Formation of Fe_3AlC Base Alloy by Mechanical Alloying and Vacuum Hot Pressing

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Abstract

Fabrication of Fe_3AlC matrix in-situ composite, reinforced by a FeAl phase, was studied by using the powder metallurgical processing route. Especially, in order to disperse the second phase more finely, we chose the mechanical alloying process. We investigated the microstructural and mechanical properties of the consolidated material. After consolidation by vacuum hot pressing, the compact showed almost full density and consisted of a Fe_3AlC matrix and FeAl second phase (average particle size was less than 1m). The compact showed HV746, which was higher than that of the arc melted Fe_3AlC monolithic material, HV603.

Keywords : Fe_3AlC, FeAl, in-situ composite, Mechanical Alloying, Vacuum Hot Pressing

1. Introduction

Fe_3AlC perovskite type carbide (phase) is an important phase for steels containing Al because of the formation of precipitation. Fe_3AlC is a hard and brittle phase and its melting point is around 1600K. The characteristics of Fe_3AlC carbide are still under discussion. For example, the exact chemical composition of the carbide has not been reported. The literature value of the chemical composition is expressed as $Fe_{4-y}Al_yC_x$ where x=0.42~0.71 and y=0.8~1.2[(1)]. The mechanical properties of near monolithic material prepared by the conventional melting method are reported[(2)]. It has been concluded that the Fe_3AlC is promising for high temperature materials and is worth further investigation. But the high temperature strength is not enough to substitute some heat resistant alloys.

It appears that the second phase, synthesized in the matrix, is effective in improving mechanical properties, such as strength and/or ductility, at room temperature in addition to the high temperature strength.

Furthermore, Fe_3AlC carbide consists of only Fe, Al and C, which are environmentally benign materials in comparison with the main or alloying element of superalloys, such as Ni, Co and Cr etc. In this investigation, we try to fabricate Fe_3AlC based in-situ composite reinforced by a B2 type FeAl intermetallic compound by using MA and vacuum hot pressing.

2. Experimental and Results

Fig. 1 shows the SEM micrographs of MA powders milled for 360ks (a) and 1800ks (b). These two MA powders were used in this investigation. As seen from the figure (a), the backscattered electron image (BEI), elemental Fe (bright contrast) penetrated into Al powder (large particle and dark contrast). The 360ks milled powder is still in the mixing stage of MA process. The 360ks milled powder exhibits a deformed shape and large particle size on the order of 100m. On the contrary, 1800ks milled powder shows a smooth surface and fine average particle size of less than 5m. A contrasting difference in the BEI of the 1800ks milled powder was not observed. From the XRD observation, the 360ks milled powder consists of elemental phase, Fe and Al. A longer time milling seems to form new compound, such as FeAl, Fe_2Al_5 and Fe_3AlC phases.

