

# Effect of WC content on properties of iron matrix composite

YE Xuan<sup>1</sup>, ZHONG Yanhui<sup>1</sup>, TU Huajin<sup>1</sup>, QIN Ling<sup>2</sup>, GAO Xuemin<sup>2</sup>

<sup>1</sup> Mechanical and Electrical Engineering College, Heyuan Polytechnic, Heyuan 517000, China; <sup>2</sup> R&D Department, Heyuan Peak metal products Co., Ltd., Heyuan 517000, China

yexuan 1216@sina.com

**Abstract.** Fe-2Cu-2Ni-1Mo-1C matrix composite with WC content of 0%, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10% were prepared. Pore morphology, density, hardness and bending strength of materials were studied. Results show, for Fe matrix composite reinforced by WC particles prepared via conventional powder metallurgy process, WC content needs to be well controlled to be 2%, which benefits the properties of the composite (hardness of HRB101.6 and strength of 945.1MPa); WC particles can effectively reduce the quantity of tiny pores, but may easily agglomerates, and excess WC particles may cut apart the matrix material and degrade the performance.

## 1. Introduction

Powder metallurgy technology is a new technique for material preparation with the advantages of low cost and good performance, especially Fe-Cu-Ni-Mo-C sintered materials, which can be used as structural parts, such as gears, bearings, etc.<sup>[1,2]</sup>. Along with the development of industrial technology, the existing materials already can't satisfy the performance requirements of modern manufacturing, while particle reinforced composites can effectively combine the excellent properties of two different kinds of material, among which, WC particle reinforced Fe matrix powder metallurgy sintering material is one of a kind<sup>[3]</sup>. Development of high wear resistance or corrosion resistance WC particles reinforced Fe-Cu-Ni-Mo-C sintered materials is of great significance<sup>[4]</sup>.

In recent years, advanced technologies, such as high energy ball mill + spark plasma sintering<sup>[5]</sup>. nanotechnology<sup>[6]</sup>, etc., have been adopted to optimize and improve WC particle reinforced Fe matrix powder metallurgy composite materials. Results show, WC particles indeed can improve the mechanical properties of matrix material, especially the wear-resisting performance. However, its preparation technology is quite different from enterprise's production practice, so its industrialized promotion may be difficult. Therefore, developing a new kind of WC particle reinforced Fe matrix PM composite with short process, low cost and high performance and its preparation technology based on the mature technology of production practice is of great practical significance. In this paper, Fe-2Cu-2Ni-1Mo-1C composites with WC content of 0%, 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9%, 10% were prepared via conventional powder metallurgy process, effect of WC content on pore morphology, density, hardness and bending strength of materials were studied.

## 2. Experiment method

### 2.1. Experiment materials



WC powder (average particle size of 2.05  $\mu\text{m}$ , purity of 99.99%), Fe-Cu-Ni-Mo prealloy powder (average particle size  $< 150 \mu\text{m}$ , purity of 99.5%), graphite powder were adopted. Composition proportion is shown at table 1, mixture was blended in small V-type mixer for 40 minutes. Green compact was prepared via hydraulic press with pressure of 500 MPa. Sintered samples was prepared via mesh belt sintering furnace with atmosphere of dissociated ammonia, sintering temperature and time are shown in table 2.

**Table.1** Specimens composition proportion (wt %)

Sample Number	Fe-2Cu-2Ni-1Mo-1C	Lubricating agent	WC
#1	100	0.5	0
#2	98.5	0.5	1
#3	97.5	0.5	2
#4	96.5	0.5	3
#5	95.5	0.5	4
#6	94.5	0.5	5
#7	93.5	0.5	6
#8	92.5	0.5	7
#9	91.5	0.5	8
#10	90.5	0.5	9
#11	89.5	0.5	10

**Table.2** Sintering process of specimens

Sintering stage	Temperature / $^{\circ}\text{C}$	Time/min
1	865	18
2	975	18
3	1110	18
4	1120	18
5	1115	18
6	Cooling stage	90

## 2.2. Performance test

Microscopic pore morphology of sintered samples was observed by metallographic microscope, density was tested, hardness and three-point bending strength of samples were tested by HR-150A Rockwell hardness tester and universal testing machine, size of three point bending specimen is 24.6 mm long, 8.1mm wide, 5.3mm high, test span is 18mm.

## 3. Results and discussion

### 3.1. Effect of WC content on the material pore morphology

Pore morphology of samples with different WC content is shown in figure 1. As shown in figure 1 (a), the sample of 0% WC has many tiny pores, which is a common pore morphology for Fe powder metallurgy products. The tiny pores are evenly distributed on the matrix, which cause a great damage to the material performance. As shown in figure 1 (b), the added 1% WC particles fill most of the tiny pores, which effectively reduces the porosity. But larger pores and WC agglomeration are formed.

