

論文の要旨

題目 Spark Sintering of Fe-B System Alloys and Their Application for Cutting Tools
(Fe-B系合金の放電焼結と切削工具への適用)

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Tungsten carbide-cobalt hard metals (WC-Co) were widely used for a variety of machining, cutting, drilling and other applications. One of the main topics of the actual research in the field of WC-Co concerned the development of new composites, with partial or total substitution of the WC and Co by other more economic and less toxic materials. By comparison refractory carbides, nitrides, borides, iron borides (FeB/Fe₂B) were expected to substitute the WC. Consideration for the low sinterability of FeB, Ni or Fe belonged to the same transition group of Co was added to prepare the fully dense compacts. However, there were few studies on the sintering of FeB with Fe or Ni as the binder phase. Therefore, the sintering behaviors and mechanical properties of FeB-Fe and FeB-Ni system alloys were investigated to evaluate the potential application in cutting field.

At first, Fe was selected as the binder phase. Fe and FeB powders were mixed by the elemental blending methods. The sintering behaviors and mechanical properties of FeB-Fe system alloys with 0, 10 and 50% Fe addition were investigated to determine the suitable amount of Fe added. After that, the sintering behaviors of the FeB with suitable amount of Fe added will be further investigated to evaluate whether Fe was suitable as a binder phase for FeB. Simultaneously, the microstructure and mechanical properties including Rockwell hardness and bending tests of the FeB-Fe alloys were also investigated.

Next, Ni as a suitable candidate binder phase was also investigated. Ni binder phase was introduced by the electroless plating method. Electroless plating was proved to be useful because of the homogeneous distribution of the coating and high adhesion. Single factor experiments were carried out to optimize the electroless plating process including the pretreatment process, treating amount, bath temperature and plating time. The effect of the treating amount at the range of 1 to 10 g/l, the bath temperature at the range of 323 to 338 K and the plating time at the range of 300 to 1200 s on the Ni coated FeB powders were investigated. After optimized the electroless plating process, the effect of the Ni content at the range of 5-30% on the sintering behaviors and mechanical properties of FeB-Ni hard materials were investigated to determine the suitable Ni content. After that, the effect of the sintering parameters including the sintering temperature and the holding time on the microstructure and mechanical properties of the FeB-Ni alloys was further investigated to prepare the fully dense FeB with suitable Ni content.

Then, the practical applications experiments including the interrupted cutting tests were carried out on the FeB-10Ni compacts as well as the wear and friction tests. The wear and interrupted cutting tests were conducted at the pin-on-disc wear tester and milling machine, respectively. The effect of the cutting speed at the range of 0.03 to 0.33 m/s on the flank wear

width of the FeB-Ni cutting tool were investigated as well as the WC-7.8Co compact. The wear and friction tests were conducted at the same speed. The wear mechanism, cutting mechanism and the cutting performance of the FeB-Ni compact were investigated.

The conclusions of this thesis are summarized as follows:

1. FeB with 0, 10 and 50% Fe alloys were successfully prepared by spark sintering process. The sintering ability of FeB was significantly improved by the addition of Fe binder phase. The relative density of FeB-Fe alloys was significantly increased with the increase of Fe content to 10%. While the increase of the relative density could be negligible when the increase of Fe content to 50%. The Rockwell hardness of FeB-Fe alloys decreased with the increase of the Fe content. The bending strength of FeB-Fe alloys showed the same trend as relative density. In this case, the FeB alloys with 10 vol% was optimum. The relative density of FeB-10Fe compacts were increased with the increment of the sintering temperature at the range of 1493 to 1523 K. The calculated and experimental densification rate, \dot{D} , of FeB-10Fe were in good agreement. However, although FeB-10Fe compacts sintered at 1493 K showed high relative density and well mechanical properties, a large number of pores still existed in this compact due to the low wet ability between FeB and Fe. In this case, Fe was not suitable as binder phase of FeB.

2. The increased treating amount of the FeB powders and bath temperature would accelerate the chemical reaction rate, increase the Ni content and affect the homogeneity of the Ni coating. Electroless plating time had a greater impact on the increase of the Ni content. But they had no effect on the composition and structure of the coating. FeB with 5, 10, 25 and 30% Ni alloys were successfully prepared by spark sintering process. The sintering ability of FeB was significantly improved by the electroless Ni plating. The relative density of FeB-Fe alloys was significantly increased with the increase of Ni content. FeB with 10% Ni alloys showed the maximum hardness, compressive strength and well fracture toughness. The calculated and experimental densification rate, \dot{D} , of FeB-10Ni were in good agreement. The sintering temperature had a significant influence on the relative density and the homogeneous distribution of the Ni of the FeB-10Ni compacts. The holding time had a significant influence on the grain size, porosity and the mechanical properties of the compacts.

3. The wear and friction experiments resulted that FeB-10Ni and WC-7.8Co exhibited similar wear characteristics. Adhesive wear was found to be the dominant mechanisms controlling the wear rate of the FeB-10Ni and WC-7.8Co alloys. Also, the breakdown of adhesive layer created hard debris, resulting in abrasive wear in subsequent sliding results showed that the mechanical properties of FeB-10Ni compacts were comparable to that of WC-7.8Co compact. Then The results showed that the wear resistance and cutting performance of FeB-10Ni compact were comparable to that of WC-7.8Co compact at low speed.