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Study of milling effect on particle size and mechanical properties of WC-Co composite

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ABSTRACT: The effect of milling on the particle size and mechanical properties Tungsten Carbide - Cobalt composite were investigated. First, raw materials ratios by mechanical milling for 4 hours at 300 rpm were mixed. The powder in the optimum temperature 1350°C at a rate of temperature rise 50°C / min and shelf life of 4 minutes and the pressure MPa 30 were sintered in SPS. The results indicated nearly full dense was obtained for sample. The calculated mechanical properties revealed optimum amounts of 14.25 GPa hardness, 772 MPa bending strength and 13.86 MPa.m1/2 fracture toughness. The XRD analysis indicated the dominant identified phases was WC. The FESEM observation showed presence of Co between ceramic particles as binder.

Keywords: *Cobalt; Fracture toughness; Mechanical properties; Milling; SPS; Tungsten carbide*

INTRODUCTION

Cemented carbides, such as WC–Co, are commonly used to manufacture cutting and mining tools, wear-erosion resistant parts or pressing dies, since they combine a high hardness with considerable fracture toughness, owing to the Co-based phase that forms around WC, which provides a ductile bonding matrix for these ceramic particles (note that this Co-based matrix will be referred to as the binder phase, as it is commonly termed in the field of cemented carbides). WC–Co composites also exhibit high-temperature strength, good corrosion resistance and an important chemical stability even at high temperatures (Wei, *et al.*, 2010, Shon, *et al.*, 2009, Fang, *et al.*, 2009, Genga, *et al.*, 2013, Zhao, *et al.*, 2008). Tungsten carbide (WC) has been well known for its exceptional hardness and wear/erosion resistance. Matrices of ductile metals, such as cobalt, greatly improve its toughness so that brittle fracture can be avoided. Cemented tungsten carbides are commercially one of the oldest and most successful powder metallurgy products (Yaman and Mandal, 2014, Zheng, *et al.*, 2013, Sun, *et al.*, 2014). These composites are essentially aggregates of particles of tungsten carbide bonded with cobalt metal via liquid - phase sintering. The properties of these materials are derived from those of the constituents –namely, the hard and brittle carbide and the softer, more ductile binder. The cutting tool and wear part applications arise because of their unique combination of mechanical, physical, and chemical properties. Several varieties of sintering

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routes have been proposed to synthesize these composites from powders into bulk materials (Zheng, *et al.*, 2012, Chen, *et al.*, 2015, Qu, *et al.*, 2012, Zhao, *et al.*, 2009). Nevertheless, a major classification, depending on whether or not any liquid phase is present during sintering, can be made between liquid-phase and solid-state sintering. Generally, the key steps for preparing WC–Co cermet can be assumed as the preparation of raw powders including optimum mixing condition and the sintering control. Moreover, sintering may be the dominant process to adapt the microstructures and mechanical properties of WC–Co cermet (Zhao, *et al.*, 2009).

EXPERIMENTAL PROCEDURES

In this study, the starting powders, tungsten carbide with purity 9/99% and the size of grains 2 microns and cobalt powder metal with a purity of 98/99% with a grain size of 25-40 microns was used. In the amount of 6% by weight of cobalt powder to tungsten carbide then added and mixed in the mill planet with cups and balls of tungsten carbide and the ratio of ball to powder 7 to 1 and the rpm150 for 4 hours, the powders into a graphite mold SPS was put and then insert the device and void it, the sintered at a rate of temperature increase of 50°C per minute and initial pressure of 10 MPa began. After reaching the sample temperature to the desired temperature final pressure was applied. Here the behavior of sintered powder tungsten carbide-cobalt by SPS at 1350°C and pressure of 20 MPa for 4 minutes were investigated. In order to identify the fuzzy raw materials from the XRD (Model: PHILIPS) was used. In order to evaluate the density of sintered samples Archimedes method was used. Sintered samples using Vickers hardness was calculated. Morphology and microstructure of sintered pellets FESEM device TESCAN mira3 model was used.

RESULTS AND DISCUSSION

Fig. 1 turnout at test XRD of powdered tungsten carbide is shown. As can be seen in this Figure, all

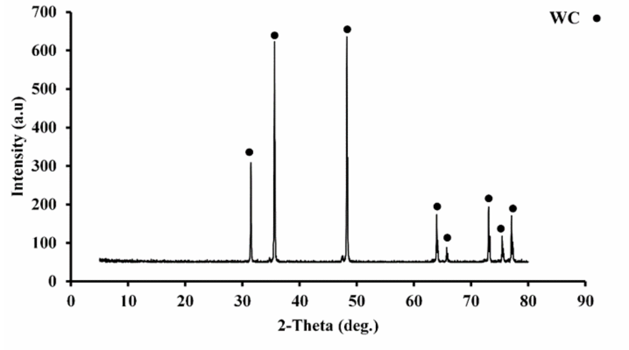

Fig. 1. XRD pattern of powder of tungsten carbide

peaks in the XRD pattern according to the reference card number 1047-025 complies with hexagonal tungsten carbide and no second phase of impurities is observed.

