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Effects of sintering temperature and nano Ti(C,N) on the microstructure and mechanical properties of Ti(C,N) cermets cutting tool materials with low Ni-Co

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ABSTRACT

The improvements of mechanical property as well as the microstructure of Ti(C,N) cermets cutting tool materials were presented. The influences of sintering temperature and nano Ti(C,N) had been studied. As rising the sintering temperature, the microstructure of Ti(C,N) cermets gradually became well-distributed, besides, the rim structure was gradually completed. The flexural strength improved obviously, but the changes of the hardness and the fracture toughness were relatively small. Nano Ti(C,N) had remarkable influence on the mechanical properties of Ti(C,N) cermets. The grain growth could be repressed by the addition of nano Ti(C,N). In the refinement microstructure, there were two typical core-rim structure, including a dark core with grayish rim structure and a bright core with grayish rim structure, besides, the formation mechanisms were both investigated. The flexural strength increased, nevertheless, the fracture toughness was slightly reduced, and the hardness kept constant. The fracture surface and crack propagation indicated that most cermets with coarse grains were easy to cause the transcrystalline fracture, meanwhile the intercrystalline fracture had the tendency to occur more in cermets with finer grains.

1. Introduction

The outstanding mechanical properties made the Ti(C,N) cermets be great important in metal cutting operation. The Ti(C,N) cermets were outclassed by conventional WC-based hardmetals, such as good high temperature hardness and low friction coefficient [1,2]. The mechanical properties were relevant to the complex microstructure. Ti(C,N) cermets were composed of two kinds of phases: one was the ceramic phase, providing high hardness; the other one was the binder phase, contributing to toughness and strength. Microstructure was made up of a typical core-rim structure, resulting from a dissolution precipitation process [3,4].

Compared with WC-Co hardmetal, the disadvantages of Ti(C,N) cermets were insufficient with strength and toughness. Efforts had been made to enhance the strength and toughness of Ti(C,N) cermets. The sintering temperature and the size of the raw powders were of great importance to the mechanical properties. The sintering temperature mainly affected the formation of the core-rim structure, which directly influenced the final properties [5–7]. Previous works showed that using nano-sized powders could greatly enhance the mechanical properties [8]. The effects of nano Si_3N_4 and nano BN on the Ti(C,N) cermets had been analyzed, which could increase flexural strength by 25%, with the addition of 1.5 wt% and 1.0 wt%, respectively [9,10]. Nanocrystalline (Ti,W)CN and (Ti,W)(C,N)-Ni powders were synthesized from oxides, leading to an ultra-fine and coreless phase, to greatly enhance the toughness [11]. It was reported that submicron hard phase powders mixture with small amount of nano hard phase powders were the optimal combination for the best mechanical properties [12–15].

Nowadays, most of the cermets systems were high metal content, which were not suitable for high speed cutting tools because of the low hardness at high temperature [16,17]. The way that different sintering temperatures affects the properties and microstructure of Ti(C,N) cermets was seldom reported. Therefore, in this paper, Ti(C,N) cermets of low metal content with nano Ti(C,N) addition were produced by a vacuum hot-press sintering technology with a high heating rate and a rapid densification process, which has a better influence on the mechanical properties due to the finer grain size. The characteristics of Ti(C,N) cermets influenced by sintering temperature were also discussed.

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Table 1
Composition ratio of the prepared Ti(C,N) cermet (wt%).

Powders	Ti (C,N)(μm)	Ti (C,N)(nm)	WC	Mo	Ni	Co	TaC
A	69	0	6	6	6	4	9
B	64	5	6	6	6	4	9
C	59	10	6	6	6	4	9
D	54	15	6	6	6	4	9

Table 2
Characteristics of the raw powders.

Powders	Ti (C,N)(μm)	Ti (C,N)(nm)	WC	Mo	Ni	Co	TaC
Particle size (μm)	0.5	< 0.1	0.5	0.3	0.6	0.6	0.5
Oxygen content (wt%)	O < 1.0	O < 2.0	O < 1.0	O < 1.0	O < 1.0	O < 1.0	O < 1.0

2. Experimental procedure

2.1. Specimen preparation

The compositions of powder mixtures for Ti(C,N) cermets and main characteristics of the starting powders commercially were shown in Tables 1 and 2, respectively. All cermet samples were prepared as following. After weighting and mechanical stirring accompanied with ultrasonic vibration for about 30 min, the raw powders were milled by a planetary ball mill (ball to power weight ratio: 7/1) in ethanol bath for 24 h. Secondly, the vacuum drying oven was used at 120 °C to evaporate the ethanol, then sieved through 120 mesh. At last the dried powders were put in a graphite mold, and pressed with some pressure, and sintered by hot-pressed sintering technology under a vacuum atmosphere at 1500 °C for 30 min.