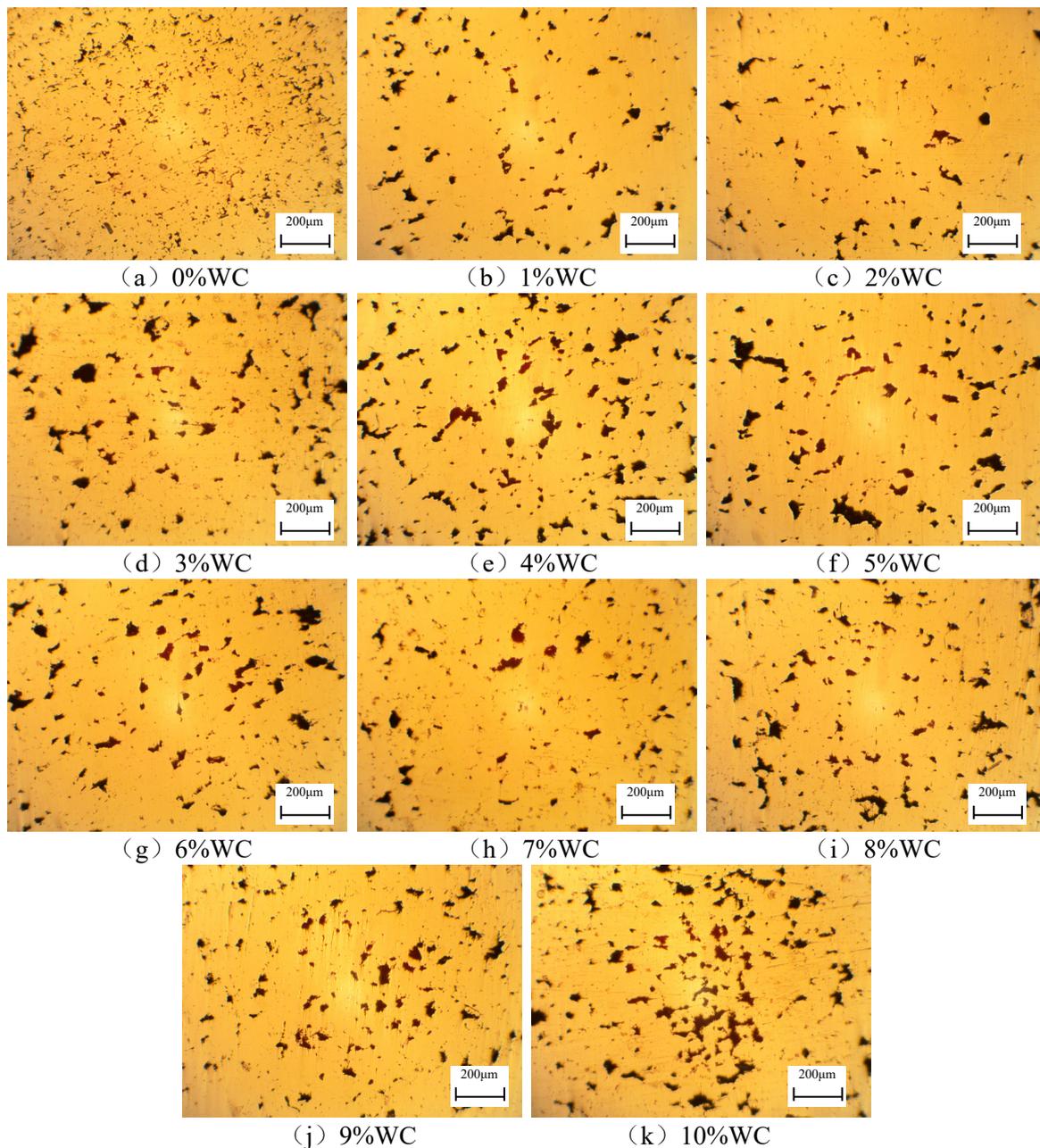


Figure.1 Pore morphology of specimens with different WC content

As shown in figure 1 (c), tiny pores of sample with 2% WC are filled by WC particles, comparing with sample with 1% WC, porosity is lower. As shown in figure 1 (d), the number of large pores of sample with 3% WC increases, and the pores trend to be connected. As shown in figure 1 (e) - (k), with the increase of WC content, pores connection and WC agglomeration become more and more obvious, which forms strong fragmentation effect to the matrix and causes a great damage on the performance of the material.

### 3.2. Effect of WC content on the hardness and bending strength of materials

Effect of WC content on hardness of Fe-2Cu-2Ni-1Mo-1C sintered sample is shown in figure 2. Sample with 1%WC and 2%WC have higher hardness, which are HRB100.4 and HRB100.4 respectively and increase the hardness by 12.9% and 12.9% respectively, while hardness of sample

with 0%WC is 88.9HRB. However, hardness of materials decreases as the content of WC continues to increase to 10%.