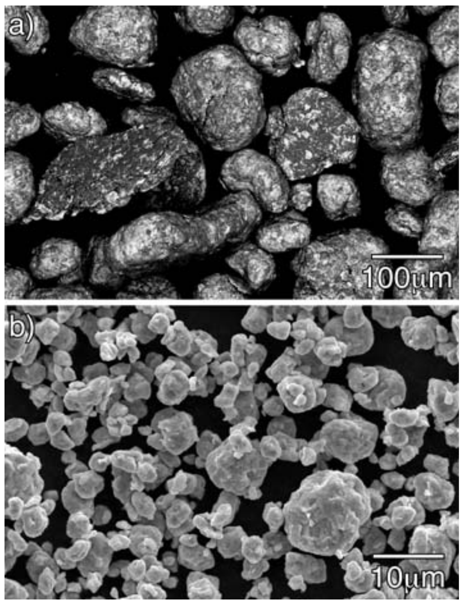

**Fig. 1 SEM micrographs of MA powders.
A)360ks, b)1800ks milled powder**

The MA powders ware consolidated by using VHP under the condition of 1273K-150MPa-3.6ks. Fig. 2 shows the microstructures (BEI) of VHP compact of 360ks (a) and 1800ks milled powder (b), respectively. As seen from Fig.2(a), the 360ks milled powder compact shows a very complicated structure. From the XRD analysis, the compact consists of FeAl (dark area), Fe_3AlC (bright area) and an unknown phase. The XRD peaks of Fe_3AlC phase were splitted, because it is thought that the Fe_3AlC might be divided into two phases having slightly different chemical compositions. XRD shows that the 1800ks milled powder compact consists of Fe_3AlC and FeAl. Therefore, the bright area and dark area of Fig.2(b) correspond to Fe_3AlC and FeAl phase having a grain size of less than 1μm.

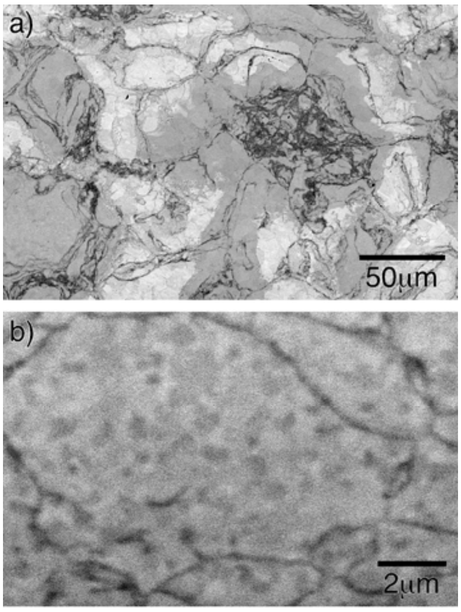

Fig. 2 SEM micrographs of VHP compact.
(a) 360ksmilled powder compact, (b) 1800ks milled powdercompact

Fig. 3 summarizes the results of Vickers hardness tests of monolithic Fe_3AlC, FeAl and in-situ composites obtained here to evaluate the mechanical property of Fe_3AlC+FeAl two-phase alloys. In addition, the figure also shows the effect of microstructures associated with the MA period on the hardness. The compact fabricated from 1800ks milled powder shows a higher hardness value of HV744 in comparison with the Fe_3AlC monolithic material, HV603 and Fe-40mol%Al powder metallurgical alloy[(3)]. The hardness of B2 type FeAl increases with increasing Al content up to 50mol%Al[(4)]. The hardness of Fe-50mol%Al is about HV600 under water quenched conditions[(4)]. Therefore, HV744 seems to be the result of a fine grain size.

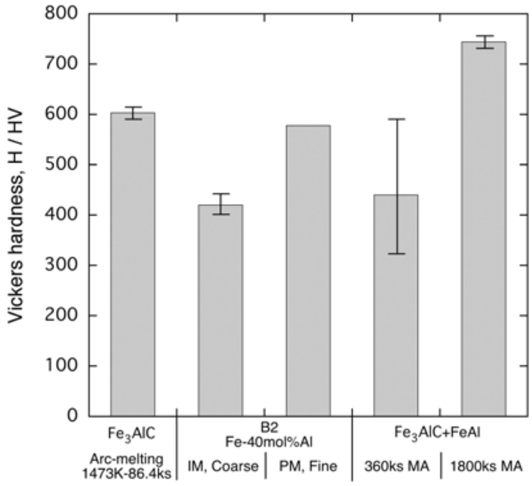

Fig.3 Results of Vickers hardness measurements.

3. Summary

The starting composition of the MA process is Fe-27mol%Al-11mol%C. The mechanical alloying and following high temperature consolidation process can synthesize two-phase materials consisting of Fe_3AlC matrix and FeAl second phase by using 1800ks milled powder. The 1800ks milled powder compact shows equiaxed and fine grain sizes of less than 1 m. The Vickers hardness is HV744, whose value is much higher than the Fe_3AlC monolithic material (HV603). It seems to be the result of a Hall-Petch effect.

4. References

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