Fig. 1 it can be said with regard to 6 percent of cobalt in mixed and because of the low accuracy of the percentage of X-ray diffraction peaks of cobalt can't be discerned. To evaluate the effects on the microstructure and mechanical properties of sintered and binder mixed impact all required parameters to the device SPS was recorded. Parameters including temperature, heating rate and shelf life record temperature for this study were 1350°C, 50°C per minute and four minutes was considered. To study the sintering behavior, a ternary diagram of displacement - time - temperature for this sample was drawn.

As has been observed that the displacement in the case of temperature 700°C started, we can say that formed neck and rearrangement and sliding particles in this temperature range is started (Fig. 2).

As can be seen in Fig. 2 sintered during expansion due to the expansion that can be attributed to the large amount of milling time. The reason for the expansion of the exhaust gas leaving the gas that is porous remains. It seems to reduce milling time, this expansion

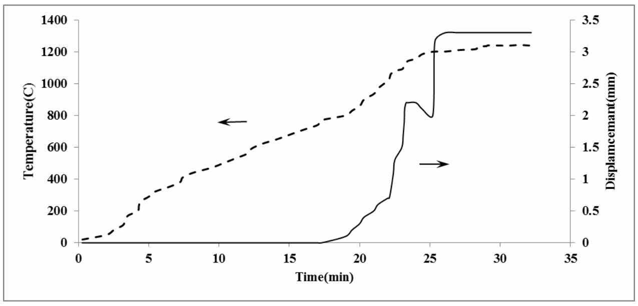

Fig. 2. Ternary diagram of displacement - time – temperature

Table 1. Relative density and mechanical properties of prepared sample

	Relative density (%)	Bending strength (MPa)	Hardness (GPa)	Fracture toughness (MPa.m-1/2)
WC-6Co	96.6	772	14.25	13.86

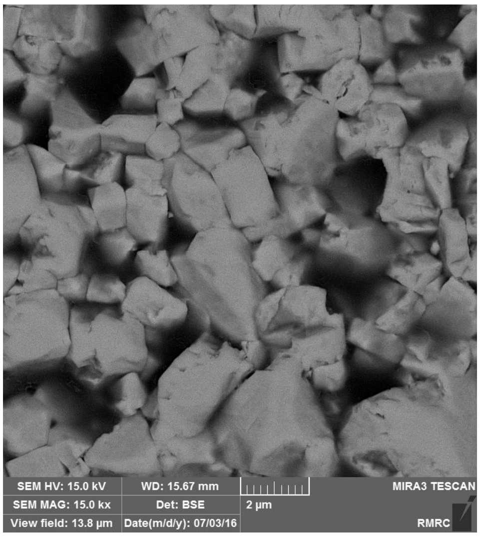

Fig. 3. The field emission scanning electron microscope image samples

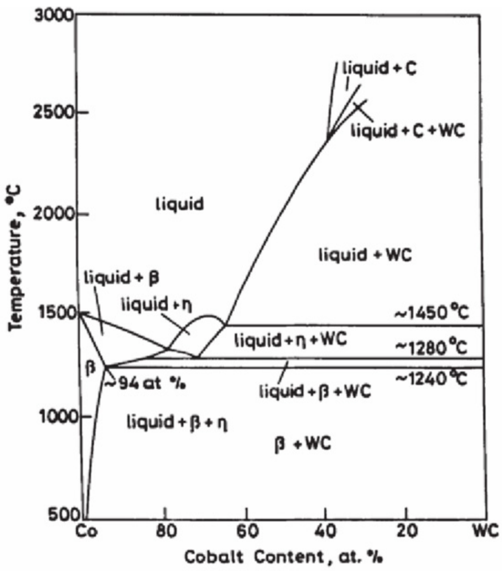

Fig. 4. Phase diagrams tungsten carbide–cobalt

does not occur. Based on previous studies, using less time and with less speed milling, sintered process to accelerate. Raw grains are finer milling has also been listed refinement reduces the sintering temperature.

The field emission scanning electron microscope image in Fig. 3 the liquid cobalt tungsten carbide grains is not covered. It seems that the rate of penetration into the liquid cobalt tungsten carbide grains, the sintered faster and has helped reduce the sintering temperature. During the liquid phase sintered process, the initial condensation Because of faster transfer occurs in the microstructure, when the liquid shaped grains are rearranged again. Condensation consequently, grain growth, but with the help of modern methods SPS and sintered high speed and short duration extreme growth process of seeds prevented.

Sinter method in the liquid phase process for sintered powder from several different than the melting temperature (cobalt and tungsten carbide 1495°C, 2820°C) (Zhao, *et al.*, 2008) have been used up. Tungsten carbide in the liquid cobalt dissolved, the solubility makes the liquid cobalt tungsten carbide grains to make and components to be connected by capillary force.

According to Fig. 4, we can conclude that in this system, however, cobalt melting point higher than the sintering temperature but the liquid at a temperature of about 1350°C due to formation of solid solution is formed first. Therefore, in the presence of the liquid phase is sintered in this system.

Mechanical properties such as hardness, strength and toughness are the other key properties in high-performance composite. Table 1 shows the typical mechanical and physical properties. It should be noted that the hardness and fracture toughness mechanical properties of composites is important.

CONCLUSIONS

4 hours for the mixing of raw materials is high. Using SPS was prevented from grain growth and mechanical properties increased. Because of oxidation of raw material during mixing, expansion occurred during that prevents the sintered density is 100%. It seems more appropriate is the use of low-energy mill.

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