The Effect of B_4C on Microstructure and Mechanical Properties of Nb-Si Based Superalloy

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Abstract: The details of microstructure and mechanical properties of Nb-Si based alloys have been shown with the addition of B4C. Results show that the addition of B4C promotes the formation of silicide phases, Moreover, the fracture toughness has been improved with doping of trace B4C, and the maximum value of the investigated alloys is 14.26 MPa·m1/2, which improves by 41.05%.

Keywords: Nb-Si based alloy, B_4C, Fracture toughness,

1 Introduction

The Nb–Si based alloys are one of the most potential candidate materials for the next generation aerospace turbine blades, because of its higher melting point (>1700 ◦C), lower density (6.6–7.2 g/cm^3) and excellent high-temperature strength [1-3]. However, the poor fracture toughness at room temperature has limited its practical application of Nb-Si alloys[4-6].

2 Experimental procedure

All the ingots have been prepared by the non-consumable electric arc melting, and the nominal chemical compositions are Nb-16Si-20Ti-20Zr, Nb-16Si-20Ti-20Zr-1B_4C, Nb-16Si-20Ti-20Zr-2B_4C, and Nb-16Si-20Ti-20Zr-4B_4C. The X-ray diffraction (XRD) is used to examine the phase structure and crystalline structures. The room-temperature fracture toughness is measured by conducting three-point bending specimens with the size of 20*4*2 mm. The room-temperature compressive test is conducted using the Instron 5569 electronic testing machine with the size of φ4*6.

3 Result and discussion

Mcrostructure

The XRD results can be seen in Fig. 1. It can be seen that the constituent phases no change with the addition of trace B_4C.All the Nbss and γ(Nb, X)$_5$Si$_3$ phases exist in the 0-2at.% B_4C alloys. As the content of B_4C exceed 4 at.%, the new silicide phases ((Nb, X)$_3$Si) appear in the matrix.

Fig. 2 shows the backscattered electron (BSE) images of investigated alloys. The Nbss/γ(Nb, X)$_5$Si$_3$ eutectic and small proportion of γ(Nb, X)$_5$Si$_3$ phases exist in 0B_4C alloys. And It is obvious that the proportion of γ(Nb, X)$_5$Si$_3$ increases as doping of B_4C, suggesting that B_4C can change the solidification of Nb-Si based alloys. In 4B_4C alloys, the gray (Nb, X)$_3$Si phases appear in the matrix.

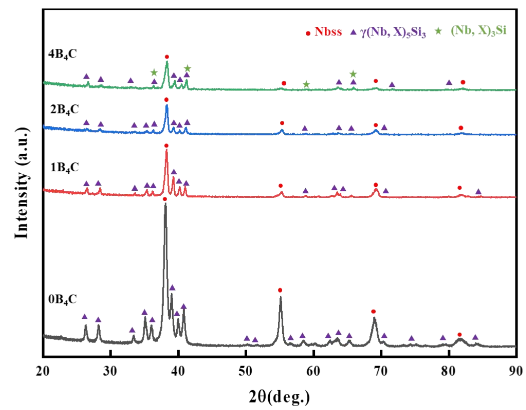

Fig. 1.XRD images of Nb-16Si-20Ti-20Zr-xB4C alloys

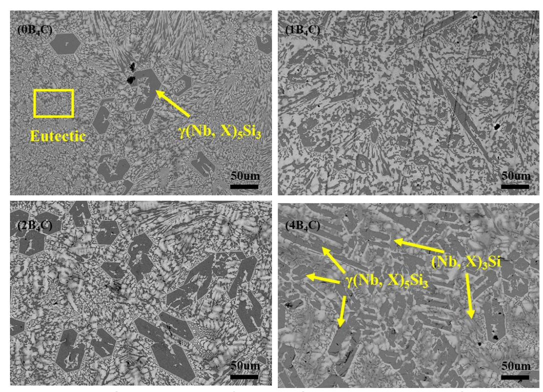

Fig. 2. BSE images of Nb-16Si-20Ti-20Zr-xB4C alloys

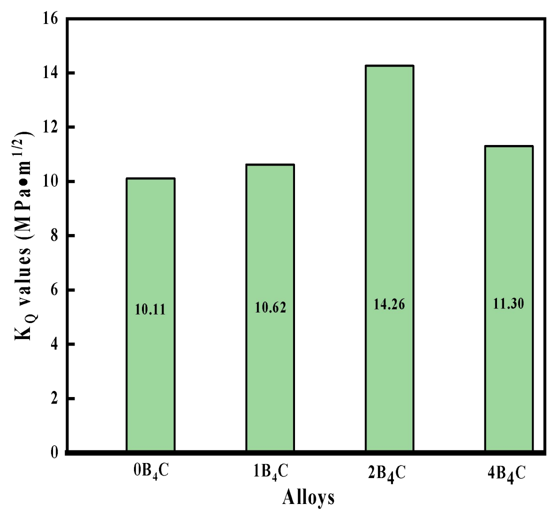

Fig. 3. The K_Q values of Nb-16Si-20Ti-20Zr-*x*B4C alloys

Room temperature fracture toughness

Fig. 3 shows the room-temperature fracture toughness of investigated alloys. The K_Q valus of based alloys is 10.11 MPa·m$^{1/2}$. The fracture toughness increase with doping of B_4C, and the fracture toughness of 1B_4C and 2B_4C are 10.62 and 14.26 MPa·m$^{1/2}$,which increase 5.04% and 41.05%. However, the fracture toughness decreases as the content of B_4C exceed 4at.%.

4 Conclusion

(1)The addition of B_4C changes the microstructure of Nb-Si based alloys. The proportion of primary γ(Nb, X)$_5$Si$_3$ phases increase with doping of B4C. In 4B_4C alloys, (Nb, X)$_3$Si phases appear in the matrix

(2)The room-temperature fracture toughness increases signally with doping of B4C. The KQ value of 2B_4C alloys is 14.26 MPa·m$^{1/2}$, which improves by 41.05%.

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References

[1] K.S. Chan, 13 - Intermetallic composites toughened with ductile reinforcements, in: R. Mitra (Ed.), Intermetallic Matrix Composites, Woodhead Publishing2018, pp. 359-407.

[2] Y. Qiao, X. Guo, Y. Zeng, Study of the effects of Zr addition on the microstructure and properties of Nb-Ti-Si based ultrahigh temperature alloys, Intermetallics 88 (2017) 19-27.

[3] Z. Li, L. Luo, B. Wang, B. Su, L. Luo, L. Wang, Y. Su, J. Guo, H. Fu, Cooperative effects of Mo and B additions on the microstructure and mechanical properties of multi-elemental Nb-Si-Ti based alloys, Mater. Charact. 206 (2023) 113421.

[4] S. Zhu, G. Zhang, Y. Bao, D. Sun, Q. Zhang, X. Meng, Y. Hu, L. Yan, Progress in preparation and ablation resistance of ultra-high-temperature ceramics modified C/C composites for extreme environment, Reviews on Advanced Materials Science 62(1) (2023) 20220276.

[5] A. Annerino, M. Lawson, P.I. Gouma, Future insights on high temperature ceramics and composites for extreme environments, International Journal of Ceramic Engineering & Science 4(5) (2022) 296-301.

[6] X. Yin, J. Liang, X. Zhang, C. Wang, S. Chen, S. Shang, C. Liu, Improving the mechanical properties and oxidation resistance of Nb-16Si-20Ti alloys with B4C addition, Int. J. Refract. Met. Hard Mater. 119 (2024) 106543.