

Effect of Cr on the Microstructure and Properties of High Nb-TiAl Alloys Prepared by Hot-pressing Sintering

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Abstract—In this paper, the effects of Cr on the microstructure and basic mechanical properties of high Nb-TiAl alloy are studied respectively. The results show that the alloying high Nb - TiAl alloy have film layer microstructure, when adding 2% Cr (at.%), compared with not adding Cr alloy, its microstructure is elaborated. And the addition of Cr makes its bending strength increased by 16.2%.

Keywords-TiAl alloy; microstructure; mechanical property; alloying

I. INTRODUCTION

As the typical high temperature structural materials, TiAl alloy has the property of low density, high specific strength and high modulus of elasticity and good creep resistance and oxidation resistance, making it applied in the fields of environment of high temperature and complex load of aerospace engines, and other fields and has a broad application prospect [1,2].

Although TiAl alloy has incomparable advantages, for its low plasticity at room temperature, high temperature oxidation resistance and poor processing performance disadvantage factors [3], its practical application in aerospace and automobile engine industries is restricted. Therefore, in view of these unfavorable factors [4], the research and innovation about advanced preparation methods and forming process of micro alloying of TiAl alloy is the key to promote its practical applications [5].

At present, adding excessive group elements, such as Nb, Mo, W, into the TiAl alloy has become a main research direction. For the large atomic radius and high melting point of the addition of Nb, the shear stress of dislocation motion is increased, improving the strength of the alloy and its high temperature performance. When add (0.2 ~ 2) % (at. %) B elements into the alloy, the generation of strip or discrete boride implements the grain refinement [6]. Diffusion ability of W which has high melting point is low and has inhibitory effect on alloy diffusion in the process of deformation, so as to improve the creep properties of the alloy [7]. W also can make the crystal interface structure and the organization stability improved, so as to improve the strength of the alloy. Y, a rare earth element, can generate the spherical or layered Y or YAl₂ in the alloy tiny, which can refine grain and improve TiAl alloy deformation, reducing the difficulty for the subsequent of plastic processing [8,9]. Taken together, the alloying of TiAl alloy

is developing in the direction of "a small amount of multivariate". Experiment shows that, when the third element Cr is added in the TiAl alloy, the doping and solid solution strengthening effect had a great influence on structure and the mechanical properties of alloy. In this article Cr will be added into Ti-45Al-8Nb-0.2B-0.2W-0.1Y in its vacuum hot pressing sintering process, and the mechanical properties and microstructure of the alloy were analyzed.

II. EXPERIMENT

A. Experimental materials

The elemental powders used in the experiment are produced by Beijing Xingrongyuan Limited Company. The specifications is as below: Ti powder 10 μ m, 99.7%; Al powder 1 μ m, 99.7%; Nb powder 10.5 μ m, 99.9%; B powder 4 μ m, 99.9%; W powder 2 μ m, 99.9%; Y powder 44 μ m, 99.9%; Cr powder 8 μ m, 99.5%.

The prepared material was put into a ball mill jar and milled for 24h, Steel ball and material ratio is 10:1, ball mill medium is absolute ethyl alcohol, and filling the N₂ to protect. Mixed powder morphology is shown in Figure 1.

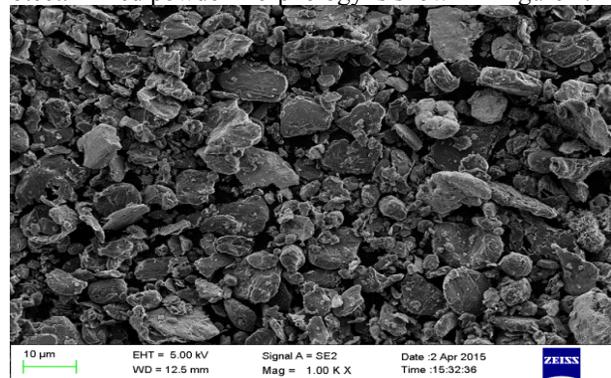


Figure 1. The Morphology of the mixed powder

B. Sintering process

By vacuum hot pressing sintering, with Ti-45Al-8Nb-0.2B-0.2W-0.1Y as the matrix alloy, the Cr content of 1%, 2%, 3% (at.%) are added to replace a part of Nb, obtaining Ti-45Al-(8-X)Nb-XCr-0.2B-0.2W-0.1Y. A ZR50B-8T multi-function vacuum hot-pressing sintering furnace which manufactured by the new material research center of

Shandong University is adapted for sintering. The vacuum hot-pressing sintering process is as follows: 10°C/min speed up to 620 °C, and insulation 1.5 h, then still with 10°C/min to 1250 °C temperature, and insulation 2h.