2.2. Experimental methods

The geometric size of the specimens were 3 mm × 4 mm × 40 mm, and the test surface was finished with diamond paste. The microstructure of polished specimens and cracks on the test surface were observed by SEM in black-scattered-electron mode coupled with EDS, and the fracture surface was observed in secondary electron mode. The flexural strength was performed using a three-point bending tester at a loading velocity of 0.5 mm/min. The Vickers hardness measurement was conducted under the condition of 20 kg load, 15 s loading time, and then the crack length was detected for fracture toughness measurement.

3. Results and discussion

3.1. Effects of sintering temperature on the mechanical properties and microstructure

The mechanical properties of cermet A sintered at different sintering temperatures were shown in Fig. 1. As rising the sintering temperature, the flexural strength did not cause a significant change. When the sintering temperature reached 1450 °C, some of the rim phases were not complete, and the aggregation of grains could not be limited (as marked in yellow circle) in Fig. 2a, resulting in a bad flexural strength. When

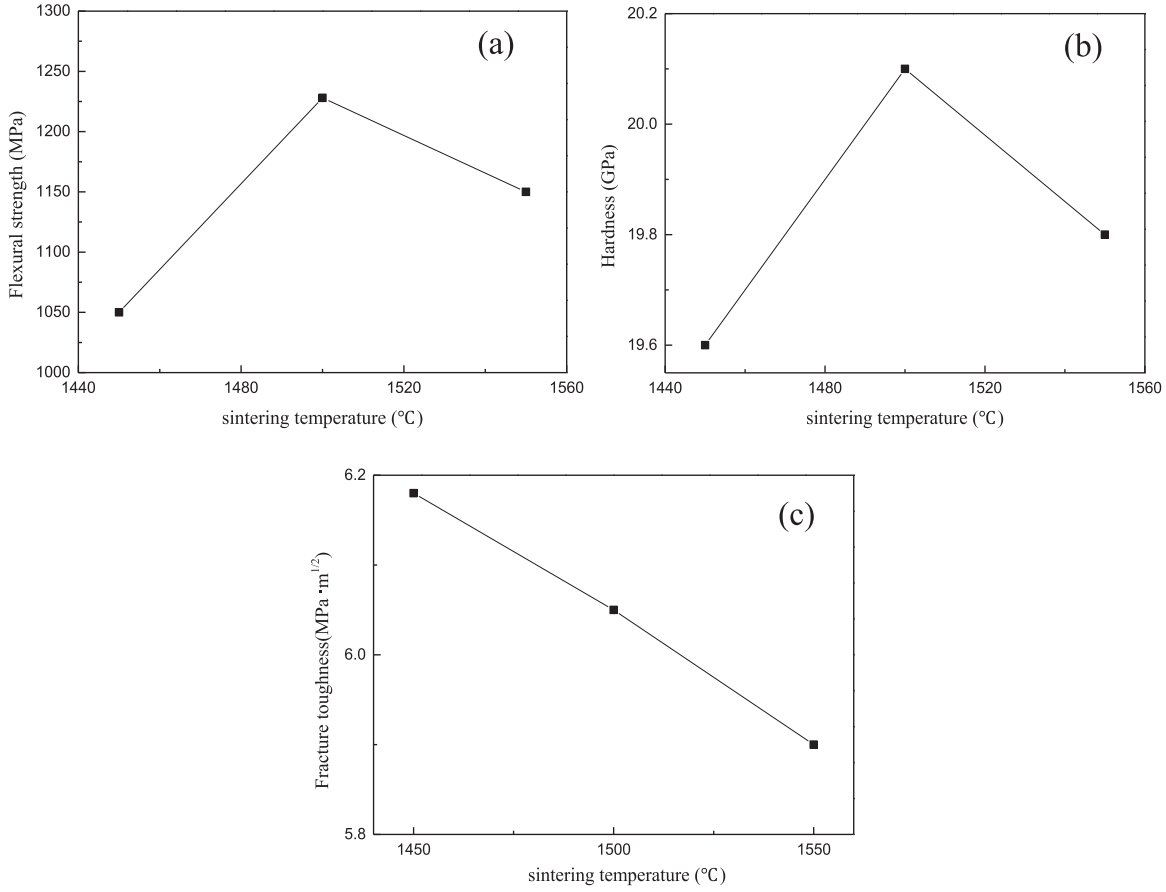

Fig. 1. Mechanical properties of Cermet A sintered at different temperatures (a) flexural strength, (b) hardness, and (c) fracture toughness.