Properties of Fe-Cu-C composite reinforced by different WC content

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Abstract. Fe-1.5Cu-0.7C matrix composite with WC content of 0%, 1%, 2%, 3%, 4%, 5%, 6%, 7% are prepared from conventionally mixed powder in mesh belt sintering furnace, microscopic pore morphology of materials is observed, material properties are tested including density, hardness and bending strength. Results show that, Fe-1.5Cu-0.7C PM materials consisting 1%WC has relatively higher performance, and its density, hardness and bending strength are 6.63g/cm³, 72.6HRB and 317.3MPa respectively.

1. Introduction
Powder metallurgy technology is a new technique for material preparation with the advantages of low cost and good performance, especially Fe-Cu-C sintered materials, which can be used as structural parts, such as gears, bearings, etc. [1-3]. 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 [4-5]. Development of high wear resistance or corrosion resistance WC particles reinforced Fe-Cu-C sintered materials is of great significance [6-7].

In recent years, advanced technologies, such as high energy ball mill + spark plasma sintering [8], Nanotechnology [9], 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, Therefore its industrialized promotion may be difficult. Therefore, developing a new kind of WC particle reinforced Fe matrix powder metallurgy composite material 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-1.5Cu-0.7C composites with WC content of 0%, 1%, 2%, 3%, 4%, 5%, 6%, 7% are prepared via conventional powder metallurgy process, properties of Fe-Cu-C composite reinforced by different WC content are studied.
2. Experiment method

2.1. Experiment materials
WC powder (average particle size of 2.05 μm, purity of 99.99%), Fe powder, Cu powder and graphite powder are adopted. Composition proportion is shown at table 1, mixture is blended in small V-type mixer for 40 minutes. Green compact is prepared via hydraulic press with pressure of 650 MPa. Sintered samples is prepared via mesh belt sintering furnace with atmosphere of dissociated ammonia, sintering temperature and time are shown in table 2.

| Sample Number | Fe-1.5Cu-0.7C | Lubricating agent | WC |
|----------------|----------------|-------------------|----|
| #1             | 99.5           | 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  |

| Sintering stage | Temperature /°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 is observed by metallographic microscope, hardness and three-point bending strength of samples are 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. Pore morphology of materials reinforced by different WC content
Pore morphology of materials reinforced by different WC content is shown in figure 1. As shown in figure 1 (a), the materials without WC have many tiny pores, which is a common pore morphology for Fe powder metallurgy products, the tiny pores are evenly distributed on the matrix, which causes 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; As shown in figure 1 (c), tiny pores of sample with 2% WC are filled by WC particles, but larger pores and WC agglomeration are formed; 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) - (h), 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. Density of materials reinforced by different WC content

Density of materials reinforced by different WC content is shown in figure 2. Density of materials shows increasing trend with the increase of WC content. The reason may be that WC particle has higher density and adding more WC results in higher density of materials.
3.3. Hardness of materials reinforced by different WC content

Hardness of materials reinforced by different WC content is shown in figure 3. Materials consisting 1%WC has higher hardness, which is 72.6HRB and increased by 11.4% comparing with materials without WC, while hardness of materials without WC is 65.1HRB. However, as the content of WC continues to increase to 7%, hardness of materials is lower than 72.6HRB except materials consisting 6%WC.

![Fig.3 Hardness of materials with different WC content](image)

3.4. Bending strength of materials reinforced by different WC content

Bending strength of materials reinforced by different WC content is shown in figure 4. Bending strength of materials shows declining trend with the increase of WC content from 0% to 4%, which are 326.4MPa, 317.3MPa, 291.1MPa, 296.9MPa and 286.0MPa. However, as the content of WC continues to increase to 5% and 6%, bending strength of materials trend to increase to 307.0MPa and 316.5MPa respectively, which are still lower than the materials without WC. Moreover, materials consisting 7%WC has the lowest bending strength, which is 270.6MPa.

![Fig.4 Bending strength of materials with different WC content](image)

4. Conclusion

(1) To improve mechanical properties of Fe-1.5Cu-0.7C PM materials, the content of WC needs to be well controlled, adding 1% of WC particles improves the pore morphology, which effectively reduces porosity of material, and lays the foundation for the material performance improvement. (2) Introduction of WC particles is good for the performance of Fe-1.5Cu-0.7C PM materials. Material consisting 1%WC
has relatively higher performance, and its density, hardness and bending strength are 6.63g/cm³, 72.6HRB and 317.3MPa respectively.

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