C. Sample preparation and testing method

The sintered bodies are cut into bending specimens of $3 \times 4 \times 5$ mm. The surface of specimens is cleaned and polished. The Kroll solution is used to corrosion of the samples after polishing. The electron microscope (SEM) and energy spectrometer (EDS) are used to observe its microstructure and energy spectrum analysis. The hardness is tested by the micro hardness tester with 100gf loading and 15s holding time.

III. RESULT AND DISCUSSION

A. Effects of different Cr contents on the microstructure of high Nb-TiAl alloy

Figure 2 is the diffraction image of the sample containing 2% Cr. It can be seen that TiAl alloy still mainly contain α -Ti₃Al and γ -TiAl phase, and β -Ti phase whose diffraction intensity peak is very weak. This shows that the addition of Cr element does not change the phase composition of high Nb-TiAl alloy. Figure 3 is the BSE images of the sintering specimens with different Cr content. Compared to the no Cr, the film layer organization becomes more significantly and the lamella spacing is smaller when 1% Cr is added. When 2%Cr is added, the alloy gets fully lamellar microstructure and smaller grain size which between 10 and 20 μ m. The lamella organization disappears when 3%Cr is added.

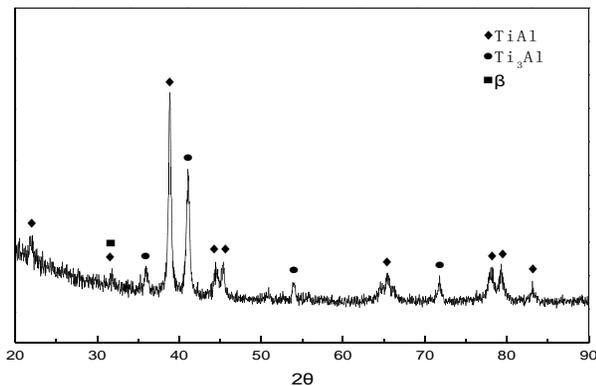
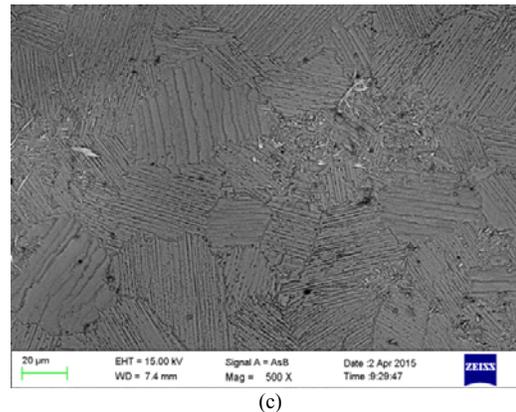
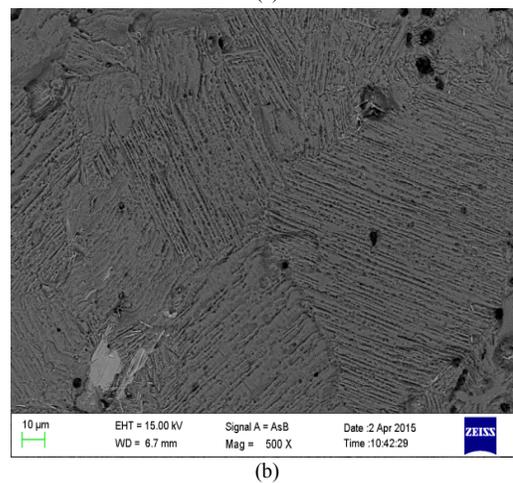
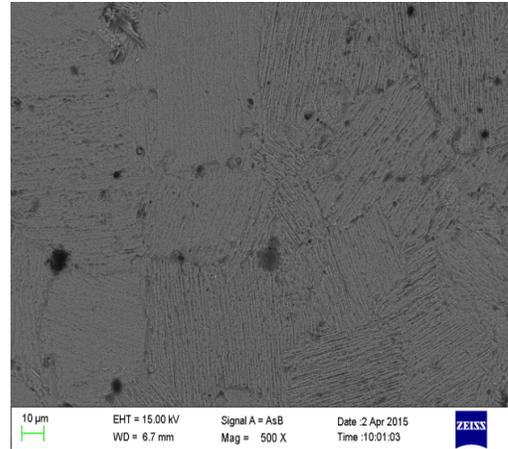
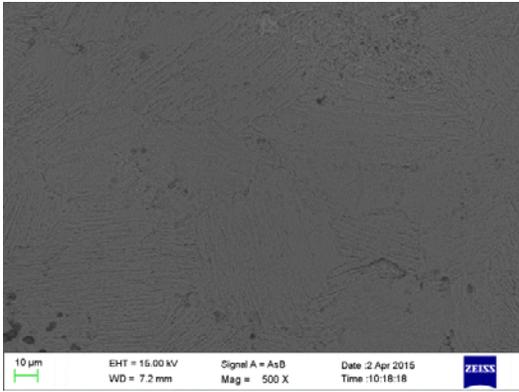


