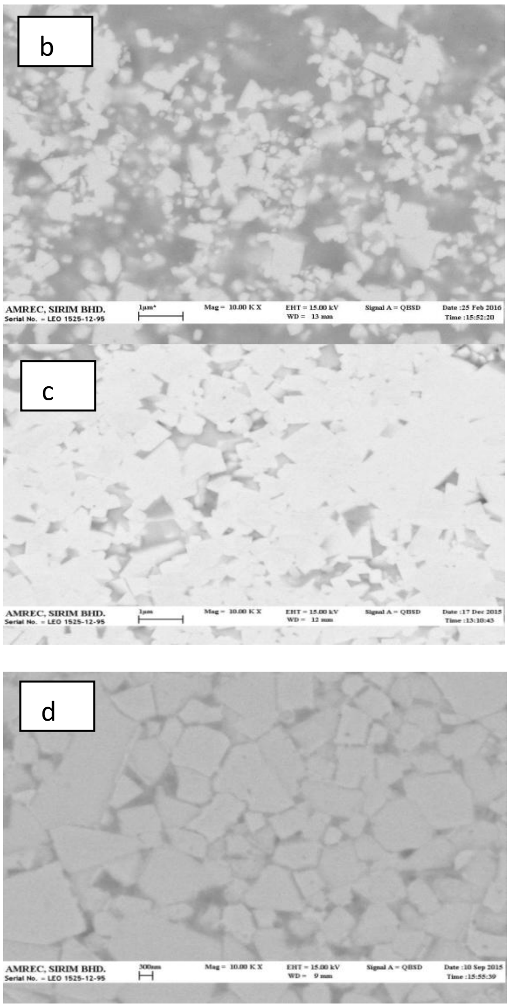


Fig. 4:SEM micrographs of each WC-Csample (a) WC-Co , (b) (WC-Co)+C (c) (WC-Co)+C+VC ,(d) Commercial

SEMmicrographsof C-Cu composites for each WC-C sample (a) WC-Co , (b) (WC-Co)+C, (c) (WC-Co)+C+VC and (d) commercial sample are shown in Figure 5. From this result, all samples indicated the grain growth boundaries are tendency to form the rectangular shape. It is proven in previous research that WC-Co sintered nitrogen-based gases prefer to form rectangular shape microstructure [5].

In term of effect the VC and C additions on microstructure condition, it showed the grain growth formed of WC-Co sample that using C addition only is not properly formed if compared with WC-Co sample that contains VC element. SEM micrographs of [(WC-Co)+C+VC] sample and commercial sample show obviously the compactable rectangular shape have been formed onto their surface morphology to develop strongly of grain growth layer as well as it will reduce the porosity formed and provides the good contact bonding between particle phase. This condition is not properly occurs onto the surface morphology of pure WC-Co and [(WC-Co)+C] instead their micrograph seem in progress to develop grain growth bonding. It exhibited the existence the Vanadium Carbide (VC) content obviously control the microstructure formed and rapidly grain growth of WC-Co samples. This statement was proven in previous research from Wong Yee Ningin his paper had declared about effects of vanadium carbide on sintered WC-Co producedby Micro-Powder Injection Molding [2].

4. CONCLUSION

Based on the discussion section, it shows that different inhibitors such as Vanadium Carbide (VC) and Carbon(C) are strongly affect the microstructure and properties of WC-Co. In the nutshell, carbon content influences the mechanical properties meanwhile the existence the Vanadium Carbide (VC) aims to control the microstructure and grain growth of ultrafine Sintered WC-6%Co.

5. REFERENCES

[1] XIAO Dai-hong, HE Yue-hui, LUO Wei-hong, SONG Min (2019). Effect Of VC And Nbc Additions On Microstructure And Properties Of Ultrafine WC-10Co Cemented Carbides, Trans. Nonferrous Met.Soc.China 19(2009) 1520-1525

[2] Wong Yee Ning, Norhamidi Muhamad, Abu BakarSulong, AbdolaliFayyaz,Muhammad Rafi Raza (2015) , Effects Of Vanadium Carbide On Sintered WC-10%Co Produced By Micro-Powder Injection Molding ,SainsMalaysiana 44(8)(2015): 1175–1181

[3] Aziz, A. A., Deraman, M., Mamat, R., Mokhtar, A., Hasan, W. H. W., Ramli, R. & Ismail, I. Carbon black from empty fruit bunch, MPOB Information Series, Malaysia (2006).

[4] Azcona I, Ordonez A, Sanchez J M, Castro F, Hot isostatic pressing of ultrafine tungsten carbide-cobalt hardmetals [J],J Mater Sci, 2002, 37(19): 4189−4195.

[5] M.A.Selamat,A.A.Mahaidin,S.AbdulManaf and T.RiaJaafar (2014) Sintering Behaviour, Microstructure And Mechanical Properties Of Sub-Micron Hardmetals Powder Processed In Nitrogen-Based Atmosphere, Advanced Materials Research Centre (AMREC), SIRIM Berhad.

[6] Zhigang Zak Fang: Correlation of Transverse Rupture Strength of WC-CO with Hardness, Utah, USA, 2011.