Effect of WC content on bending strength of Fe-2Cu-2Ni-1Mo-1C sintered sample is shown in figure 3. Sample with 1%WC and 2%WC have higher bending strength, which are 932.8MPa and 945.1MPa respectively, which increase the bending strength by 6.53% and 7.93% respectively, while bending strength of sample with 0%WC is 875.6MPa. However, bending strength of materials decreases as the content of WC continues to increase to 10%.

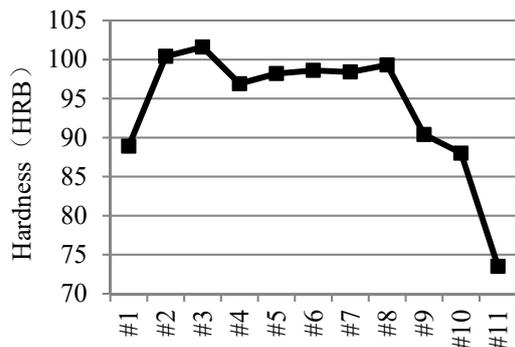


Figure.2 Effect of WC content on hardness of Fe-2Cu-2Ni-1Mo-1C sintered specimens

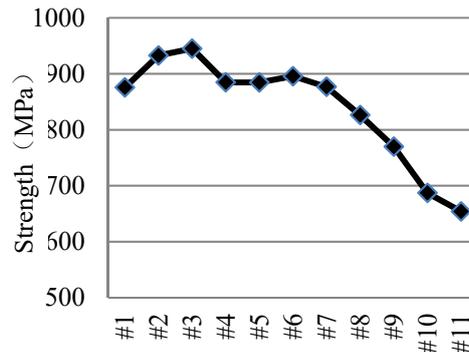


Figure.3 Effect of WC content on bending strength of Fe-2Cu-2Ni-1Mo-1C sintered specimens

#### 4. Discussion

In order to improve mechanical properties and expand application scope of Fe matrix powder metallurgy material, WC was introduced to prepare particle reinforced composites. Results show, hardness and bending strength of Fe-2Cu-2Ni-1Mo-1C can be elevated by adding the right amount of WC particles, especially hardness. Sample of 1%WC and 2%WC have higher hardness, which are HRB100.4 and HRB100.4 respectively, which increase the hardness by 12.9% and 12.9% respectively, while hardness of sample with 0%WC is 88.9HRB. And sample with 1%WC and 2%WC have higher bending strength, which are 932.8MPa and 945.1MPa respectively, which increase the bending strength by 6.53% and 7.93% respectively, while bending strength of sample with 0%WC is 875.6MPa. On the contrary, an excess of WC harms the mechanical properties of material, including hardness and bending strength<sup>[7]</sup>.

For Fe matrix PM material, adding a certain amount of WC can effectively enhance the composite via solid solution strengthening, dispersion strengthening, coarse particle strengthening, fine-grain strengthening, etc.<sup>[8]</sup>. In addition, adding the right amount of WC can also effectively perfect the pore morphology.

In the test of this paper, composites with 1%WC and 2%WC have better pore morphology. The reason may be, the average particle size of WC particles is much smaller than Fe-Cu-Ni-Mo prealloy powder particles, so the pores of Fe matrix can be effectively filled by WC particles. Literature [9] also believes, adding right amount of WC particles can decrease the material porosity, and the smaller the particle size of WC particles, the lower the porosity of the composite. Therefore, WC particles can well fill the pores of Fe matrix and, in turn, lower porosity, then leading the higher hardness, wear resistance, and strength along with other reinforcement effect.

However, an excess of WC may easily form agglomeration of hard particles, which trends to be connected with the new precipitated carbide, and it may form strong fragmentation effect to the matrix and cause a great damage on the performance of the material. In addition, too much WC particles may lead to direct contact between each other, while there is no formation of metallurgical combination between each other. This may become the weakness of the material, therefore, micro crack may easily initiate in the place of coarse WC particles, WC agglomeration, interface and pores, and leads to material fracture. As a result, the hardness and strength reduced instead. Therefore, how to further

optimize the process, to lower porosity and reduce the formation of large pore and agglomeration at the same time, has the vital significance.

## 5. Conclusion

(1) To improve mechanical properties of Fe-2Cu-2Ni-1Mo-1C PM materials, the content of WC needs to be well controlled, adding 1% and 2% of WC particles perfects pore morphology, which effectively reduces porosity of material, and lay the foundation for the material performance improvement.(2) Introduction of WC particles benefits the performance of Fe-2Cu-2Ni-1Mo-1C PM materials, especially hardness. Sample with 2%WC has higher performance, of which hardness and bending strength are 101.6HRB and 945.1MPa respectively, increased by 14.3% and 7.93% respectively comparing with the sample with 0%WC.

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