Figure 2. The X-ray diffraction pattern of the sample containing 2% Cr





(d)

Figure 3. BSE images of the samples with different Cr content (a)no Cr (b)1%Cr (c)2%Cr (d) 3%Cr

B. Effects of different Cr content on mechanical properties of high Nb-TiAl alloys

Table I is the Vickers hardness and bending strength value of high Nb-TiAl alloys with different Cr content. Figure 4 is draws the visual line chart of the data in table I. It can be seen from table I, Cr is not good to improve the hardness of alloy, when Cr content is up to 3%, and the hardness of the alloy reduced. But from the point of bending strength, the addition of Cr can greatly improves the bending strength of the alloy and the maximum bending strength will reach 979.82 MPa when added 2% Cr which has a relative increase of 16.2% than that of the alloy without Cr.

TABLE I. MECHANICAL PROPERTY OF HIGH Nb-TiAl ALLOYS

Cr content/at. %	0	1	2	3
Vickers Hardness	752	757	757	681
Bending Strength	843.34	921.02	979.82	908.81

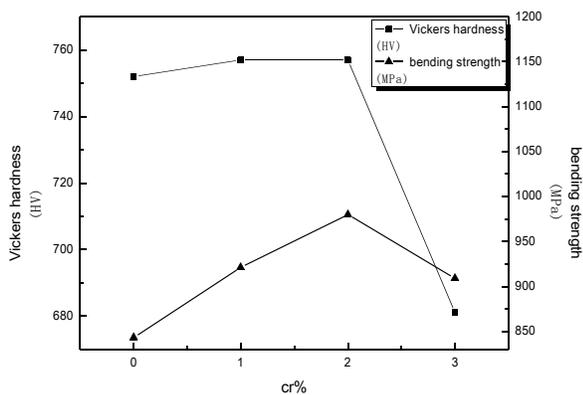
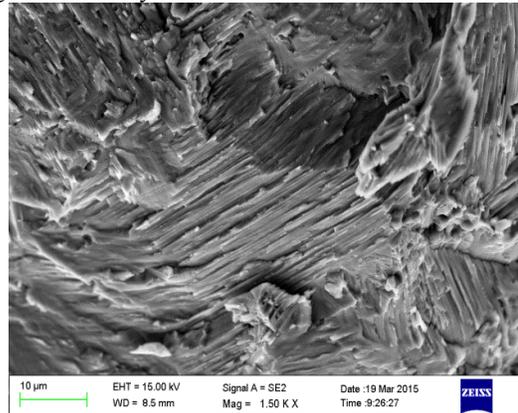


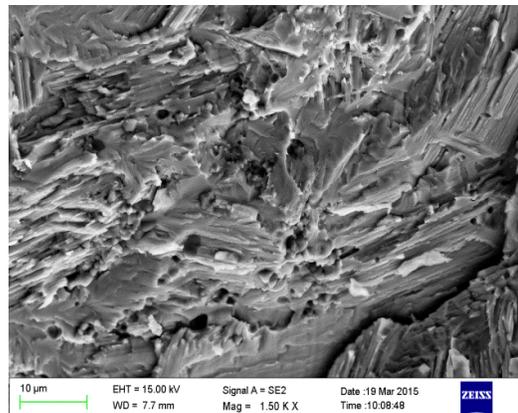
Figure 4. Effects of different Cr content on mechanical properties of high Nb-TiAl alloys

Figure 5 is the fracture section morphology of the high Nb-TiAl alloy with different Cr content. As shown in Figure 5(a), high Nb-TiAl alloy not containing Cr element has

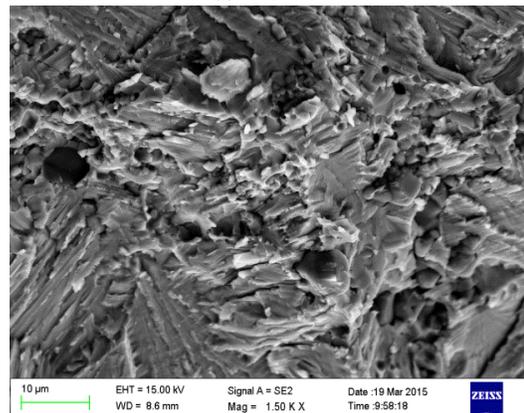
typical tear-shaped trans granular fracture that has a clear break level. Fracture steps disappear and trans granular fracture morphology reduce when adding Cr element. And toughening nest begins to appear. The toughening nest phenomenon becomes more obvious when the Cr content reaches 2%. It shows the alloy has good plasticity, and this is in agreement with the previous analysis about the bending strength of the alloy.



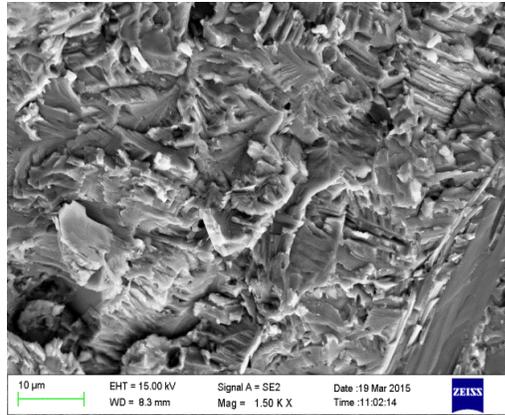
(a)



(b)



(c)



(d)

Figure 5. The section morphology of the alloys with different Cr content
(a)no Cr (b)1 %Cr (c)2%Cr (d)3 %Cr

Rod-shaped particle phases can be found in Figure 6, the partial enlarged detail of Figure 5(c). The X-ray energy spectrum analysis results are shown in Figure 7. Learned from the analysis results, the small particle phase is γ -TiAl phase which is rich in Nb, Cr and W. The atomic percent of Nb, Cr and W is close to that of the raw powder. It shows that the alloying elements dissolve in the matrix phase very well and generate the rod-shaped particles which playing a role in pinning and blocking effect when fracture.

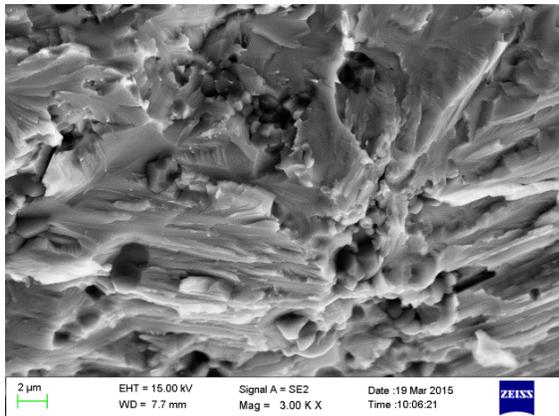


Figure 6. The partial enlarged detail of Figure 5(c)

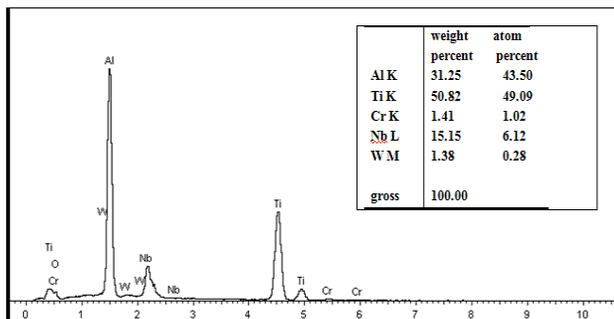


Figure 7. The X-ray energy spectrum analysis of the rod-shaped particle phase

IV. CONCLUSIONS

(1) Cr element has obvious effect on the microstructure and bending strength of high Nb-TiAl alloy. The crystalline grains of the alloy are refined with the increasing of the Cr content.

(2) The alloy achieves the best bending strength and hardness when Cr contents reaching 2%. The bending strength increases by 16.2%. But the hardness is not much improved.

ACKNOWLEDGMENTS

This work was supported by the Science and Technology Development Project of Shandong Province (No. 2014GGX103009) and the Domestic Visiting Scholars Project of Shandong Provincial Education Department.

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